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MAUMAHARA PAPAHOU

A mobile augmented reality memory treasure box based on Māori mnemonic aids

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Abstract

He aha te mea nui o te ao? He tangata, he tangata, he tangata.
What is the most important thing in the world? It is people, it is people, it is people.

Traumatic brain injury (TBI) is a worldwide "silent epidemic" causing a variety of memory issues for those affected. Although several software approaches aim to aid memory recollection, they are inadequate for many TBI survivors and none address aspects of cultural awareness in New Zealand. We explored design concepts of traditional Māori cultural artefacts and techniques and how they helped Māori people recall past information. This paper describes our research and development of Maumahara Papahou, a mobile app that uses augmented reality features to create a digital memory treasure box based on the concepts of Māori mnemonic aids.

Keywords

mobile app, traumatic brain injury, augmented reality, memory aid, tikanga Māori

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Introduction

Traumatic brain injury (TBI) is the leading cause of long-term disability of children and adult survivors, with an estimated 10 million people affected each year worldwide. It is expected that TBI will become the third largest global medical burden by 2020 (Feigin et al., 2013). Further, TBI is considered a worldwide "silent epidemic" (Rusnak, 2013) affecting the lives of the patients as well as their caregivers, families and friends. Māori are disproportionately affected by TBI (Foster et al., 2012, p. 1857), and they also face the risk of poorer outcomes (Barker-Collo, Wilde, & Feigin, 2009; Elder, 2012). Elder (2013, 2017) recommends taking guidance from Māori culture to best understand the needs of a whānau in which a person has TBI.

A number of technological aids are available for TBI survivors, including smartphone apps, web-based interventions, voice recorders and brain-injury-specific digital games. Many of these are suitable for TBI survivors, although they were not created especially for this particular user group. For children and adolescents with memory impairment, smartphone technology is particularly well received (Plackett, Thomas, & Thomas, 2017). Digital interventions for TBI survivors are available both commercially (e.g., Cogmed [https://www.cogmed.com] and Lumosity [https://www.lumosity.com]) and in the form of research prototypes (e.g., Chang, Hinze, Bowen, & Starkey, 2014; Gilbert, Hinze, & Bowen, 2017). There are still a number of gaps in the research into how to best support memory recollection for TBI survivors. We also observe that none of the existing works on digital interventions are informed by mātauranga Māori.

We are committed to taking guidance from the Māori culture to identify suitable approaches to guide the development of memory aids (Hinze et al., 2017). This paper describes our first foray into transferring concepts from Māori mnemonic aids into mobile memory aids for TBI survivors. Here we describe our explorations of design concepts of traditional Māori cultural tools and techniques that were used to help in recalling past information, especially in oral story and history telling.

We describe the research and development of a mobile app that uses augmented reality (AR) features to create a digital memory treasure box based on the concepts of Māori mnemonic aids. AR technology superimposes digital elements over real-world environments: our app creates a digital papahou that is superimposed over the users' environment as seen through the phone's camera. This creates an immersive experience in which users can explore their memory cues in an interactive manner. We have called this app Maumahara Papahou.

We begin by introducing background information about TBI and discussing related work. The next section introduces Māori design concepts for training and retaining memories. We then introduce our design ideations and details of the prototype implementation and interaction design. We critically evaluate the prototype application in the following section. Finally, we draw conclusions about insights gained from our work and opportunities for future work.

Background: Traumatic brain injury

The consequences of a brain injury causing psychological harm will in most cases significantly affect both the lives of the TBI survivors and those of the people around them. Depending on the gravity of the injury, symptoms of TBI may ensue for a short time (days or weeks) or have long-term impact (months or years) (Bramlett & Dietrich, 2007).

