

Older Adults' Design Preferences for Augmented Reality in Cultural Tourism: An Experimental Study

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Abstract—Augmented Reality (AR) has increasing potential to support cultural heritage experiences by presenting historical and cultural information through interactive and immersive media. However, its effectiveness depends on design choices that accommodate users' preferences and perceptual needs. This study investigated AR design preferences among 11 older adults through seven design preference experiments examining visual, textual, multimedia, and interaction elements intended for cultural tourism applications. The experiments evaluated marker size, font size, line spacing, information delivery, presentation method, letter spacing, AR object size, and marker type. Participants evaluated alternative configurations and indicated their satisfaction ratings and final preferences. The findings revealed statistically significant differences in satisfaction ratings for font size after multiple-testing adjustment, while the line-spacing result was no longer statistically significant after adjustment. Based on participants' final selections, 18-point text and 1.0-line spacing were the most frequently preferred alternatives. Other design elements did not demonstrate statistically significant differences, although descriptive ratings and participants' final selections provided useful guidance for subsequent prototype development. Participants generally favored a combination of audio and text, multimedia presentation options, moderate-sized AR elements, and markerless access. Overall, the results suggest that textual presentation characteristics, particularly font size and line spacing, may play a more prominent role in shaping adult users' AR design preferences than several physical and multimedia presentation characteristics. These findings provide empirical guidance for designing and evaluating AR applications intended to support cultural heritage engagement among adult users.

Keywords—Augmented reality; mid-fidelity prototype; cultural heritage; older adults; design preferences; human-computer interaction

I. INTRODUCTION

Augmented Reality (AR) has emerged as a promising technology for enhancing cultural heritage and tourism experiences by integrating digital information with physical environments. In cultural heritage settings, AR can provide visitors with additional layers of interpretation through textual, visual, audio, and interactive content while maintaining engagement with physical sites and artifacts. Recent research continues to demonstrate interest in AR as a means of supporting visitor engagement and learning in museums and cultural heritage environments [1,8-10]. Nevertheless, the effectiveness of AR experiences depends not only on technological functionality but also on whether the interface and interaction mechanisms suit the characteristics and requirements of their intended users.

This consideration is particularly important for older adults. Older users may differ substantially in their prior technology experience, digital literacy, visual comfort, manual dexterity, and familiarity with AR. In the context of cultural heritage, these individual differences may affect how older visitors interact with digital information while simultaneously engaging with physical environments. Recent work concerning older visitors and AR heritage interpretation highlights this heterogeneity and emphasizes factors such as visual comfort, prior AR experience, digital literacy, manual dexterity, and tolerance for divided attention [2,10]. Therefore, AR interfaces intended for older adults should not assume that interaction approaches developed for general users will necessarily provide an equally accessible or comfortable experience.

Recent systematic reviews further emphasize the importance of age-inclusive interface design. Gomez-Hernandez et al. [12] identified design guidelines for mobile applications targeting older adults, highlighting the relevance of visual presentation, navigation, cognitive demands, and interaction requirements. Similarly, Ceyssens et al. [11] emphasized the importance of user-centered approaches when developing augmented reality applications for older populations. The need for age-sensitive design is also evident in existing research on AR usability. Nishchik et al. [3] identified a lack of established guidelines, recommendations, and testing techniques for effective, efficient, and satisfactory AR use among older adults and, after reviewing the literature, developed elderly-centered usability heuristics for AR design and development.

Visual presentation represents one particularly important design consideration. Gonzalez Cardenas et al. [4], for example, experimentally examined typography and font size in AR with older adults and found that font size significantly affected reading performance, with smaller sizes producing longer reading times. Their participants also demonstrated preferences concerning the visual presentation of AR text. These findings show that seemingly basic interface characteristics can shape older adults' experiences and therefore warrant direct evaluation with intended users. Furthermore, Gomez-Hernandez et al. [12] identified visual design and interaction-related guidelines for mobile applications intended for older adults, reinforcing the importance of evaluating interface characteristics according to users' needs. Their findings further support investigating typography and presentation configurations through direct evaluation with older participants rather than relying solely on general design recommendations.

However, designing an accessible AR experience involves more than typography alone. Users must also perceive AR

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content, access the application, interpret information presented through different media, and interact with physical or digital triggers. These considerations matter especially in cultural tourism, where visitors may receive information through text, audio, video, virtual objects, and other multimedia while navigating a physical environment. Recent research on older visitors' AR heritage interpretation similarly argues that interaction quality and ease of use must be considered alongside the situated heritage experience because visitors divide their attention between the physical environment and digital information [2]. Consequently, researchers should consider individual interface elements as part of the broader interaction experience rather than treating them as isolated visual characteristics.

In the context of cultural heritage, Tsepapadakis and Gavalas [13] investigated an audio-augmented reality conversational guide, showing how audio-based interaction can support immersive visitor experiences and engagement with cultural information. Their study highlights the potential of alternative information delivery methods in heritage environments, further justifying the examination of audio and text presentation preferences in AR applications across users of different age groups. From a broader extended reality (XR) perspective, Sylaiou et al. [14] reviewed how immersive technologies can support older adults' engagement with digital cultural heritage. Their work provides broader context for accessibility and age-inclusive design, while the present study specifically examines older adults' interface and interaction preferences in augmented reality applications.

Despite growing attention to AR accessibility and usability for older adults, a practical gap remains between general usability guidance and selecting specific interface and interaction configurations for Web-based AR in cultural tourism. Existing studies provide evidence on specific design considerations, such as AR typography and elderly-centered usability principles, but this evidence does not automatically determine which configuration older adults will prefer when presented with alternative designs in a specific application context. This matters because older adults are a heterogeneous user group, not a single set of age-defined requirements. Therefore, it is valuable to complement general recommendations with empirical design-preference evaluation involving older adults before incorporating specific interface and interaction elements into a complete AR application.

This study aimed to empirically investigate older adults' preferences for selected interface and interaction elements for a Web-based AR cultural tourism application. We conducted seven design preference experiments using a mid-fidelity prototype to examine marker size, font size and line spacing, information delivery, presentation method, letter spacing, AR object size, and marker type. Participants evaluated alternative design options and indicated their final preferences, allowing direct user evaluation to inform design decisions rather than relying solely on general recommendations.

