Interactive Organ Locator

Multimodal Interaction and Interfaces
DT2140 HT24

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January 10, 2025

Abstract

Augmented reality (AR) has been increasingly applied across diverse domains, including education, where it demonstrates the potential to enhance spatial learning and interaction. By incorporating feedback through different modalities, such as auditory cues and haptic responses, AR systems provide users with immersive and dynamic ways to engage with complex spatial information. Interactive Organ Locator App was developed to aid users in identifying human organs in an engaging AR environment. While similar interfaces have been previously developed, they have not incorporated multi-modal feedback to enhance the learning experience. The study hypothesized that sound feedback would facilitate more naturalness, immersion, learning, and task completion compared to haptics. Participants (N=24) from diverse demographics tested two app versions featuring audio or haptic feedback while locating organs like the heart, pancreas, and kidneys. Statistical and qualitative analyses revealed that contrary to expectations, haptics offered higher naturalness and immersiveness, with comparable performance in learning and task completion across modalities. Participants praised the educational potential of both versions, though technical challenges and design limitations were noted. The findings highlight the importance of refining AR applications for usability and inclusivity, highlighting haptics as a promising modality for AR-based spatial tasks in educational and clinical contexts.

CCS Concepts
Human-centered computing → Interactive systems and tools, Empirical studies in HCI.
Keywords
Augmented Reality, AR, Haptics, 3D

Introduction

Advances in media technology have paved the way for our digital devices to enable an abundance of sensory experiences. Augmented reality allows users to interact with virtual objects in their physical surroundings. One area of research focuses on designing feedback systems that guide users through spatial or locational tasks. The choice of feedback modalities can significantly influence the usability and overall user experience of such setups [1]. By investigating this, we can gain an understanding of the strengths and limitations of feedback modalities.

In this study, the authors investigate the perception of two feedback modalities; sound and haptics (vibration), in an AR application. The authors have developed an application called the "Interactive Organ Locator App". It is a tool that allows users to identify and locate internal human organs in an exploratory and engaging manner. This application is valuable in both educational and clinical contexts, offering users alternative ways to learn and interact with human autonomy through technology.

Background and Related work

The growing field of Augmented Reality (AR), in which physical reality is enriched with virtual elements, has a plethora of use cases [2]. These applications run the gamut from pure entertainment like gaming to practical applications like navigation [2].

Among these, uses in medical and teaching fields have exciting potential [2, 3]. At the intersection of these fields lies applications that utilize AR to teach human anatomy. These apps employ visual AR-based interactions to render 3D anatomical models, enabling users to explore bones, muscles, organs, and systems dynamically. As smartphones are light-weight and easy to move around, the mobility of these apps facilitates real-time, spatial interaction with virtual models, enhancing understanding compared to static representations. In terms of learning outcomes, the integration of AR significantly improves engagement, autonomy, and retention by making anatomical studies more interactive. AR's immersive qualities allow students to visualize complex structures, leading to a better comprehension of spatial relationships [4].

An example of an educational medical technology is a Kinect-based Augmented Reality system that shows the internal anatomy of the user. The user can move and see how their internal anatomy reacts in real-time. The system is designed to be used as a tool in anatomy education for medical and athletic students. However, the authors also see its potential in communication between medical professionals and their patients [5]. Like in this potential application, AR systems continue to be used in professional medical settings, making comfort in utilizing these technologies imperative beyond education. For example, AR technologies have been used to plan and practice surgical procedures [2]. They also are being developed to aid examinations such as transcranial Doppler (TCD) ultrasounds. Preliminary demonstrations suggest that AR guidance can significantly improve the localization of target blood vessels, making it a valuable tool for clinical practice and training [6].

One study investigated the use of Augmented Reality via Microsoft HoloLens for teaching anatomy with a focus on the mediastinum, the area between the lungs. Students found AR engaging but pointed out challenges, such as unclear instructions in the non-quiz group and difficulties with gesture control. The study concluded that AR is a valuable tool for improving spatial understanding, but requires a better app and learning design to realize its full potential [7].