Traumatic brain injury is a significant cause of long-term disability, especially for children and young adults (Sariaslan, Sharp, D'Onofrio, Larsson, & Fazel, 2016, p. 1). Menon, Schwab, Wright and Maas (2010) defined TBI as "an alteration in brain function, or other evidence of brain pathology, caused by an external force"

(p. 1637). Traumatic brain or intracranial injuries are often caused by impacts occurring during falls, motor vehicle crashes, assaults or similar events (Langlois, Rutland-Brown, Wald, & Rosenthal, 2006). The personality and mental abilities of a brain-injured person may be affected long term, and restrictions of memory functions are one of the main outcomes (Khan, Baguley, & Cameron, 2003; Ponsford, Cameron, Fitzgerald, Grant, & Mikocka-Walus, 2011; Rapoport, McCullagh, Shammi, & Feinstein, 2005).

In New Zealand, Indigenous studies have shown that different cultural practices, practitioner insensitivity towards cultural practice, socioeconomic status, communication issues and patients' personal experiences have been contributing factors to poor treatment outcomes for Māori with TBI (Davis, 2006). Māori traditionally hold a more holistic view towards health and prefer to seek treatment within their extended family instead of seeking medical help in the hospital (Elder, 2013). Our work is inspired by Elder's (2013, 2017) recommendation to take guidance from the Māori culture, which we apply to our field by exploring concepts of cultural artefacts in a digital space. This paper describes our first foray into transferring concepts from Māori mnemonic aids into mobile memory aids for TBI survivors.

Related work

This section briefly describes our exploration of relevant related software developments and research. Our focus for related work here is on the retention of memories of significance, rather than to facilitate remembering to-do items and future events. A selection of the diverse range of Māori mnemonic tools and techniques that have helped in the retention, recall and sustainability of the Māori culture is discussed in the next section.

Memory applications research

Chang et al. (2014) proposed a mobile augmented memory system, called MyMemory. This mobile app aims at assisting TBI survivors with memory impairments, particularly autobiographical memory deficits (i.e., impairments to the recollection of episodes from one's life). The researchers used memory cues to help trigger the memory of the event that occurred. This was achieved by using flashcards or ticker widgets (similar to digital sticky notes). Users can also share their memories by sending emails and text messages to the people who were involved in the memory event or to the people who require the information, such as other family, friends or caregivers. These features were found to be helpful in the recording and sharing of autobiographical memories (i.e., reminiscing). Traumatic brain injury survivors using the MyMemory app reported improvements in well-being and overall feeling of being in control of their lives and memories. Neither the app nor the user studies included aspects of cultural awareness.

Khong (2016) proposed an application that would promote community and social support to those who suffer from long-term illness including memory impairments. Their primary focus was on TBI survivors and their support networks. They developed a digital memory aid that offers user collaboration features. The Digital Memory Chest application enables TBI survivors to store and retrieve memories and for their family members and friends to input their relevant or connecting memories and make comments. Several timeline models were considered, and a "Z-pattern accompanied with grouping" model was chosen to reflect the demands for a simple and uncomplicated design. This pattern displays icons depicting chronological "life phases", reading left to right and top to bottom, from earliest to most recent. The prototype was studied in terms of community collaboration, and no aspects of cultural awareness were included.

Gilbert et al. (2017) explored an AR mobile phone game for survivors of TBI. They centred their research on the possibilities of using augmented and mixed reality technology for their application development. They observed significant challenges when using AR, such as sensor noise, precise location, distraction, information fusion, complex information visualisation and computational complexity. They concluded, however, that contemporary mobile devices are a suitable and affordable platform for AR applications, avoiding the need for complex AR gear. Their Matching Pairs AR Card Game, developed using Wikitude software, is a digital version of the simple matching pairs card game. The goal of this application is to encourage users to physically move while using the game to trigger muscle memory for memory learning. They acknowledged the need for extensive testing of mobile memory rehabilitation games within AR environments to explore their impact on memory function. The focus of the Matching Pairs AR Card Game is on technical exploration of mobile AR games in this context but not on storage and recall of memories.