This study is organized as follows: Section II details the Literature Review of this study. Section III describes the Method for this study. Section IV describes the study's results, Section V

presents the study's discussion, and lastly, Section VI presents the conclusions.

II. LITERATURE REVIEW

A. Older Adults

Older adults are becoming one of the world's largest age groups. With low birth rates among younger populations, we will have many older adults in the coming years [29]. Beyond self-reported health monitoring and education research on older adults, tourism is another area of growing interest among gerontology researchers, particularly in developing countries, as this population group finds ways to stay active throughout their lives.

In this study, we define older adults as individuals aged 55 years and above. This age threshold reflects the traditional association of age 55 with retirement-related transitions in Malaysia [16]. Retirement is a major life transition that may shape individuals' lifestyles, social participation, and technology use. Therefore, selecting 55 as the starting age provides a contextually relevant basis for examining older adults' experiences, needs, and technology interactions in Malaysia.

B. Augmented Reality (AR) Designs for Older Adults

Williams et al. [20] investigated different types of AR prompts for older adults, highlighting how instructional presentation can influence task performance and user preferences. Similarly, Gomez-Hernandez et al. [12] identified important design considerations for mobile applications for older adults, including visual presentation, navigation, and interaction requirements. These studies provide a foundation for examining interface characteristics that may influence older adults' experiences when interacting with AR applications.

The presentation of information is another important consideration in interface design. Song et al. [21] examined how users with different experience levels use text and multimedia content, while Jin et al. [22] investigated interactive guidance for older adults using smartphone applications. Yang and Gan [23] also discussed age-friendly information animations, emphasizing the importance of visual clarity and manageable information presentation. Although these studies were conducted in different technological contexts, they provide relevant considerations for evaluating text, audio, and multimedia presentation alternatives.

C. Related Work

This study followed a user-centered design approach [15] informed by two preceding research stages. The first stage explored ten older adults' perceptions, needs, and concerns about AR applications in cultural tourism through a focus group [10], highlighting the need for a decent older-adult interface and interaction when using AR. Then, a low-fidelity AR prototype for older adults in cultural tourism was designed, and the second stage conducted an expert heuristic evaluation of the lo-fi prototype using the elderly-centered usability heuristics proposed by Nishchik et al. [3]. This evaluation identified 23 usability issues that informed the selection of design elements requiring further investigation.

Thus, the considerations identified in these studies were reviewed and adapted based on their relevance to older adults' cognitive, perceptual, and physical abilities, as well as the interaction requirements of AR applications. Where the existing AR literature provided insufficient guidance, we incorporated relevant design principles from studies on mobile and web applications for older adults to address visual presentation, navigation, interaction, feedback, and accessibility.

This study investigated seven design preference experiments, including information delivery methods, which may influence how older adults access and understand content presented through digital interfaces. Previous research has examined text, multimedia content, and interactive guidance to support information presentation for users with different experience levels [21-22]. Text provided a visual reading-based approach, whereas audio offered a listening-based approach to accessing information.

The inclusion of AR object size as an experimental variable was informed by the broader visual accessibility concerns identified in [10]. The focus group findings highlighted the importance of visual clarity and larger interface elements for older adults. Presentation method is another important consideration in designing accessible digital information for older adults. Previous studies have discussed the role of text, multimedia content, and interactive guidance in supporting information accessibility and user engagement [21-23]. Text enabled participants to read the information, audio provided spoken explanations, and video combined visual and auditory information. Letter spacing is another typographic characteristic that may affect text readability, particularly for older adults who experience age-related changes in visual abilities. The Web Content Accessibility Guidelines [24] identify adjustable letter spacing as an important accessibility consideration, including spacing of at least 0.12 times the font size.

The method used to access AR content is another important consideration in designing accessible experiences for older adults. AR applications may use different approaches to initiate an experience, including QR codes, image markers, and markerless access through direct links. These approaches require different interactions, such as scanning a code, recognizing a predefined image, or opening a link without scanning a physical marker.

User-centred AR research further supports the involvement of older adults in evaluating design alternatives. Achilleos et al. [25] reported design considerations emerging from the development and evaluation of an AR-supported system with older users, including interface clarity and interaction guidance. However, findings from general mobile applications, instructional systems, and AR prototypes do not directly establish which specific interface configurations older adults will prefer in cultural tourism applications.

Font size is an important design consideration for older adults due to variations in visual abilities and reading requirements. Hou et al. [5] systematically reviewed font-size recommendations for older adults using mobile devices, highlighting the importance of appropriate text sizing for readability. Similarly, Cauz et al. [26] identified font size as an important parameter in augmented reality text readability.

Line spacing is another typography consideration that may influence text readability and accessibility. The Web Content Accessibility Guidelines [24] recommend a line height of 1.5 times the font size as an important reference for accommodating user-adjusted text spacing.

Marker size is another important factor in augmented reality applications because it can affect tracking accuracy and marker recognition. Pérez-Pachón et al. [27] investigated three image marker sizes (4×4 , 8×8 , and 12×12 cm) and reported that smaller markers were associated with greater registration errors. Similarly, Colley et al. [28] evaluated the tracking performance of graphically designed AR markers and demonstrated that smartphone-based AR technology could reliably detect 20×20 cm markers.

III. METHODOLOGY

A. Research Design

This study employed a within-participant experimental design to investigate older adults' preferences for selected interface and interaction elements intended for a Web-based Augmented Reality (hereafter "WebAR") application in cultural tourism.

This current study investigated seven design preference experiments: 1) marker size, 2) font size and line spacing, 3) information delivery, 4) presentation method, 5) letter spacing, 6) AR object size, and 7) marker type, as explained in Section II-C. The experimental materials included AR markers, mobile interface configurations, audio and textual cultural information, multimedia presentation alternatives, three-dimensional AR content, and different AR access methods. For each experiment, participants were presented with two or more design alternatives. Participants compared the design alternatives and selected their preferred options by answering a post-study questionnaire.

The instrument collected participants' satisfaction ratings, final design preferences, and supplementary qualitative feedback. This process ensured that the experimental evaluation was grounded in previously identified user needs and usability concerns, rather than relying exclusively on general interface design recommendations [18, 19].