Handheld AR devices, which are often based on the framework of a smartphone, have a narrow field of view. This results in an aperture problem where the most salient points are not always immediately visible to the user. Visual cues could help mitigate this, but these cues are often ambiguous because of the translation from 2D to 3D [8]. For this reason, other modalities, such as sound and haptics offer a potential way to enhance AR experience by providing location feedback. Many humans naturally use sound to perceive spatial information by fusing timing, frequency, and amplitude [9]. However, some preliminary work using vibration-like feedback to assist visually impaired pedestrians shows the potential of haptics to effectively aid navigation, particularly in unfamiliar environments [10]. One study explores the use of audio-tactile proximity cues, finding that they improved spatial awareness, reduced collisions, and enhanced precision. However, this study does not compare the modalities, leaving an open area to explore [11].

The Interactive Organ Locator App

The Interactive Organ Locator App is an interactive tool to help participants learn and explore the spatial locations of internal organs in the human body [12]. The app's primary goal is to offer an engaging and applied learning experience that can be used across different age groups. Following initial discussions with project supervisor Björn Thuresson, the authors went on to develop a tool that allows for calibration to map the organs onto a person's torso. This would act as a sort of X-ray displaying where specifically in one's body the organs are positioned. However, due to time constraints and technical limitations, authors have modified the initial idea and following another supervision meeting, began deployment of the current version of the app. As part of a university project, the app is specifically designed for this study, focusing on user interaction in an augmented reality (AR) environment.

The app presents a simplified torso image, featuring a cartoonish but recognizable 2D representation. To enhance interaction, 3D models of the organs were embedded within the torso image. These organs are initially invisible, with only slight outlines occasionally visible due to reflections. Once participants believe they have located the correct organ, they can tap on the torso image. The app provides immediate visual feedback: the organ turns green for a correct selection and red for an incorrect one. If the user clicks on an area with no associated organ, no feedback is given.

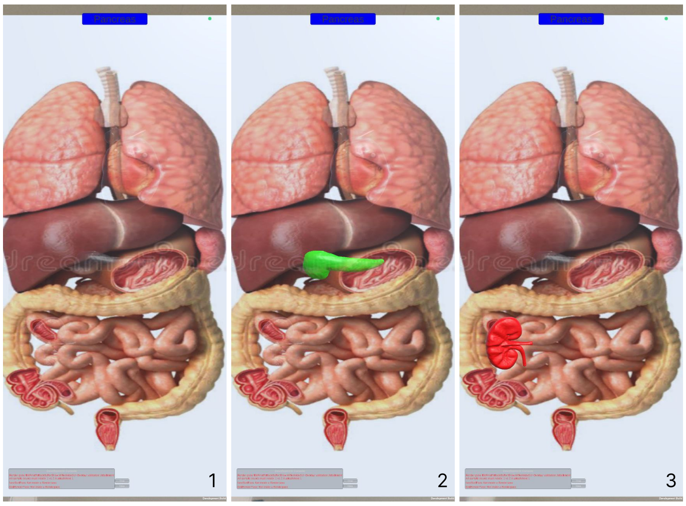

Figure 1: Interface of the Organ Locator app showing three states in the pancreas finding task: (1) Initial state with all organs hidden, (2) Correct identification of the pancreas (highlighted in green), and (3) Incorrect identification of another organ (highlighted in red).

Participants interact with the app by holding their phones upright and moving them horizontally (in the x and y directions) to search for the hidden organs. The app does not respond to movement along the z-axis (depth). The torso image remains fixed, ensuring participants focus on using the feedback modalities—audio or haptics—to locate the organs. Audio feedback increases in volume and intensity as participants approach the target, while haptic feedback grows stronger and more frequent when they near the correct organ.