Within neuropsychology, a number of digital memory aids have been explored for persons with memory deficits, originally using mostly desktop-based technology (Kapur, Glisky, & Wilson, 2004). Assistive technology for cognition typically focuses on specific personal needs, such as speech recognition for people with visual impairments and digital assistants for people with memory impairments (Lopresti, Mihailidis, & Kirsch, 2004). For memory impairments, such as those occurring with TBI, a strong focus of rehabilitation (Wilson, 2013) and assistance (De Joode, Van Heugten, Verhey, & Van Boxtel, 2010) is on prospective memory, helping with task planning, scheduling and reminders. Mobile technology is predominantly being explored for cognitive support for complex-task completion, scheduling and navigation (Chu, Brown, Harniss, Kautz, & Johnson, 2014). This strong focus on assistance in everyday tasks (Charters Gillett, & Simpson, 2015; Jamieson, Cullen, McGee-Lennon, Brewster, & Evans, 2014) differs from our focus on autobiographical memory and reminiscing.

Commercial memory applications

Some commercial applications claim to improve memory functions, and we briefly consider two: Lumosity (2018) and CogniFit (2018). Both applications offer a number of training games and assessments, including tools and resources that help in the rehabilitation of TBI survivors. They both provide adaptive and personalised training programs to help increase cognitive skills. Neither focuses on training or memory retention with personal data, but rather with generic data; neither are intended specifically for TBI survivors or address issues of cultural awareness.

Augmented reality

Hinze et al. (2017) outlined the challenges encountered and lessons learned from developing augmented memory aids for people with TBI. In particular, their paper discusses methodologies used to elicit potentially sensitive and personal data and aspects of cultural awareness. They observed that cultural expectations may vary about acceptable personal questions for experiences with TBI, and how to understand concepts of health and impairment. They recommend a community-based approach to design that encompasses Māori cultural aspects. Our work reported in this paper is directly influenced by their considerations.

Mātauranga Māori

While aspects of Māori culture have been acknowledged and built upon in the context of TBI care (most strongly in the work of Hinemoa Elder), we did not find any digital TBI support systems that take Māori cultural preferences, experiences and mātauranga Māori

perspectives into account. We therefore believe that the work reported in this paper is unique in its approach.

Design inspiration: Māori mnemonic aids

Māori have traditionally used a wide range of tools to retain and recall information. Oral tools include pūrākau (Lee, 2009, p. 2), mōteatea, waiata, haka and the naming of landmarks, places and people. Physical tools include pou pupuru whenua and building adornments such as tukutuku (Brown, 2014, p. 3), poupou, kōwhaiwhai and tekoteko. Personal artefacts include tāniko, rākau whakapapa, taonga, wakahuia and papahou.

We explored a diverse range of Māori mnemonic tools and techniques that have helped in the retention, recall and sustainability of the Māori culture, a selection of which are discussed here. In our exploration, design concepts were considered for inspiration and suitability in a mobile app for TBI survivors.

Pūrākau are a traditional form of narrative: the retelling of stories about events and people of long ago. Lee (2009) stated that pūrākau "should not be relegated to the category of fiction or fable of the past" (p. 1) but be recognised as a worldview that is fundamental to Māori identity and protected for generations to come. The recent Disney movie *Moana* is a prime example of fictional pūrākau, and it mentions the Māori fabled hero Maui (Osnat & Clements, 2016).

Objects are great examples of storehouses for cultural memory and practice. Māori people regard objects as taonga, especially those that hold significance, such as by having been passed down from tūpuna (Lyons & Marshall, 2014). A typical taonga that is passed down is a piece of pounamu (see Figure 1) or bone jewellery that may have been carved or engraved using traditional visual symbology. They are reminders of the connections people have with deceased ancestors and allow them to continue the succession to subsequent descendants, giving the object additional meaning.

Paki and Peters (2015) described how "traditionally, whakapapa forms a view of the world and reality for Māori as an interconnected system" (p. 53). Whakapapa means "to lay one thing upon another" (p. 50) and is the Māori term for genealogy or family tree. It is considered by Māori people to be the building blocks of our existence on this Earth and our connection to our ancestors (Te Rito, 2007). Whaikōrero speakers, in most cases the kaumātua of a tribe, are given the task of retaining whakapapa. Traditional Māori orators have been known to use a rākau whakapapa (see Figure 2) with protruding notches to help them memorise tribal lineage (Taonui, 2011). They move their fingers over the protruding notches reciting different genealogy at each new notch.