B. Participants

We recruited participants based on predefined inclusion criteria aligned with the study's target population. Eligible participants were 55 years of age or older. In addition, participants were in sufficiently good physical condition to participate in the experimental activities and able to use a smartphone to interact with the experimental materials. Previous AR experience was not required.

Initially, 12 participants were recruited. We excluded one participant from the final analysis because they did not meet the predefined criterion. Consequently, we included 11 eligible participants in the final analysis, a number that fits a Human-Computer Interaction (HCI) usability study [18].

Participant background information included age, gender, education, occupation, smartphone type and screen size, visual condition, technology experience level, frequency of technology

use, and prior AR experience. The final sample included participants using different Android and iOS smartphones and with varying levels of technological experience. Most participants had no prior experience with AR, allowing the evaluation to capture responses from older adults largely unfamiliar with the technology.

Participation was voluntary and conducted one-on-one with the first author, and participants were recruited via snowball sampling [17]. Participants were invited to welcome their friends, colleagues, or family members to join the experiment. Participants received an information sheet describing the study before providing informed consent. They were informed of their right to withdraw and that their information would be kept confidential and anonymous. The experimental session lasted, on average, 90 minutes, with breaks as needed.

C. Materials

This experimental study used a mid-fidelity prototype with multiple design options for different WebAR features. These design options drew on augmented reality and older adults literature and included variations in navigation layouts, topic button designs, instructional presentation methods, multimedia content arrangements, font size options, audio features, and AR interaction methods [e.g., 21-29].

1) *Experiment 1 - Marker size*: Four AR marker sizes were evaluated: 4×4 cm, 8×8 cm, 12×12 cm, and 20×20 cm. The same marker design was used across conditions, so marker size was the primary variable. We printed the markers individually on A4-sized paper at their actual physical dimensions (4×4 cm, 8×8 cm, 12×12 cm, and 20×20 cm). The marker is placed in front of the participant. The participant may hold the marker or scan directly on the table, whichever suits their style of interaction. After scanning the marker, the AR object size is the same for all four options.

2) *Experiment 2 - Font size and line spacing*: We evaluated typography on a mobile-phone interface. We compared four font sizes: 12pt, 14pt, 16pt, and 18pt. Line spacing alternatives of 1.0, 1.5, and 2.0 were also evaluated. All participants evaluated the font-size and line spacing alternatives in a fixed ascending order, without counterbalancing the presentation sequence. This means we investigated 12pt x 1.0 spacing, then 12pt x 1.5 spacing, then 12pt x 2.0 spacing. This was followed by 14pt, 16pt, and lastly 18pt. All fonts used in this study (i.e., Experiment 2 - 5) were sans serif, as the letterforms may support readability and visual clarity for older adults [30].

Participants explored different combinations of font size and line spacing, in the same order, before providing overall satisfaction ratings for each font-size and line-spacing alternative. These ratings were analyzed separately using Friedman tests. However, because the typographic settings were explored in combination, the analysis did not isolate potential interaction effects between font size and line spacing. The same cultural information text was presented across all evaluated typographic configurations to maintain consistency in reading content.

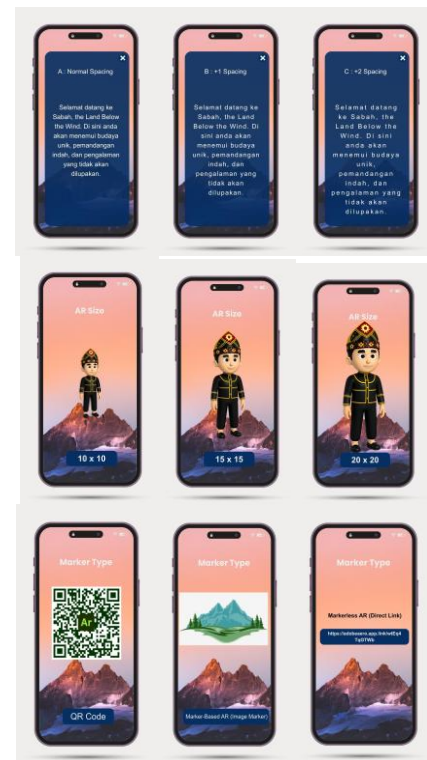


Fig. 1. (Top-middle-bottom) The design options for experiment 5; experiment 6; experiment 7.

Fig. 1 shows some of the study's design options. The mid-fidelity AR prototype was designed using tools such as Adobe Aero, Photoshop, and Illustrator.

3) *Experiment 3 - Information delivery*: Participants evaluated cultural information presented through audio and text. In addition to rating each mode, participants indicated whether they ultimately preferred audio, text, or a combination of both. Participants were also asked about their preferred narration voice and whether they experienced any challenges while receiving the information.

4) *Experiment 4 - Presentation method*: We presented cultural information through text, audio, and video. The wording was the same across all three methods. We did not investigate the pace and/or brightness of the audio and/or video. Participants evaluated each method and then indicated their preferred method, including the option to select a combination of the available media.

5) *Experiment 5 - Letter spacing*: Three letter-spacing configurations were evaluated: 0 pt, 1 pt, and 2 pt. These conditions were presented using culturally relevant text to determine which spacing configuration participants found most suitable.

6) *Experiment 6 - AR object size*: Participants evaluated a three-dimensional cultural AR object presented at 10×10 cm, 15×15 cm, and 20×20 cm. The same AR object was used across conditions, with its displayed size varied.

7) *Experiment 7 - Marker type*: Three approaches to accessing AR content were evaluated: QR Code, Marker AR, and Markerless AR. The QR Code condition required scanning a QR code; the Marker AR condition required recognizing a designated image; and the Markerless AR condition provided access without a physical marker. The experimental development materials illustrate these three alternative access approaches.

We recorded AR activation time in seconds for each access method, starting when participants initiated the QR code scan, image-marker scan, or markerless link and ending when the AR content appeared on the screen. Therefore, this experiment compared different AR activation approaches rather than isolating the effects of tracking technology alone.

D. Procedure

The first author conducted the experiments one-on-one with each participant. The experiments took place in the first author's workplace, participants' homes, or other locations that suited participants to support natural environmental settings. During the experiments, no one else was present.