The Interactive Organ Locator App was developed using Unity's AR Foundation and AR Kit for Android. Due to the platform-specific nature of haptic feedback, the app is only compatible with Android devices running version 11 or higher. No additional features beyond those necessary for task completion were included, ensuring that the app remained streamlined and easy-to-use for all participants. The final implementation consisted of six versions of the app, each tailored to a specific organ (heart, pancreas, or kidneys) and a single feedback modality (audio or haptics). A demonstration of the application can be found on Vimeo and the final Code and Applications in a Google Drive folder [12, 13].

Study

Hypothesis

Two sets of hypotheses were formulated to describe the expectations of the study. The hypotheses were created to get a sense of how well the Interactive Organ Locator App is received and how well it is to be used.

Immersiveness and Naturalness:

H0A Participants experience the same sense of natural interaction and immersion with sound and haptic location cues while using the Interactive Organ Locator Application.

H1A Participants experience a different sense of natural interaction and immersion with sound and haptic location cues while using the Interactive Organ Locator Application.

Learning and Task Completion:

H1B Participants experience similar levels of learning and task completion with sound and haptic location cues while using the Interactive Organ Locator Application.

H0B Participants experience different levels of learning and task completion with sound and haptic location cues while using the Interactive Organ Locator Application.

In addition to the formal hypotheses, it is predicted that the sound modality will lead to greater immersion and higher levels of learning due to the biological predisposition of using sound to determine locality [14].

Methodology

To compare the Naturalness & Immersion and Task Completion & Learning across the two implementations of the Interactive Organ Locator Application, one using haptics and the other using audio, a combination of subjective quantitative and qualitative approaches was employed.

Participants In total, N=24 participants took part in our study, of whom 10 were female, 13 were male, and 1 identified as non-binary. The participants were recruited via snowball sampling and personal inquiry, and their ages ranged from 21 to 61 years. As shown in Table 1, most participants were in the 21-30 year old age group (n=17).

Table 1: Frequency table of the participant ages by category.

Age Group	Haptics	Sound	Total
21-30	9	8	17
31-40	0	2	2
41-50	0	0	0
51-60	1	2	3
61	2	0	2

The participants represented a wide variety of cultures and countries, with the majority from either Germany (n=8), Poland (n=6), or Sweden (n=4). The remaining participants came from Argentina (n=3), Bolivia (n=1), the United States (n=1), and Spain (n=1).

Regarding prior experience with organ location, 4 participants reported no prior experience, while the remaining participants reported varying levels of familiarity: some had experience (n=6), some reported "kind of" having experience (n=6), and some knew at least one organ beforehand (n=8). This prior experience covered three organs: the heart, pancreas, and kidneys.

Regarding participants' familiarity with augmented reality (AR), 4 participants stated they felt confident using AR, 11 had tried it but were unsure, and 8 had never used AR but had heard of it. One participant responded with, "What is AR?".

Material The study was conducted using Google Forms [15] survey platform. To ensure a consistent testing environment, all participants were assessed in a quiet space that allowed free movement. The testing area included an empty white wall positioned in front of the phone to minimize visual distractions. If ambient noise was present, participants were instructed to wear headphones to further reduce potential distractions. The participants used the researcher's smartphone with the apps already installed using Android 11 or higher to complete the tasks. The researcher's laptop was used to complete the survey.

Study Design The study was conducted as an experimental study using a between-subjects design. Participants were randomly assigned to one of two conditions, where they either used audio or haptic feedback as guidance while performing tasks in an Augmented Reality (AR) application. The primary goal of the study was to compare the perceived Naturalness & Immersiveness, as well as Task completion & Learning outcomes, of the two feedback modalities.

Participants interacted with a Unity-based interface on Android devices. The AR app presented a simplified image of organs within the torso, where participants had to identify and locate specific organs guided by either audio or haptic feedback. The feedback intensified as participants approached the target organ, and they could tap on the displayed organ torso where they believed they had found the correct organ. Successful identification was indicated by a green highlight, while incorrect selections were marked in red.

