Review of Magnetic Resonance Imaging (MRI) Scan Mobile Applications for Paediatric Patients: A Room for Improvement

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Abstract

The MRI process can be a challenging experience for young children. Therefore, general anaesthesia is often used to ensure paediatric patient's compliance. A recent attempt by researchers and practitioners has been the development of mobile applications that are designed to provide a virtual real-like MRI experience. The paper aims to review and provide insight into some of the available MRI mobile applications regarding their functionality and use as well as providing practical suggestions for future mobile application developers in the field. MRI mobile applications that are available on the two platforms of IOS and Android were downloaded and tested to gain the user experience in terms of functionality and overall use. The findings revealed that the available MRI mobile applications designed for the paediatric community lack features and functionalities in terms of appealing to the age groups they had been designed for. Such features include the lack of availability of interactive games, aesthetic layouts, localisation to suit the culture, lack of dual language, etc. The review of the available MRI mobile applications that are designed for paediatric users clearly showed that more work should be done and there is a room for improvement in terms of their designs and functionality.

Keywords: magnetic resonance imaging; general anaesthesia; paediatric; mobile application.

1. Introduction

During the past few decades, Magnetic Resonance Imaging (MRI) has become the primary method of imaging in the medical field, and this is attributed to its ability to represent neuroanatomy, excellent grey-white matter distinction, the status of myelination, and identification of focal structural brain lesions [1]. Not only could MRI determine the cause of partial seizures, but its advantage over computerised tomography (CT) scan is also evident when MRI images in temporal lobe origin. It improves the detection rate of specific intracranial lesions, especially those involving the meninges and those of a vascular nature ([2]; [3]; [4]; [5]). Moreover, it improves radiologic specificity significantly, particularly when defining the degree of existence of certain neoplasms and distinguishing aggressive from benign processes [6]. In addition, MRI technology allows for image contrast manipulation, giving the radiographer more freedom for better representation of ossification centres and highlighting various tissue types ([7]; [8]). MRI images can also extract and interpret more detail than two-dimension (2D) radiographs since they are volumetric [9].

The use of MRI for paediatric patients has increased in recent years due to its advantage as a non-ionizing radiation modality compared to a CT scan. For example, in assessing children with developmental disabilities, MRI tends to be the most trusted neuroimaging method. It offers more image data in the brain than CT, resulting in increased diagnostic accuracy [10]. An irregular MRI is observed in around 60% of children with developmental delays. With these statistics, MRI has further strengthened its position as one of the most promising techniques in detecting children's developmental delay [11]. However, patient compliance has been the main problem in the paediatric population, given how difficult it is to ask children to comply and remain motionless for an extended period, which is required while undergoing MRI scans. Therefore, sedation for children, also known as general anaesthesia (GA), is used for various surgical and dental procedures and in the emergency room all over the world to overcome the paediatric patient's compliance [12]. What complicates things further is that MRI machines produce loud noise comparable to rock drills and industrial noise, idea suggesting that young patients might not complete their scanning process. Also, MRI has to be operated in a narrow tube-like device, which is challenging for claustrophobic patients. Therefore, GA is used to calm the patient and smoothen the imaging procedure [13]. A study in the year 2011 found that approximately 1% to 15% of all patients scheduled for MRI have claustrophobia, and administration of

GA is needed to complete the scan [14].

Researchers and practitioners in the medical field have been attempting to develop and try out several alternatives to help increase patient safety, and optimise costs in paediatric patients by reducing the impact of GA. Such alternatives include but are not limited to mock scanners and remote and MRI-compatible audio-visual systems [15]. A recent attempt by these researchers and practitioners has been the development and utilization of mobile applications that are specifically designed to provide a virtual and real-like experience of the MRI experience. This research paper will review some of the MRI-related mobile applications currently available on the application platforms, mainly for Android and IOS users.

2. Current MRI Mobile Applications: Issues & Perspective

During the past few years, especially with the advancement of technology and mobile applications specifically, several mobile applications have been developed and utilised by professionals in the medical field [16]. In this context, [17] attributes this rapid increase in mobile applications utilisation in different fields to provide a unique opportunity to allow distant connectivity with the flexibility of function, design, and accessibility. Other sweeping conditions also contributed a great deal to more mobile applications adoption and utilisation in the healthcare sector, and this can be seen right after the beginning of the Covid-19 pandemic with several mobile applications dedicated to testing, tracking, intervention, and prevention as suggested by [18]. Another example of the utilisation of mobile applications in the healthcare sector in general and the cancer screening and early detection was addressed by [19]. They pointed out that the integration of mobile applications into standard cancer care and screening has recently gained popularity among both healthcare providers and the public users. More importantly, this partnership between mobile applications and the healthcare sector has become part of our everyday life practices nowadays with our constant updates and monitoring of our Covid-19 applications status and green passes when individuals attempt to travel and, at times, to get into places like malls, banks, and much other public or private entities.