Before the experiments began, participants were briefed on the study and completed the informed consent procedure. During the briefing session, participants were shown using an iPhone 12 Pro (running iOS 17.6.1) and Samsung Galaxy A52 (running Android 14). However, during the experiment, participants used their own devices.

They then completed the seven design preference experiments and interacted with the alternative configurations for each design element. For each experiment, participants rated their satisfaction on a 10-point Likert scale. Preference responses complemented the condition ratings and indicated which alternative participants would choose after experiencing the available options.

All participants completed the seven experiments in the same sequential order, from Experiment 1 to Experiment 7. The experimental order was not counterbalanced across participants. Participants were allowed to take breaks as needed between experimental activities, although no fixed rest intervals were imposed.

Additional qualitative feedback was also obtained. We encouraged participants who experienced challenges during the experiments to verbalize their experiences. These comments provided context on issues such as audio clarity, volume, language comprehension, and the readability of textual information. We retained the qualitative responses as supplementary evidence to help interpret the quantitative findings. However, due to the length of this study, we present only the quantitative results. The qualitative results are intended to be published elsewhere.

Light snacks, water, and fruit juices were available throughout the experiments. Participants were offered a RM100 monetary reward for their time and effort.

E. Data Analysis

The quantitative data were analyzed using descriptive statistics and non-parametric inferential statistics. The mean and

standard deviation were calculated to summarise participants' satisfaction ratings for the alternative configurations. Frequency and percentage were used to summarise participants' final preferences.

As the same participants evaluated multiple alternatives within each experiment, the Friedman test was used to determine whether statistically significant differences existed among the repeated conditions. We evaluated statistical significance at $p < .05$. When the Friedman test indicated an overall significant difference, we then examined Durbin–Conover pairwise comparisons to determine which specific conditions differed. Pairwise comparisons were not interpreted where the overall Friedman test was non-significant. To account for multiple testing, the Holm adjustment was applied to the p-values obtained from the Durbin–Conover pairwise comparisons. Kendall's coefficient of concordance (W) was calculated from the Friedman chi-square statistic to quantify the effect size. The Holm adjustment was also applied across the eight omnibus Friedman tests, with font size and line spacing analysed separately within Experiment 2.

The final design decisions were informed by the overall pattern of descriptive ratings, statistical comparisons, participant preference frequencies, and relevant qualitative feedback, rather than statistical significance alone. The satisfaction ratings and final selections were used to evaluate participants' design preferences rather than to establish objective usability performance. Therefore, the findings should not be interpreted as direct evidence of improvements in task efficiency, reading speed, comprehension, or error reduction. This was particularly relevant because several experiments demonstrated clear descriptive preferences despite non-significant Friedman results.

IV. RESULTS

The final analysis included 11 older adults. Participants included six females (54.55%) and five males (45.45%). Most participants were aged between 60–69 years ($n=6$, 54.55%), followed by those aged 70–79 years ($n=3$, 27.27%) and 56–59 years ($n=2$, 18.18%). In terms of educational background, six participants (54.55%) held a diploma, four (36.36%) had completed SPM, and one (9.09%) held a master's degree.

Most participants used Android smartphones ($n=10$, 90.91%), while one participant (9.09%) used an iOS device. Seven participants (63.64%) used glasses, whereas four (36.36%) reported normal vision. Previous AR experience was limited: one participant (9.09%) reported prior AR use, and ten participants (90.91%) reported no prior AR experience.

A. Experiment 1: Marker Size

Experiment 1 evaluated four physical marker sizes: 4×4 cm, 8×8 cm, 12×12 cm, and 20×20 cm. The 8×8 cm marker had the highest mean rating ($M = 6.00$, $SD = 1.00$), followed by the 12×12 cm and 20×20 cm markers, both with a mean rating of 5.45. The 4×4 cm marker received the lowest mean rating ($M = 5.00$, $SD = 1.73$). However, the Friedman test showed no statistically significant difference in participants' ratings across the four marker sizes, $\chi^2(3) = 3.49$, $p = .322$. The corresponding Kendall's W was 0.106, indicating a small degree of

concordance in participants' ratings across the four marker-size conditions.

The final preference results showed that 12×12 cm was the most frequently selected marker size, chosen by five participants (45.45%). This was followed by 8×8 cm ($n = 3$, 27.27%), 20×20 cm ($n = 2$, 18.18%), and 4×4 cm ($n = 1$, 9.09%).

B. Experiment 2: Font Size and Line Spacing

1) *Font size*: Participants evaluated four font sizes: 12 pt, 14 pt, 16 pt, and 18 pt. The 18 pt obtained the highest mean rating ($M = 6.45$, $SD = 1.04$), followed by 16 pt ($M = 4.73$, $SD = 1.90$), 14 pt ($M = 3.55$, $SD = 1.92$), and 12 pt ($M = 2.64$, $SD = 1.80$). A Friedman test showed a statistically significant difference in participants' ratings across the four font sizes, $\chi^2(3) = 18.70$, $p < .001$. The font-size result remained statistically significant after Holm adjustment across the eight omnibus Friedman tests (adjusted $p < .008$).

Following Holm adjustment, Durbin–Conover pairwise comparisons showed significant differences between 12 pt and 16 pt, 12 pt and 18 pt, and 14 pt and 18 pt (adjusted $p < .006$ for each comparison). The remaining comparisons were not statistically significant after adjustment. In particular, the difference between 16 pt and 18 pt was not statistically significant (unadjusted $p = .051$), indicating that the higher mean satisfaction rating for 18 pt should not be interpreted as statistically significant superiority over 16 pt. The Friedman test yielded a Kendall's W of 0.567. Final preferences strongly favoured 18 pt, which was selected by eight participants (72.73%), while 12 pt, 14 pt, and 16 pt were each selected by one participant (9.09%).