The experiment involved three tasks in total. The first task was a training task, designed to familiarize participants with the AR interface and the guidance modality. In this task, participants located the heart using the assigned feedback modality. After the training task, participants completed two additional tasks in randomized order: locating the pancreas and locating the kidneys. All participants completed the same tasks, but the feedback modality (audio or haptics) differed depending on their assigned condition.

Once the tasks were completed, participants answered a survey designed to measure their perceptions and gather feedback. The survey contained 13 Likert-scale questions (7-point scale) used to assess perceived Naturalness & Immersiveness, and Task Completion & Learning. A multiple-choice question gathered information about prior knowledge of human anatomy. Additionally, three open-ended questions captured qualitative feedback on the experience, difficulty, and enjoyment of using the AR application. Four demographic questions (two multiple-choice and two text-field) were also included to gather insights on cultural background, age, gender, and previous experience with AR.

The subjective quantitative data collected focused on comparing the categories of Naturalness & Immersiveness between the two modalities, as well as Task completion & Learning between the two conditions. The qualitative data provided further insights into participants' subjective experiences, focusing on the fun aspect, overall experience, and any difficulties encountered while using the AR app.

The survey questions were adapted from a revised version of Witmer and Singer's Presence Questionnaire, which evaluates the sense of being in an alternate reality using 7-point Likert scales [16]. To later evaluate the answers according to the categories defined for this study, the questions picked from the Presence Questionnaire developed by Burke et al. [16] were divided into this study's categories. The original survey includes items assessing realism, which closely aligns with this study's focus on Naturalness & Immersiveness. Consequently, questions from this category (specifically questions 3, 5, and 13) were incorporated into the study's "Naturalness & Immersiveness" category for evaluation. The remaining survey questions were independently categorized by team members, followed by a consensus process to finalize the categorization. This process resulted in questions 2, 3, 5, 9, 13, 14, 15, and 20 being assigned to the "Naturalness & Immersiveness" category, while questions 8, 16, 19, and 22 were grouped under the "Learning & Task Completion" category. Additionally, a custom question was introduced, which was not part of the original questionnaire, to assess whether the modalities aided task performance.

To minimize potential learning effects and ensure fair comparison between conditions, a between-subjects design was chosen. Furthermore, a pre-test was conducted, where participants could practice using the AR interface before starting the actual tasks. This ensured that all participants, regardless of prior experience with AR, could familiarize themselves with the app and guidance modality before providing data for analysis.

Procedure At the start of the study, participants were provided with a detailed explanation of the study's purpose and procedures. They were then asked to fill out a consent form before proceeding. The experiment began with a training task designed to familiarize participants with the augmented reality (AR) environment and the assigned feedback modality (audio or haptics). In this task, participants were instructed to locate the heart by navigating the environment and tapping on the torso where they believed the heart was located. Since the heart's approximate location was generally known, and its outline was partially visible, this task was relatively simple, allowing participants to become comfortable with both the interface and feedback mechanism.

Following the training task, participants moved on to two more challenging tasks: locating the pancreas and the kidneys. These tasks were more difficult because the torso image was less helpful; the organs were partially obscured by other organs, and the 3D organ models in the AR environment lacked clearly defined outlines. As previously described in the Organ Locator section, participants received visual feedback after selecting an organ or no feedback if an unrelated organ was tapped. After completing all three tasks, participants were asked to fill out the survey.

Statistical Analysis

The statistical analysis was conducted using JASP [17] against an $\alpha = 0.05$. In order to statistically demonstrate that our division into different categories led to reliable results, Cronbach's alpha was calculated to assess internal consistency for each of the groups. The analysis for the first group of Naturalness & Immersiveness led to a Cronbach's alpha of 0.831 ($95\%CI[0.723, 0.938]; SE = 0.055$). According to established guidelines [18], a Cronbach's alpha value above 0.8 indicates good internal consistency, suggesting that the items used in the scale for Naturalness & Immersiveness reliably measure the intended construct.