In a study performed in Denmark, using a mobile educational application with interactive features could help young patients understand MRI [4]. This method is among the most cost-effective ways to allow children to complete a successful MRI scan without using GA. It does not require regular maintenance as compared to the mock scanner. The cost of its development is also anticipated to be lower than other methods like MRI-compatible audio-visual and mock scanners. Furthermore, mobile applications are easy to use and can be tailored to suit various needs through an application software update. For example, the application can be improved by adding more features in the future. Language and user interface can be modified accordingly as well. However, several factors must be considered while developing the mobile application, such as children's point of view on audio and video comprehension, target groups, ease of understanding, and questionnaire generation [20].

The primary obstruction in most paediatric MRIs is the young patient's cooperation and compliance ([21]; [22]). Due to their young age and mental unpreparedness, many children have to perform MRI examinations under GA [23]. Without GA, children may not be able to hold still or stay calm during the scan [24]. To ensure a clear and sharp image can be obtained, patients are requested to minimise movement or even to hold their breath during the scanning procedure. Even some adults might face difficulties, especially those who suffer from sensitive ears or claustrophobia [15]. MRI scan is indeed a challenging procedure for children. Therefore, paediatric MRIs are often performed under GA.

Even though the use of GA among patients, in general, is considered to be safe and non-harmful [25], some researchers and practitioner expressed their concerns over the long-term effects of using GA among paediatric patients ([26]; [27]; [28]; [29]; [30]; [12]). Though not widely studied, the administration of GA in children might affect their behavioural and emotional development. In the existing literature, there is an alarming rate of 61–100% for children aged 4–6 years, and 47–71% for children aged 4–10 years were given GA for MRI procedures [4]. In Saudi Arabia, the paediatric MRI usage rate demonstrated per MRI unit visit is up to 5.1% among young patients aged 2 to 7 years old [31].

A few MRI mobile applications are available on App Store (IOS) and Play Store (Android), as shown in Table 1. Specifically, four paediatric MRI related mobile applications are currently available on the two platforms. This review of the four mobile applications addresses four main themes of categories, namely the availability of a character choice for users (male/female), the availability of interactive features such as games or activities, the platform(s) the applications are available on, and finally the availability of more than one language for the application.

Table 1. MRI Mobile Applications Available on IOS and Android Platforms.

Mobile Application	Character Choice	Interactive Features	Platform	Updated	Language Availability

HC And https://bit.ly/3N7dKEZ	No character choice is available. The app shows a video of a story of a baby penguin undergoing MRI scanning accompanied by his parents. All users do is watch the events of the story.	One interactive feature is available where users can colour the penguin family while standing next to the MRI machine. No games or other activities are available.	IOS and Android	15 January 2020 (Installs 500+)	No dual language available. The app targets Danish language speakers only.
My MRI at GSTT https://bit.ly/3FFToQE	No character choice is available. The application represents a track a video of a little boy who undergoes MRI scanning, and it shows the boy's journey from the moment he entered the hospital until the moment he left the MRI scan room. No girl's option is available as a character.	There is no interactive feature available in which users have only one option: watching the little boy getting into the hospital and experiencing the MRI scanning.	IOS and Android	15 February 2019 (Installs 500+)	No dual language is available. The app targets English language speakers only.
MRI Scan Experience https://bit.ly/3M7Y0lj	No character choice is available in terms of gender, but users can choose between an adult option or a kid's option.	One interactive feature was included in the app where users can listen to the MRI noise from the MRI machine, and at the same time, they can compare the noise to the sound from other objects and animals such as a vacuum cleaner, trumpet, a dog, or an elephant.	Android users only. Not available on IOS	24 January 2019 (Installs 10,000+)	No dual language is available. The app targets English language speakers only.
Hetty's Hospital https://apple.co/3yv7nY2	No character choice is available. The application is not explicitly designed for MRI but a video of a general visit experienced by Hetty and her friend, Charlie, to the hospital. One MRI scanning scene was included for a post leg fracture.	Yes. The application included features of interactive games and a conversation platform to allow interaction among kids and hospital personnel.	IOS users only. Not available on Android	13 Oct 2017 (Installs 1,000+)	No dual language is available. The app targets English language speakers only.