2) *Line spacing*: For line spacing, participants evaluated 1.0, 1.5, and 2.0 spacing. The 1.0 condition obtained the highest mean rating ($M = 6.18$, $SD = 1.47$), followed by 1.5 ($M = 4.00$, $SD = 1.34$) and 2.0 ($M = 2.82$, $SD = 1.83$). The Friedman test showed a statistically significant difference among the three conditions, $\chi^2(2) = 9.26$, $p = .010$. However, after applying the Holm adjustment across the eight omnibus Friedman tests, the line-spacing result was no longer statistically significant (adjusted $p = .070$). The effect size was Kendall's W = 0.421. Following Holm adjustment of the Durbin–Conover pairwise comparisons, only the difference between 1.0 and 2.0 line spacing remained statistically significant (adjusted $p = .003$).

In terms of final preference, seven participants (63.64%) selected 1.0, three (27.27%) selected 1.5, and one (9.09%) selected 2.0.

C. Experiment 3: Information Delivery

Experiment 3 examined participants' preferences for audio and text as information delivery methods. When evaluated individually, audio obtained a slightly higher mean rating ($M = 6.91$, $SD = 1.81$) than text ($M = 6.55$, $SD = 1.86$). However, the Friedman test showed no statistically significant difference between the two methods, $\chi^2(1) = 0.143$, $p = .705$. The corresponding Kendall's W was 0.013, indicating a very small effect size for the difference between audio and text presentation.

When participants indicated their final preference, six participants (54.55%) selected a combination of audio and text, four (36.36%) selected text only, and one (9.09%) selected audio only. Participants were also asked about their preferred narration voice. Five participants (45.45%) preferred a female voice, four (36.36%) preferred a male voice, and two (18.18%) indicated no preference. Thus, the results showed only a slight preference for a female narration voice.

D. Experiment 4: Presentation Method

Experiment 4 evaluated audio, text, and video as ways to present cultural heritage information. Video obtained the highest mean rating ($M = 7.91$, $SD = 2.30$), followed by audio ($M = 7.27$, $SD = 1.79$) and text ($M = 6.09$, $SD = 2.07$). The Friedman test showed no statistically significant difference among the three presentation methods, $\chi^2(2) = 4.56$, $p = .102$. The corresponding Kendall's W was 0.207, indicating a modest degree of concordance across the three presentation methods.

Participants divided their final preferences between video and a combination of presentation methods, with each selected by four participants (36.36%). Text was selected by two participants (18.18%), while audio was selected by one participant (9.09%).

E. Experiment 5: Letter Spacing

Experiment 5 evaluated three letter-spacing configurations: 0 pt, 1 pt, and 2 pt. The 0 pt condition obtained the highest mean rating ($M = 8.36$, $SD = 1.75$), followed by 1 pt ($M = 6.55$, $SD = 2.42$) and 2 pt ($M = 5.36$, $SD = 3.35$). However, the Friedman test showed no statistically significant difference among the three conditions, $\chi^2(2) = 2.89$, $p = .236$. The corresponding Kendall's W was 0.131, indicating a relatively small effect size across the three letter-spacing conditions.

Five participants (45.45%) selected 0 pt as their final preference, while three participants each selected 1 pt and 2 pt (27.27%). All participants reported no challenges during this experiment.

F. Experiment 6: AR Object Size

Experiment 6 evaluated three AR object sizes: 10×10 cm, 15×15 cm, and 20×20 cm. The 15×15 cm object obtained the highest mean rating ($M = 5.64$, $SD = 1.21$), followed by 20×20 cm ($M = 5.45$, $SD = 2.02$) and 10×10 cm ($M = 4.18$, $SD = 1.94$). The Friedman test showed no statistically significant difference among the three AR object sizes, $\chi^2(2) = 4.92$, $p = .085$. The corresponding Kendall's W was 0.224, indicating a modest degree of concordance across the three AR object-size conditions.

Final preference results were equally divided between 15×15 cm and 20×20 cm, with five participants selecting each (45.45%). Only one participant (9.09%) selected 10×10 cm.

G. Experiment 7: Marker Type

Experiment 7 compared three approaches for accessing AR content: QR Code, Marker AR (Image Marker), and Markerless AR. Markerless AR obtained the highest mean rating ($M = 6.00$, $SD = 1.26$), followed by QR Code ($M = 5.09$, $SD = 1.64$) and Marker AR ($M = 4.64$, $SD = 2.06$). The Friedman test showed no statistically significant difference among the three marker

types, $\chi^2(2) = 2.58$, $p = .275$. The corresponding Kendall's W was 0.117, indicating a small effect size across the three AR marker-type conditions.

Five participants selected Markerless AR (45.45%), while three each selected QR Code and Marker AR (27.27%). AR activation time was recorded for all three access methods. Descriptive analysis showed that QR Code had the shortest mean activation time ($M = 3.67$ s, $SD = 1.33$), followed by Markerless AR ($M = 7.97$ s, $SD = 17.33$) and Image Marker ($M = 29.24$ s, $SD = 45.35$). The corresponding median activation times were 3.53 s, 3.00 s, and 10.00 s, respectively. These findings describe the observed activation times and do not establish statistically significant differences in efficiency between the methods. Based on the descriptive ratings and final preferences, Markerless AR was selected for subsequent prototype development.

V. DISCUSSIONS

A. Visual Readability and Text Presentation

The findings highlight text presentation as an important design consideration for the older adults in this study. Among the typography variables evaluated, only font size remained statistically significant after Holm adjustment across the eight omnibus Friedman tests, whereas line spacing and letter spacing did not demonstrate statistically significant differences after adjustment. In particular, 18 pt was selected by 72.73% of participants and received the highest mean rating among the four font sizes. The significant Friedman result ($p < .001$) further indicates that participants did not respond equally to the different font-size conditions. However, after Holm adjustment, only pairwise comparisons between 12 pt and 16 pt, 12 pt and 18 pt, and 14 pt and 18 pt were statistically significant. In particular, the difference between 16 pt and 18 pt remained non-significant after adjustment. Thus, the findings provide stronger evidence for a general preference for larger text, with 18 pt as the most preferred configuration among the alternatives tested in this study.

This pattern aligns with previous research showing the importance of font size for older users. Gonzalez Cardenas et al. [4] found that font size significantly affected reading time among older adults using AR, with smaller text resulting in longer reading times; participants also preferred the largest font size tested, which was 14pt. Similarly, Hou et al. [5], a study on mobile apps, concluded that readability generally deteriorates as character size decreases and showed that recommended sizes for older adults vary by device, reading task, viewing distance, and experimental context. These studies support the present finding that designers should pay particular attention to larger typography when designing digital information for older adults.