There is a design commonality between each of the following components: tekoteko, poupou, wakahuia and papahou; they each present ornate carving. Both tekoteko and poupou (see Figure 3) represent the embodiment of an ancestor but are placed at different locations on

FIGURE 1 Pounamu taonga

FIGURE 2 Rākau whakapapa (Taonui, 2011)

the marae; tekoteko may sometimes be placed on the roof at the gable or left freestanding at the front of the meeting house (Robinson, 2013). Poupou are placed around the inside of the wharenui with tukutuku panels separating each one (Museum of New Zealand Te Papa Tongarewa, 2018a).

The wakahuia and papahou (see Figure 4) are two types of carved wooden containers that hold personal treasures such as amulets, pendants, combs or feathers. Wakahuia and papahou are similar in design; wakahuia are mostly oval-shaped containers whereas the papahou has an oblong or rectangular shape. Their length ranges between 30 and 60 centimetres. A wakahuia usually contained a feather from the huia bird, hence the name wakahuia. Commonly known as "Māori treasure boxes", they were elaborately carved. Traditional wakahuia were given names and became valued taonga, and were often hung from the ceiling so the underside could be admired (Revolvy, 2018).

Of these traditional Māori techniques, the papahou seems to most closely embody the aim of the app as a place to gather memory cues. The rākau was considered as a design alternative, but seems to impose a stronger linearity of memory cues than desired. Taonga shapes are incorporated as representations of memories or stories. Other tools, such as the pūrākau, waiata and poupou, seem to aid recall of well-known stories and events, and were therefore not considered for this app.

Design process and method

To address the design problem of how to reimagine and implement Māori mnemonic aids in a mobile app to support TBI survivors, we identified user personas and created a use case description to guide the design process. We then explored the details of the interaction design, that is, the interface elements through which users interact within the app, as well as other visual elements. These conceptual ideations were then encoded during the implementation of an app prototype. To evaluate the suitability and quality of our concepts and their implementation, we carried out an expert user study. We used an expert analysis in combination with cognitive walkthrough (this combination of techniques is sometimes referred to as an expert walkthrough; Polson Lewis, Rieman, & Wharton, 1992). Krug (2000) reported that a group of experts can detect more than 85% of software problems while using this cost-effective technique (Nielsen & Molich, 1990). The cognitive walkthrough was done based on the user personas and their usage scenario.

User personas

We first identified two specific user groups: (a) TBI survivors (main users) who had sustained a brain injury and their supporters (secondary users), and (b) the people who would use the application in support of the main user—who

FIGURE 3 Poupou between tukutuku

FIGURE 4 Papahou

is likely their parent or family member. The needs of the main user were the central focus of the design and development of this mobile app.

We personify Aroha, a 23-year-old female (main user) who suffers from mild TBI (i.e., she would score between 9 and 15 on the Glasgow Coma Scale; Feigin et al., 2013, p. 55) because of a vehicle accident one year ago, and her 45-year-old mother Maia (secondary user), who cares for Aroha. Both users are computer "savvy", and each owns a smartphone. Aroha used several support tools immediately after her traumatic event to help with memory and time management. These support tools ranged from alerts and notifications via calendar schedules to text reminders from her mother. The tools were cumbersome but relevant for reminding Aroha of future tasks, and there was not "one" application to manage her retrospective memories; she used several applications to achieve this, such as a Word document and slideshow to record memories as she remembers them or whenever friends and family members reminisce with her.

Scenario description

Maia finds the Maumahara Papahou mobile app and they download and install it onto Aroha's phone. They explore the app together using both the touch and augmented, motion-controlled features of the app. Aroha is able to select objects, and add and remove memory associations. She can edit details of memories, such as places, times and people involved.

Together the pair discuss and reminisce about the events and activities that Aroha wishes to store in her papahou. Having the memory cues in the app allows Aroha to talk about events she remembers and supports Maia in triggering Aroha's memories.