As shown in the table above (Table 1), most of the applications reviewed did not offer a character choice in terms of gender. Instead, they adopted a video as the primary medium to explain the MRI process and used the hospital as the background setting. Specifically, the first mobile application of 'HC And' showed a video of a story of a baby penguin undergoing MRI scanning accompanied by his parents. The users had no other option but to watch the video without the ability to select a male or a female character. Similarly, the second mobile application of 'My MRI at GSTT' did not offer a character choice in terms of gender in which the application shows a video of a little boy who undergoes MRI scanning and his journey from the moment he entered the hospital until the moment he left the MRI scan room. No girl's option is available as a character in this mobile application. As for the third application of the 'MRI Scan Experience', again, no character choice is available for users in terms of gender while they can choose between the 'For Kids' and 'For Adults' options. Finally, and on a similar note, the last mobile application of 'Hetty's Hospital' did not provide a character choice in terms of gender where the application shows a video of a general visit experienced by a girl named Hetty and her friend who is a boy by the name of Charlie. Thus, all four mobile applications did not offer a character choice for kid users, which could negatively affect the user experience as it would not provide them with a sense of agency or ownership when using the mobile applications. Moreover, children would be able to relate more to the experience if they could select their gender, be it a male or a female [32].

As for the second aspect, the four mobile applications are compared against which is the availability of the interactive features such as games and activities; one could not help but notice the limited incorporation of interactive features in most of these applications. Specifically, the first mobile application of 'HC And' included only one interactive feature where child users had the option to colour the penguin family when they are standing next to the MRI machine without the availability of any other games or activities. While colouring could be fun for children, it does not relate to any actual experience inside the MRI room, nor does it relate to any of the experiences that are encountered by the children who are undergoing the MRI scanning experience. The second mobile application of 'My MRI at GSTT' did not offer any interactive feature. All users can do is just

watch the video of the little boy who undergoes an MRI scanning experience. Unlike the second mobile application, 'Hetty's Hospital' included interactive games and conversation platforms to allow interaction among kids in the hospital and the hospital personnel, making the user experience more fun and engaging. What is also interesting about the MRI scene in the 'Hetty's Hospital' mobile application is that the conversation between Charlie and the MRI radiographer was informative as it included a detailed explanation about the anticipated MRI scanning experience. The conversation also included helpful information for children, such as the need to stay calm and motionless during the scan. Figure 1 shows the MRI scanning scene from the 'Hetty's Hospital mobile application.

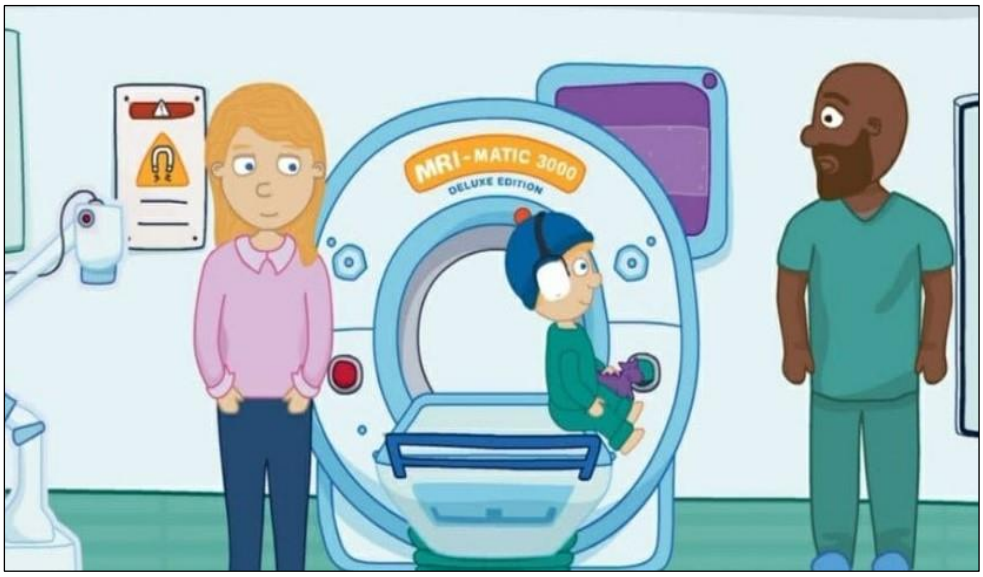

Figure 1. MRI Scanning Scene in 'Hetty's Hospital' App.