Nevertheless, the present results should not be interpreted as establishing 18 pt as a universal optimum for older adults. Hou et al. [5] demonstrated substantial variation in recommended font sizes across devices and reading scenarios, while immersive-display research has similarly shown that text legibility depends on factors beyond nominal font size, including viewing conditions and display characteristics. Therefore, the present study's contribution is more context-specific: among the four sizes evaluated for the proposed mobile

Web AR cultural-tourism application, 18 pt produced the strongest participant preference and was therefore considered the most appropriate configuration for subsequent prototype development.

The line-spacing findings contrast with the font-size results. Participants most frequently preferred 1.0 line spacing (63.64%). Although the Friedman test initially indicated a statistically significant difference among the three spacing conditions ($p = .010$), this result did not remain statistically significant after Holm adjustment across the eight omnibus tests (adjusted $p = .070$). In the post-hoc analysis, only the comparison between 1.0 and 2.0 line spacing remained statistically significant after Holm adjustment of the Durbin–Conover pairwise p -values (adjusted $p = .003$), whereas the comparisons between 1.0 and 1.5 and between 1.5 and 2.0 were not statistically significant after adjustment. This suggests that increasing line spacing to the widest condition did not necessarily provide a more favourable reading experience. More importantly, the result challenges the assumption that accessibility for older adults can always be improved simply by maximising spacing.

This finding is particularly interesting when compared with earlier research. Hou et al. [5] reviewed studies showing that increased inter-character and inter-line spacing can improve aspects of reading performance for older adults, but the review also shows that suitable typography depends on the reading scenario and display conditions rather than a single fixed configuration. The current finding therefore does not necessarily contradict previous evidence. Instead, it reinforces the importance of evaluating spacing within the specific interface and content context in which it will be used. For the participants in this study, 2.0 line spacing was less favorably evaluated, while 1.0 emerged as the final preferred configuration.

A similar pattern was observed for letter spacing. Although 0 pt received the highest mean rating and was most frequently selected, differences among 0 pt, 1 pt, and 2 pt were not statistically significant ($p = .236$). Consequently, the result should be interpreted as a descriptive preference for the default spacing rather than evidence that 0 pt objectively improves readability. Taken together, the typography experiments indicate that larger text was more clearly supported than increased spacing. For this participant group, improving visual accessibility therefore involved increasing the prominence of the text without necessarily expanding the spacing between lines or characters.

These findings also reinforce the value of involving older adults directly in AR interface design. Elderly-centered AR usability research has highlighted that general usability principles alone may not adequately capture the requirements of older users and has emphasized the importance of considering their perceptual and interaction needs during design and evaluation. In the present study, direct comparison of alternative typography configurations revealed that recommendations that may appear intuitively age-friendly, such as progressively increasing spacing, were not necessarily the configurations participants preferred. The results therefore support a user-centred and context-sensitive approach in which accessibility

recommendations provide an initial design direction but are subsequently validated with the intended older users.

B. Information Delivery and Multimedia Presentation

The findings indicate that older adults did not demonstrate a clear preference for a single information modality. In Experiment 3, audio obtained a slightly higher mean rating than text, but the difference was not statistically significant ($p = .705$). More importantly, when participants indicated their final preferred method, more than half (54.55%) selected a combination of audio and text, compared with 36.36% who preferred text only and 9.09% who preferred audio only. Rather than showing one modality is superior, this pattern suggests that providing information in multiple formats may better accommodate differences in how older adults prefer to receive cultural information.

This interpretation is consistent with emerging work on age-inclusive AR heritage interpretation. Zhu et al. [2] identify readable text, audio alternatives, replay, enlargement, and pace control as relevant features for supporting ease of use among older heritage visitors. Furthermore, their work conceptualizes these features as alternative forms of support rather than assuming that one information channel is universally appropriate for older users. Recent empirical work involving older adults with visual impairments also demonstrates that audible information can support accessibility, while excessive or poorly structured audio may itself increase cognitive strain [6]. Together with the present participants' comments, this suggests that audio is most appropriately treated as a complementary and controllable information channel rather than a replacement for visual information.

A similar pattern emerged in Experiment 4. Although video obtained the highest individual mean rating ($M = 7.91$), differences among video, audio, and text were not statistically significant ($p = .102$). When considering final preferences, video and the combination of presentation methods were equally preferred, with each selected by 36.36% of participants. Therefore, the decision to incorporate video, text, and audio into the high-fidelity prototype should not be interpreted as evidence that multimedia presentation was statistically superior. Instead, it reflects the distribution of participant preferences and provides multiple ways of accessing the same cultural content.

This flexibility is particularly relevant within cultural heritage environments. Visitors interact with digital interpretation while also attending to physical artefacts, surroundings, and movement through the heritage space. Zhu et al. [2] similarly argue that AR heritage interpretation requires visitors to divide their attention between the physical environment and digital information. Recent research on audio augmentation in outdoor cultural heritage has also examined text and different forms of audio delivery as alternative mechanisms for presenting heritage information, highlighting the continuing importance of how information modality shapes the visitor experience [7]. Consequently, providing complementary media may allow users to select an information format appropriate to their immediate needs and surrounding context.

The narration-voice results further demonstrate why these preferences should not be converted into rigid design rules.

Although female narration received the largest share of preferences (45.45%), many participants preferred male narration (36.36%), while 18.18% expressed no preference. The relatively small difference does not provide sufficient evidence to establish one narration voice as universally preferable. Instead, the finding reinforces the broader pattern observed in the information-delivery experiments: older adults should not be treated as a homogeneous user group with a single preferred mode of receiving information.

Overall, the results support a flexible multimodal approach to Web AR cultural-tourism design. In this context, multimodality does not mean presenting as much information as possible simultaneously. Instead, text, audio, and video can serve as complementary options, keeping cultural information accessible through different channels. This distinction matters because simply increasing multimedia may add information demands rather than improve accessibility. The findings therefore suggest that multimodal Web AR for older adults should emphasise choice, complementarity, and clarity, with readable text retained as an important information source and audio and video used to supplement the experience where appropriate.