Conceptual app design

The design of our app was guided by design concepts from traditional Māori tools and techniques that help people retain and recall past information. We took further guidance provided by the design concepts and features of MyMemory (Chang et al., 2014) and Digital Memory Chest (Khong, 2016), and utilised AR technology similar to that of the Matching Pairs AR Card Game (Gilbert et al., 2017).

User interaction

The design considerations for the development of user interactions with the app were inspired by the Māori mnemonic aids discussed above. Figure 5 gives an overview of the possible user

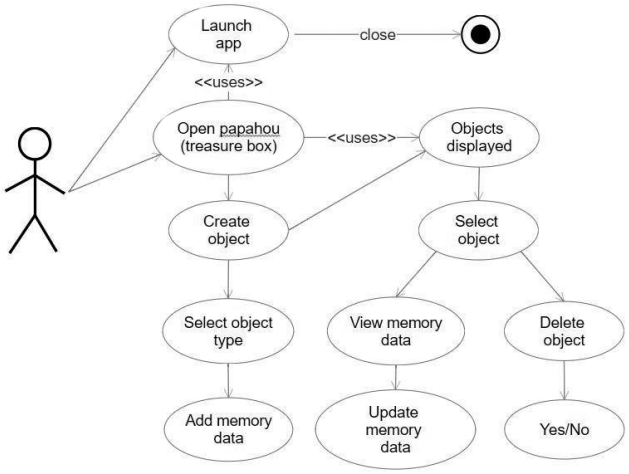

FIGURE 5 Use case diagram showing a user interacting with the app

interactions with the app. We describe here how users might interact with the app in light of the use case shown below.

Users start by launching the application; they are then presented with the papahou ready to be opened. Users can open the papahou by tapping the main screen. They can then zoom in and out within the box, viewing the taonga. Tapping and holding a taonga allows users to drag it around inside the virtual space of the papahou.

Users can view the memories of a taonga, and edit or delete them. Text, images and videos can be associated with each taonga. To input new memory cues, a new taonga is placed within the papahou. Via a menu, users select the type of taonga with which they want to associate their memory and add memory cues. After it is saved, the newly created taonga will be displayed in the papahou.

To reminisce and explore memories, users tap on a taonga, which will bring up details of the memory.

Interface elements

We discuss here the interface design elements that are used during the user interaction. Our app specifically reimagines the papahou as a digital 3D AR object and allows users to virtually see and touch taonga that represent their memories.

Treasure Box (Papahou): Augmented reality elements used in the mobile app are based on a papahou design (Museum of New Zealand Te Papa Tongarewa, 2018b). Figure 6 shows one of the conceptual drawings, and the finished AR design is shown in the walkthrough discussed below.

Memory Objects (Taonga): We conceptually designed graphical representations of Māori taonga to be interpreted as memories (see Figure 7). The finished AR designs include a rei puta (3D data provided by Cults3D, 2017) and kōauau (3D data provided by SketchFab, 2017) and a Māori carving design that adorns the sides and lid of the papahou (3D data provided by Koru Korua Tae, 2017).

Prototype walkthrough

To achieve the user interactions described above, we developed the Maumahara Papahou app prototype, which provides a 3D AR experience. To showcase the app, we present a walkthrough of the prototype implementation from the viewpoint of the personas Aroha and Maia. A similar walkthrough was used by the experts in their analysis. Details of the reflective analysis are discussed in the next section.

FIGURE 6 Concept drawing of the Maumahara Papahou

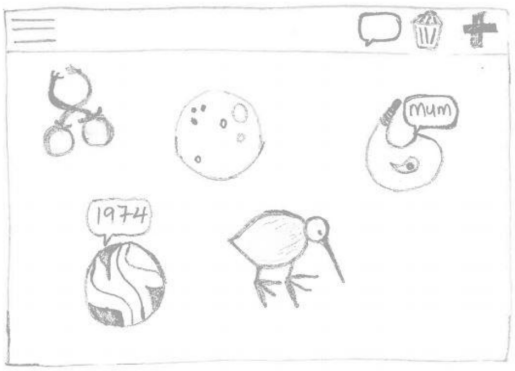

FIGURE 7 Conceptual design of taonga used as memory cues

Step 1: Opening the papahou

Aroha and Maia sit down in their living room to explore the app. Aroha uses the app with her tablet, Maia looks over her shoulder as they sit side by side. Aroha starts the app by selecting the app launcher icon (see Figure 8).