As for the mobile application of the 'MRI Scan Experience', only one interactive feature was available for users where they could listen to the MRI noise from the MRI machine. they also can compare the noise to the sound from other objects and animals such as a vacuum cleaner, trumpet, a dog, or an elephant at the same time. This listening exercise is helpful as it provides the children with the opportunity to familiarise themselves with the noise level in preparing themselves for the real MRI scan experience. It is done interactively and interestingly where users can click on a picture of an animal and listen to the sound. For example, if the users click on dog's picture, they will listen to the barking sound, or if they click on a picture of an elephant to listen to how they trumpet and then compare the sound level and intensity to the natural sound of the MRI scan machine. This activity is helpful for the kid users as they become familiar with the sounds produced by these animals and objects, in comparison to the anticipated and upcoming sound from the MRI machine. Getting familiar with something helps kids become less anxious given that they had already been exposed to the noise and the environment be it in a digital outlook and when they are less anxious, they will become calmer and in turn more cooperative which is helpful in following the instructions of the radiographer which leads to a chance of avoiding having to revert to using GA. Figure 2 shows the Snapshots from the MRI Scan Experience app where the sound level comparison option is available for users.

Figure 2. Snapshots from the MRI Scan Experience app with Noise Level Option.

The other aspect the four mobile applications are compared against is the platform(s) the applications are available on. There

are two significant platforms most mobile application developers develop their different applications on, namely App Store for IOS users and the Play Store for Android users. While the two mobile applications of 'My MRI at GSTT' and 'HC And' are available on both platforms of IOS and Android, the mobile application of 'MRI Scan Experience' is only available on Android, and the other mobile application of 'Hetty's Hospital' is only available on IOS. Logically, it is safe to assume that when an application is available on the two platforms, it will reach out to more mobile users and benefits to bigger population.

As for the fourth aspect that we would discuss for all the mobile applications is the availability of more than one language for the user, the table clearly shows that not a single mobile application from the four reviewed ones provides more than one language as an option for the users. Specifically, the three mobile applications of 'My MRI at GSTT', 'MRI Scan Experience', and 'Hetty's Hospital' utilise English as the only language to operate and use the applications, while 'HC And' targets Danish language speakers only with Danish as the only language available to operate and use the application. Given the limited widespread popularity of the Danish language worldwide, an additional English language option could have enriched the application and expanded its use in more countries and regions. Given the widespread popularity of the English language and how it is widely spoken across the globe, with over 2 billion speakers of the language [33].

The main issue in most of the currently available mobile applications for MRI is the idea that they are designed for adult users through their lengthy scientific texts and lack of interactive and animated features. Although there are efforts to include sections within the applications designated for kids, such as the section in the 'MRI Scan Experience' application, this section does not appeal to kids. Specifically, there is an option on the first page to select whether users want to view it for adults or kids, as shown in Figure 1. Once the "For Kids" option is selected as the user, users are met with some lengthy text instead of expecting some animated cartoon pictures or probably some interactive games (Figure 3). This text may not necessarily appeal to kids in general but is less suitable for young kids below 10 years old. Furthermore, the scientific and complicated language used in nature might not necessarily help young children overcome their anxiety or fear associated with the anticipation of the upcoming MRI scanning experience.