C. AR Visualisation and Physical Interaction

The findings on marker size and AR object size suggest that participants generally favored moderate-to-large visual configurations, although neither experiment showed a statistically significant difference. For marker size, the 8×8 cm condition received the highest mean rating, while participants most frequently selected the 12×12 cm marker as their final preference (45.45%). The Friedman test was non-significant ($p = .322$), indicating that participants did not statistically differentiate the four marker sizes. Therefore, selecting 12×12 cm should be understood as a participant-informed design choice among the tested alternatives rather than evidence of an objectively superior marker size.

The distinction between the highest-rated and most frequently preferred marker size is noteworthy. While 8×8 cm received the highest mean satisfaction rating, more participants ultimately selected 12×12 cm. This illustrates the value of considering both condition ratings and final design preferences when evaluating interface alternatives. A rating captures participants' responses to an individual configuration, whereas a final preference requires participants to select among the alternatives after experiencing them. In the present study, these two measures did not always yield the same design choice, showing why relying on a single descriptive measure may not fully represent user preference.

The AR object-size experiment showed a comparable pattern. The 15×15 cm AR object received the highest mean rating and the lowest standard deviation, while participants selected the 15×15 cm and 20×20 cm objects equally as final preferences, each at 45.45%. In contrast, only 9.09% selected the smallest 10×10 cm condition. Nevertheless, the overall difference among the three object sizes did not reach statistical significance ($p = .085$). The findings therefore indicate a descriptive tendency away from the smallest AR object rather than statistical evidence that larger objects were superior.

These findings are relevant to age-sensitive AR design because the visibility of virtual content and the interaction required to perceive that content are closely connected. Elderly-centered AR usability heuristics proposed by Nishchik et al. [3] emphasize accounting for age-related perceptual and interaction requirements rather than applying general AR design principles without adaptation. Their framework also considers the relationship between AR content, hardware, the surrounding environment, and users' comfort during interaction. This broader perspective is relevant to the current findings because users experience marker and virtual-object dimensions through a mobile device while simultaneously orienting the device toward physical or virtual content.

At the same time, the present results do not support a simple assumption that increasing the physical or virtual size of every AR element will continuously improve the experience. The largest 20×20 cm marker was not the most frequently preferred marker configuration, while the 20×20 cm AR object did not obtain a higher mean rating than the 15×15 cm condition. This pattern complements the typography findings discussed earlier: age-inclusive design may require sufficient visual prominence, but larger is not necessarily better once an element is already adequately perceivable.

Accordingly, selecting 12×12 cm for the marker and 15×15 cm for the AR object reflects context-specific design preferences derived from the tested configurations. These dimensions should not be interpreted as universal recommendations for all older adults or all Web AR applications. Instead, the findings demonstrate the usefulness of evaluating physical and virtual presentation parameters with the intended users before finalizing an AR interface, particularly when the application is intended to operate within a cultural-tourism environment.

D. Access to AR Content

The marker-type experiment extends this discussion from the presentation of AR content to the way users access the AR experience. Among the three approaches evaluated, Markerless AR obtained the highest mean rating ($M = 6.00$, $SD = 1.26$) and was selected by the largest proportion of participants (45.45%). QR Code and Marker AR were each selected by 27.27% of participants. However, the Friedman test showed no statistically significant difference among the three access methods ($p = .275$). Markerless AR should therefore be interpreted as the strongest descriptive preference within this participant group rather than as a statistically superior access method.

This finding is particularly relevant because the three approaches require different forms of interaction before users can access AR content. In the experimental design, the QR Code condition required participants to scan a code, the image-marker condition required participants to recognize a designated image, and the Markerless AR condition enabled access without a physical marker. The descriptive preference for Markerless AR may therefore indicate that some participants favoured an access approach involving fewer dependencies on a physical trigger. However, because the study did not independently manipulate or statistically test interaction complexity as a construct, this explanation should be treated as an interpretation rather than a directly measured effect.

This interpretation aligns with the broader principle of reducing unnecessary interaction demands in AR interfaces for older users. Nishchik et al.'s [3] elderly-centered AR heuristics emphasize the importance of considering users' physical capabilities, interaction comfort, hardware characteristics, and the surrounding environment when designing AR systems. Within cultural tourism, these considerations are especially relevant because visitors may need to manage the smartphone while simultaneously observing their surroundings and engaging with cultural content. A method that reduces dependence on an additional physical trigger may consequently be advantageous in some contexts, although the present study does not establish this relationship statistically.

The marker-type result also needs to be considered alongside the limited AR experience of the participant sample. Ten of the eleven participants (90.91%) reported no prior AR experience. Despite this limited familiarity, participants evaluated QR Code, image-marker, and markerless approaches and expressed preferences after experiencing the alternatives. This supports the methodological decision to obtain direct evaluations from the intended older users rather than assuming that familiarity with a particular access mechanism would automatically make it the preferred option.

The descriptive activation-time results provide additional context for interpreting participants' preferences. QR Code recorded the shortest mean activation time, whereas Markerless AR recorded the shortest median activation time. However, these observations do not establish statistically significant differences in efficiency. Therefore, the selection of Markerless AR for subsequent prototype development was primarily informed by participants' satisfaction ratings and final preferences rather than demonstrated superiority in activation speed.

Taken together, the marker-type findings suggest that AR access mechanisms should be considered part of the overall usability experience rather than merely as a technical implementation choice. For the subsequent high-fidelity Web AR prototype, Markerless AR was selected because it produced the highest descriptive rating and the largest final preference share. Within the scope of this study, this selection represents a user-informed design decision, while further evaluation would be required to determine whether markerless access also provides measurable advantages in efficiency, learnability, or interaction effort.

E. AR Design Implication

The seven design preference experiments demonstrate that designing Web AR for older adults requires attention to both statistically distinguishable interface characteristics and context-specific user preferences. After Holm adjustment across the eight omnibus Friedman tests, only font size remained statistically significant. The remaining elements, marker size, information delivery, presentation method, letter spacing, AR object size, and marker type, did not differ significantly among their individually evaluated conditions. This distinction matters because the findings should not be interpreted as showing that every selected configuration was objectively superior to its alternatives.