The start screen of the app appears, showing a carved treasure chest with a slowly revolving lid superimposed over a view of Aroha's living room as seen by the tablet's camera (see Figure 9).

As Aroha taps the start screen, a sound effect chimes twice and the revolving lid disappears. An animation zooms into the treasure box and Aroha's memory objects come into view (see Figure 10).

These are memory objects Aroha created earlier. Some of these were also created by Maia, who has access to Aroha's app so she can help create memory items that they can talk through.

Step 2: Interacting with objects

Aroha then moves the memory objects around within the memory box. As she touches them, she talks with Maia about the memories they are connected with. She uses the items similarly to how the notches on a rākau talking stick are used, to remember each event and tell her story.

When she taps on the wooden flute, she realises she does not quite remember the event connected to it. Aroha decides to select the memory object to explore its content further. She taps the wooden flute and the View & Cancel buttons appear hovering above the object (see Figure 11). Aroha could choose a different object now by tapping the Cancel

FIGURE 8 App launcher icon

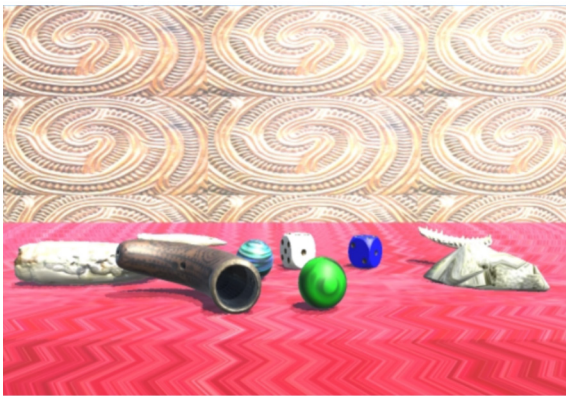

FIGURE 10 Objects are visible in the papahou

FIGURE 9 Start augmented reality view of papahou

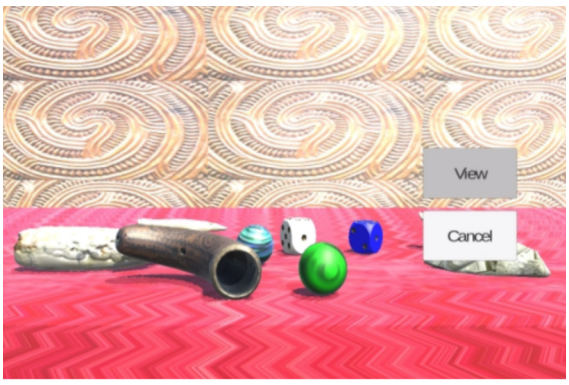

FIGURE 11 Selecting an object to view memory details

button but decides to go ahead and taps the View button.

Step 3: Viewing memory details

Now that she has tapped the View button, the memory details connected to the wooden flute object appear as a separate screen (see Figure 12). Maia and Aroha look at these, and Aroha realises that the title she originally chose for this memory appears misleading to her.

As they look at the memory details, Aroha finds them easy to take in at a glance, since each of the memory details is very brief. Overall, only seven aspects are connected to the memory: the date, time frame, a title, a place, people involved in the memory event, the activities linked to the memory event and a short text. Aroha particularly likes naming all the people who are connected to the event as it helps her to feel in touch with the rest of her family. The screen design is clear and almost sparse, so Aroha does not feel cluttered and overwhelmed. The seven memory aspects were chosen by the design team based on the memory dimensions that are relevant for TBI survivors (Chang et al., 2014).

Step 4: Editing memory details

Aroha taps the Edit button next to the memory details and the application loads the Update memory screen (see Figure 13). Each of the seven memory details can be modified here and saved again. Aroha decides to tap the text input box to change the memory title via the device's keyboard to be more suitable for her remembering.