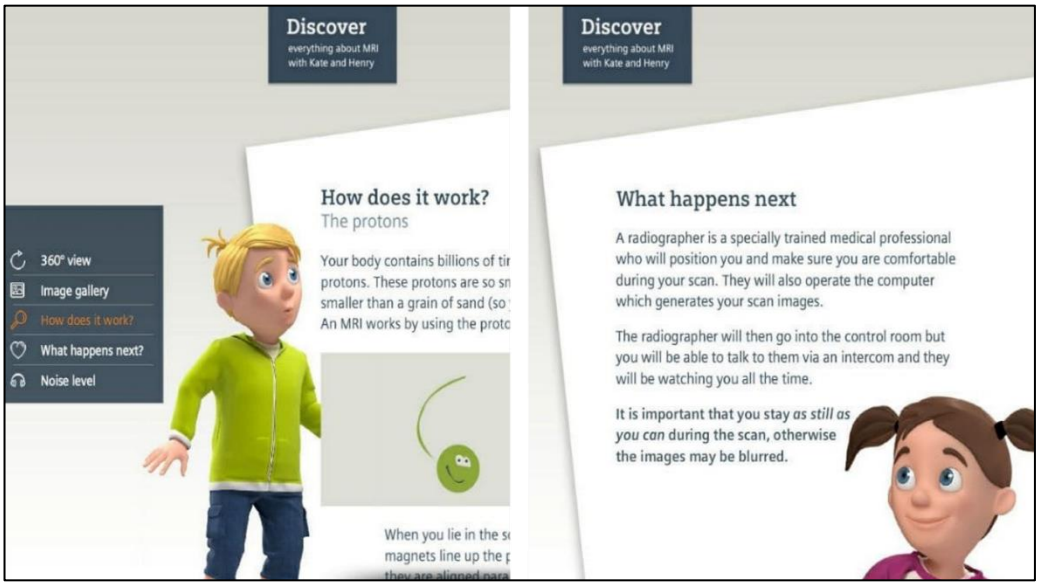

Figure 3. Snapshots from the MRI Scan Experience apps with lengthy text.

On top of that, the tiny font size used on the cover page or the interface of the 'HC And' application makes it difficult to read the information provided. The users also are unable to zoom in or out to make the font bigger and leave the users the option of using a convex lens to read through the lines. Having such a tiny font size could make the users lose interest in using the apps until the end. Figure 4 shows the tiny font size text from the 'HC And' mobile application.

Figure 4. Snapshot of Main Interface of the 'HC And' App.

Moreover, most of these mobile applications have been developed to target a specific group of MRI patients, specifically western and English-speaking populations, when three of the four mobile applications reviewed used English as the only language to operate and use the applications. This may negatively affect the widespread use of these applications to include children from other speaking backgrounds who may not possess the English language proficiency needed to operate the application functionally. It is even more relevant among Arabic language speakers in general and the Saudi children, are given that English is a foreign language that is not spoken widely in the country. Limited command of English with low language proficiency generally characterises Saudi children, which will hinder them from using English-based applications that do not provide Arabic language options, which is the case in all MRI mobile applications available in the market. Future MRI mobile application developers must localise the designs and related develop the MRI-related mobile applications for children to respond to and target children from various cultural and linguistic backgrounds. It would be even more appealing if the characters in these localised mobile applications reflect the culture of that targeted group in terms of clothing, for example. It would enrich the application experience, and children of these cultural and linguistic backgrounds could potentially relate more to the application

In addition, most of these applications have a rigid format of animated MRI scans video with purely scientific notes and voiceovers rather than games and other interactive features that suit the children's interest. On top of that, the extremely small font size used on the cover page or the interface of the HC And application making difficult to read the information provided in it. The users also are unable to zoom in or out to make the font bigger. The idea of improving the available mobile applications has been addressed in the literature where [4] expressed their concerns that available MRI mobile applications were called for improving their usability and practicality by future developers. Furthermore, it was unclear whether those existing mobile applications were developed based on clinical research or the on the market validation process. Although some of the were built based on healthcare professionals' opinion such as radiologists and radiographers but did not fit the paediatric users. Unfortunately, very little to no studies conducted on effectiveness of the available mobile applications. Future research attempts to conduct studies on the development process of MRI-related mobile applications for children are crucial to ensure that healthcare professionals and users' perceptions and opinions are taken into account throughout the development process to address the limitations existed in the reviewed mobile applications.

3. Concluding Remarks

Overall, the availability of MRI mobile application for children is still lacking not only in terms of the functionality and the features of these mobile applications but also in terms of the number itself; there are just a few available mobile applications that are designed for MRI paediatric users. Moreover, the review of the available MRI mobile applications that are designed for paediatric users clearly showed that more work should be done and there is a room for improvement in terms of their designs and functionality. Specifically, the existing MRI mobile applications in the market are lacking in terms of being child friendly with the excessive use of bulky academic texts and the lack of the availability of interactive and fun features that ae appealing and engaging for paediatric users. Therefore, developers of future MRI-related mobile application for children should examine the physiological, psychological, and linguistic development needs and characteristics of children prior to embarking on developing their mobile applications and ensure that these needs and characteristics. This should ensure that paediatric users of these mobile applications would utilise such applications effectively that would in turn reflect on their compliance and cooperation inside the MRI room.

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