Instead, the study illustrates the complementary roles of inferential statistics, descriptive ratings, and final participant preferences in informing design decisions. After Holm adjustment across the eight omnibus Friedman tests, only the font-size experiment retained a statistically significant difference among the evaluated conditions. The line-spacing result was no longer statistically significant after adjustment (adjusted $p = .070$). The Holm-adjusted pairwise comparisons revealed that, for line spacing, only the difference between 1.0 and 2.0 was statistically significant (adjusted $p = .003$), whereas the comparisons between 1.0 and 1.5 and between 1.5 and 2.0 were not statistically significant. Similarly, for font size, the difference between 16 pt and 18 pt was not statistically significant after adjustment. Thus, the final selection of 18 pt and 1.0 line spacing reflected both the statistical findings and participants' stronger final preferences rather than significance alone.

For the remaining design elements, the absence of statistical significance does not mean that the experiments provided no useful design information. Instead, the findings indicate that participants did not differentiate the alternatives strongly enough to detect statistically significant differences in this sample. Their final choices nevertheless provided practical evidence about which configurations they preferred after experiencing the alternatives. This resulted in the selection of a 12×12 cm marker, audio combined with text, multimedia presentation through video, text and audio, 0 pt letter spacing, a 15×15 cm AR object, and Markerless AR. These selections should therefore be understood as preferred configurations within the specific alternatives and study context, rather than universal design standards for older adults.

An important implication across the experiments is that age-inclusive design does not necessarily require maximising every accessibility-related parameter. Participants preferred the largest font size tested, but this pattern was not replicated for line spacing, letter spacing, marker size, or AR object size. For example, participants preferred 1.0 line spacing and 0 pt letter spacing over more widely spaced alternatives, while selecting intermediate sizes for the marker and AR object. Collectively, these findings suggest that visual accessibility should be approached through an appropriate configuration of multiple interface characteristics rather than assuming that increasing size or spacing will consistently produce a more suitable experience.

The information-delivery findings further suggest that flexibility is an important consideration. Participants did not collectively converge on audio or text as a single preferred modality; instead, the largest proportion selected audio combined with text. Similarly, preferences for presentation methods were split between individual and combined media, leading the subsequent prototype to incorporate video, text, and audio. This supports an approach in which Web AR cultural information can be accessed through complementary formats, allowing users with different preferences to engage with the content without relying on a single mode of presentation.

These findings are consistent with the broader argument for age-sensitive and user-centred AR design. Nishchay et al. [3] emphasize that AR applications for older adults require

consideration of perceptual, physical, interaction, environmental, and hardware-related factors rather than reliance on general usability principles alone. Similarly, previous research on typography for older adults has demonstrated that interface parameters should be considered in relation to the specific device and usage context rather than treated as universally applicable values [4,5]. The present study extends this user-centred approach by applying direct preference evaluation not only to typography but also to information modality, AR visualisation, physical markers, and methods of accessing Web AR content.

From a practical perspective, the experiments provided an empirical basis for moving from design alternatives to a defined set of configurations for the subsequent high-fidelity prototype. Rather than implementing interface decisions solely from literature-based recommendations, the prototype incorporated configurations that the intended older-user group had first experienced and evaluated. The resulting design consisted of a 12×12 cm marker, 18 pt font size, 1.0 line spacing, audio and text information delivery, multimedia presentation incorporating video, text, and audio, 0 pt letter spacing, a 15×15 cm AR object, and Markerless AR access.

Overall, this study demonstrates the value of incorporating design preference experiments as an intermediate stage between general design guidance and full prototype implementation. The findings do not establish a universal set of optimal Web AR parameters for older adults. Instead, they provide participant-informed design preferences for the cultural-tourism context examined in this study and show how direct evaluation can refine literature-informed design decisions before a complete application is developed.

VI. CONCLUSION

This study investigated older adults' preferences for selected interface and interaction elements intended for a Web-based Augmented Reality application in cultural tourism. The study conducted seven design preference experiments to evaluate marker size, font size and line spacing, information delivery, presentation method, letter spacing, AR object size, and marker type. By allowing older adults to experience and evaluate alternative configurations directly, the study provided an empirical basis for refining design decisions before developing the high-fidelity Web AR prototype.

After Holm adjustment across the eight omnibus Friedman tests, only font size remained statistically significant. Nevertheless, 18 pt font size and 1.0 line spacing were the most frequently preferred configurations within their respective tested alternatives. For the remaining elements, although the differences were not statistically significant, participants' descriptive ratings and final preferences informed the selection of a 12×12 cm marker, audio and text information delivery, multimedia presentation incorporating video, text and audio, 0 pt letter spacing, a 15×15 cm AR object, and Markerless AR. These findings indicate that designing for older adults should not be based simply on maximising size, spacing, or the amount of multimedia content. Instead, consider appropriate configurations based on the specific interface, interaction context, and preferences of the intended users.

The study contributes a participant-informed approach to translating general age-sensitive AR design considerations into specific configurations for Web AR cultural-tourism applications. Rather than treating the identified preferences as universal or optimal design standards, the findings provide context-specific evidence to support prototype development and demonstrate the value of involving older adults before interface decisions are finalized. The selected configurations were subsequently incorporated into the high-fidelity Web AR prototype for further usability and user-experience evaluation.

Nevertheless, this study has some limitations. The final sample consisted of 11 older adults, and the experiments examined a predefined set of design alternatives within a specific cultural-tourism context. Consequently, the findings may not be generalised to all older adults or all AR applications. The small sample size also limits the statistical power of the analyses, and non-significant findings should not be interpreted as evidence of equivalence between design alternatives. Therefore, the findings should be regarded as exploratory and interpreted within the specific participant group and experimental conditions examined. However, this study aimed to establish web-AR design preferences, and the results suggest this is largely the case.

Future research could evaluate the identified configurations with larger and more diverse samples, investigate additional interface and interaction alternatives, and examine whether the preferences observed in controlled design experiments translate into improvements in usability, accessibility, task performance, and user experience during actual Web AR use.

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VII. DECLARATIONS

We declare that we used language editing software solely to check and improve the English language, including grammar, spelling, punctuation, and sentence structure, during the preparation of this manuscript. We reviewed and approved all suggested changes and remain fully responsible for the accuracy, originality, content, and conclusions presented in this study.

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