For the second group (Learning and Task Completion), we obtained a Cronbach's alpha of 0.762 ($95\%CI[0.589, 0.934]; SE = 0.088$). This value suggests acceptable internal consistency, as values above 0.7 are typically considered acceptable for exploratory research [18]. As the values were at least acceptable we proceeded to conduct our final analysis.

Subjective Quantitative Results

To compare the groups, average scores were calculated for each participant across all questions within each specific category. This approach transformed the data from the original ordinal scale of the Likert items to an interval scale, allowing for parametric testing.

The normality of the data was assessed using the Shapiro-Wilk test. The results indicated that the data were normally distributed for all variables: Average Haptic Naturalness (W = 0.949, p = 0.617), Average Haptic Task Completion (W = 0.925, p = 0.330), Average Audio Naturalness (W = 0.955, p = 0.709), and Average Audio Task Completion (W = 0.969, p = 0.897). Therefore, an independent samples t-test can be applied to test the hypothesis.

An independent samples t-test was conducted to compare whether the Average Haptic Naturalness & Immersiveness differ between groups. There is a statistically significant difference between the groups, $t(22) = -2.286, p = 0.032, Cohen'sd = -0.933, 95\%CI[-1.769, -0.078]$. Since the p-value is below 0.05, the null hypothesis can be rejected in favor of the alternative hypothesis, indicating that immersiveness differed between the groups that received audio or haptic cues.

Contrary to the prediction, the descriptive statistics showed that the haptic condition resulted in higher naturalness and immersiveness ($M = 4.917, SD = 0.677, Mdn = 4.875$) compared to the audio condition ($M = 4.208, SD = 0.833, Mdn = 4.125$). This finding suggests that the haptic condition was perceived as more natural and immersive than the audio condition.

In the test for the difference in Mean Task Completion & Learning levels between Haptic and Audio cues, no significant difference was observed between the groups, $t(22) = -0.453, p = 0.655, Cohen'sd = -0.185, 95\%CI[-0.985, 0.619]$. This supports the null hypothesis, which states that audio and haptic cues have similar task completion and learning levels. The descriptive statistics support this conclusion a they show similar results for both the haptic condition ($M =$

$5.000, SD = 0.961$) and the audio condition ($M = 4.800, SD = 1.191$).

Qualitative Results

After completing the Presence Questionnaire [16], participants were asked three open-ended questions to gather qualitative insights about their experience, their insights on the experience, the perceived difficulty in locating each organ, and their enjoyment in using the application. The qualitative data were analyzed using affinity diagramming, a method that groups related ideas to identify overarching themes and patterns [19]. Responses were transcribed and collaboratively organized into clusters by the research team. The analysis revealed distinct themes, which are separately reported for participants who used the haptic application and those who used the audio application.

Insights on Experience with the Interactive Organ Locator App

Audio Modality Participants using the audio modality found the experience engaging and described it as a fun and potentially effective tool for teaching anatomy. However, several technical issues were reported, which affected the overall experience. These included problems with plane detection, which often obscured the image, and visual glitches that disrupted the smoothness of interaction.

Some participants provided additional feedback for improvement. For example, one participant described the depiction of organs as "gross", potentially suggesting a preference for less explicit or more abstract representations. Another participant suggested that the audio feedback could be slower and more gradual to improve clarity and ease of understanding. Despite these challenges, participants recognized the educational potential of the audio modality.

Haptic Modality Participants generally reported positive experiences with the haptic modality, describing it as intuitive and fun for locating organs. Some participants noted that the haptics alone were sufficient to complete the task, as well as highlighting its potential utility in broader contexts. One participant remarked that the haptics could make the application inclusive for visually impaired users.

In addition to praising the functionality, participants provided constructive feedback for improving future iterations of the application. For instance, one participant suggested implementing a feature to "display a target to show what is in focus", addressing the common issue of losing spatial orientation within the virtual Augmented Reality (AR) environment. In addition to that, they also proposed adjustments to the phone's movement scaling, suggesting that "the 10 cm movement of the phone needs to be according to the image size (not 1:1 but percentage-based)". Some participants also remarked that it would have been beneficial to implement all organs from the displayed image. This would ensure that if a user misclicked, they would always receive visual feedback, improving the overall interactivity and reducing potential frustration. These insights point to areas where usability and user experience could be refined.

Difficulty in Locating Organs Using the Interactive Organ Locator Application

Participant responses regarding the difficulty of locating each organ in the Interactive Organ Locator App were analyzed collectively, as audio participants provided fewer detailed answers to this question.

Participants reported a wide range of difficulty levels in finding each organ, from very easy to difficult. Most, however, described the experience as moderately difficult.

Participants across both modalities highlighted challenges with the visual component of the application, which did not effectively assist in target localization. Many organs were obscured behind others, a deliberate design choice intended to increase task complexity. However, this design element often caused confusion, suggesting that future iterations could better integrate visuals to enhance usability and use them as additional guidance in task completion.

Audio Modality Participants using the audio modality reported technical issues with the stability of the image, which frequently disrupted the interaction. This instability made it harder to rely on audio cues for precise localization and reduced the overall effectiveness of the modality.

Haptic Modality Participants using the haptic version identified several challenges affecting their ability to locate organs. Some noted inconsistencies in the alignment between the phone's position and the displayed image, making it difficult to determine the exact location of organs visually, even when haptic feedback was detected. This misalignment sometimes left participants uncertain about where they were within the virtual space.

The difficulty of locating organs varied depending on the target. Participants consistently identified the heart as the easiest organ to locate, as its outlines were visible, and its location was familiar to most participants. The pancreas was moderately difficult to locate but provided an immediate cue through vibrations when starting the application, which participants found helpful. The kidneys, however, were reported as the most challenging organs to find, requiring participants to move significantly further down the interface to detect them.

Despite these issues, participants found the haptics particularly helpful for identifying organs whose positions were less commonly known. The haptic modality also excelled in assisting with locating organs that were visually obscured, adding value to the interaction.

Perceived Fun Using the Interactive Organ Locator App

Audio Modality Participants who tested the audio version of the Interactive Organ Locator App reported mixed perceptions of fun. Some participants found the experience stressful and not particularly user-friendly, which may have contributed to less favorable feedback.

For instance, participants described the application as "not that fun", "okay" or remarked, "I have more fun things in life."

Despite these criticisms, other participants enjoyed the experience, describing it as "Good fun", "Excellent!", or affirming, "Yes, it is [fun]." This split feedback suggests that while the audio modality has the potential to be engaging, addressing user experience issues could enhance its overall enjoyment.

Haptic Modality Participants testing the haptic version of the Interactive Organ Locator App generally agreed that the experience was enjoyable. Many described it as "very fun", the "best experience :)," or remarked that they "loved it."

However, some participants noted frustrations with the application's limitations, particularly the inability to interact with all organs on the display. They suggested that enabling interaction with all organs could make the application more responsive and, in turn, more enjoyable. Despite these critiques, participants praised the creativity of the haptic implementation and found it to be an engaging and entertaining approach to learning anatomy.

Discussion

The aim of this study was (1) to develop an interactive augmented reality (AR) application to facilitate education of human organ anamtomy through interactive feedback. Specifically, the study meant (2) to examine the potential of audio and haptic feedback modalities to provide navigational cues in this setting. In order to assess the differences between modalities, two categories were introduced: Immersion & Naturalness and Task Completion & Learning.

The results show that while the change in modality does not have any impact on learning and task completion, haptic cues provide a greater sense of immersion and naturalness. This stands in contrast to the initial hypothesis, indicating audio cues to provide a greater sense of immersion and naturalness.

When analyzing potentially confounding factors to explain the adeptness of haptics over sound cues, the research team noted that the audio apps seemed to have more technological issues. The cause of these issues, like unstable plane detection and inconsistent audio cues, is unclear, but it could explain why the immersiveness of audio scored lower. The age of participants was relatively evenly distributed, so comfort with using emerging technology is not a potential factor in this difference. Furthermore, haptic feedback may have provided more assistance in such an unfamiliar environment, aligning with findings from prior studies on vibro-like feedback in spatial tasks [10].

Limitations and Future Work If repeated, this study could benefit from a more robust data collection plan and statistics. For many of the qualitative answers, participants did not respond with interesting or detailed information. More statistically significant data could result from having these structured as subjective quantitative questions instead. However, if qualitative aspects are still desired, the questions should be reformulated and be less general. In addition, while the subjective quantitative results obtained are statistically significant, a larger test group would help differentiate if indeed the haptics had better immersiveness.

For widespread adoption, the ease of use must be significantly improved. Similar to the study conducted by Nørgård et al., participants had difficulties with usability, echoing the need for better app design to truly analyze full learning potential[7]. More specifically, the plane detection issues need to be solved and the scale should be corrected. In addition, based on participant feedback a full implementation for all components displayed is necessary.

The participant's open-ended feedback underlines the importance of studies involving AR to have a robust interface, with usability testing conducted prior to testing between modalities as visual confusion impacts learning and task completion. This requires more time dedicated to the creation of the interface.

The initial design concept aimed to create a more anatomically accurate, body-fitted experience, but due to time and implementation constraints, this feature was not fully realized. Future development should prioritize this aspect, as it could enhance intuitive learning and foster a more social, collaborative environment when using the app. Our results show that haptics provide an innovative approach to mitigate the aperture problem discussed by Wieland [8], where users may struggle to maintain spatial awareness in AR environments with a limited field of view.

A potential explanation for why haptic feedback creates a greater sense of immersion is that, while sound and visual cues give more detailed directional information, this information has to be processed, and instead, haptics provide a trial-and-error methodology: body-based percepts give users instant feedback on the direction their arm is initiating. More research should be conducted to explore this outcome.

Additionally, future studies should explore the potential for sensory overload. This study did not evaluate the effects of the interface, audio, or haptics being overwhelming or restricting. Still, studies have shown that poor interaction design undermines the value that AR holds for education. [7]. In addition, participants may have differing preferences for feedback modalities, so varying the type and intensity of audio or haptic cues could improve the overall experience. For example, more varied sound cues or different types of haptic responses might enhance engagement and reduce cognitive load.

Beyond educational applications, this approach could have practical implications in medical and therapeutic contexts. Haptic feedback could be used to aid doctors or physical therapists in situations where visual feedback is limited, such as locating internal structures like blood vessels or muscles. Implementing toggleable layers that allow users to switch between visible and hidden anatomical elements could enhance both learning and professional use cases. This aligns with prior research suggesting that haptic cues are not only beneficial for individuals with visual impairments but also hold promise for general navigation and spatial awareness tasks [10].

Lastly, incorporating elements of fun and creativity, such as using less serious or more stylized organ images, could improve user engagement.

Conclusion

This study demonstrated that augmented reality applications can serve as effective educational tools for teaching human anatomy. The Interactive Organ Locator App provided participants with an engaging experience, with haptic feedback proving to be more immersive and natural compared to audio cues. However, the study also revealed significant design and usability issues that would need to be addressed before the app could be tested any further.

Future iterations of the app should focus on enhancing usability, improving spatial accuracy, and expanding the scope of interactive features. Additionally, further research is needed to explore the broader applicability of haptic feedback in AR, particularly in clinical and professional environments.

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