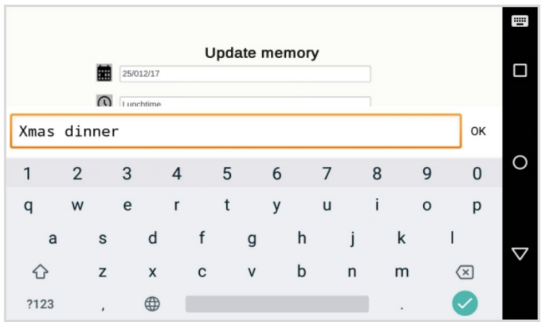

FIGURE 13 Editing the details of a memory

Step 5: Saving the details of a memory

When she is done typing, Aroha selects the Save button (see Figure 14) and the data are updated with the new memory details. Then she goes back to the AR view of the object in the memory box. She selects the wooden flute object again and tells Maia about the Christmas event her family had in 2016.

Aroha and Maia continue exploring the memory chest in more detail, still looking at various objects in the treasure box, zooming and moving around the 3D virtual space.

FIGURE 12 Memory details of an object is displayed

FIGURE 14 User input is saved, and data are updated

Prototype evaluation

We used seven questions to guide the reflective analysis of the walkthrough. The analysis was carried out by three independent expert researchers who specialise in app development, TBI and human–computer interaction in a New Zealand context. All of the researchers have considerable expertise in working in a New Zealand multicultural context, speak te reo Māori and have experience with mātauranga Māori to varying degrees; one of the experts is of Tainui descent.

Reflective analysis: Q&A

The seven questions shown in Table 1 explore performance, functionality, ease of use and interface design, while considering the context of an app developed for people with TBI.

Q1. Does the app allow TBI users to perform predetermined tasks?
The app allows for exploration of previously created memory cues linked to AR taonga and for editing memory details in the context of an AR visualisation. The creation of memory objects and their details is not provided within this tablet app but is done via a pre-existing mobile phone app. The advantage of this split is that each app can focus on its main function. However, this also creates a sense of discontinuity. The first task is that of reminiscing, which relies on the objects being looked at or touched. This creates an illusion of haptic engagement. However, the recall may be hindered by the complexity of the task of bringing up memory details. Easier access to view details may be provided via simple pop-ups on touch. The second task of editing memories uses a simple structure that does not distract from the task. It suitably breaks out of the AR world to restrict confusion or a sense of being overwhelmed.

Q2. Is the app easily navigable for people with TBI?
The targeted functionality of the app results in an intuitive interaction design, almost realistic in its treatment of the box and items. The interaction design is reminiscent of the interactions with a physical object that carries the same aims of remembering and reminiscing. The focus is on the memories, not the items, which carry the memories.

Q3. Is the app visually complex for people with TBI?
The management of the box requires some dexterity, which may be an issue for some TBI survivors. The complexity of the interaction elements is suitable. If the user were to create a large number of objects, the user's interaction and ability to manipulate may be somewhat hampered. Here a scaling of the treasure box may assist, perhaps even to the point at which the user can virtually climb inside.

Q4. Are the text styles, sizes and colours used in the app suitable for people with TBI?
The text styles and font sizes are suitable for

TABLE 1 Reflective analysis questions

1.	Does the app allow TBI users to perform predetermined tasks?
2.	Is the app easily navigable for people with TBI?
3.	Is the app visually complex for people with TBI?
4.	Are the text styles, sizes and colours used in the app suitable for people with TBI?
5.	Does the app implement aspects of Māori culture appropriately?
6.	Do the Māori cultural aspects contribute to the TBI users' remembering?
7.	Is the app suitable for both Māori and non-Māori?

reading on a tablet device and are legible for both members of the intended user group: the TBI survivor and the support person. It could be helpful to colour code the overview of the memory details to align with the colour of the object to create a stronger visual link to support memory retention. An additional repetition of the object image within the memory details could serve the same purpose. Colour coding has been successfully included in other apps for TBI survivors (Chang et al., 2014). Currently, the app does not support customisation of the lining or the carving of the box. Adaptation to different tribal patterns and traditions could create an element of familiarity. It would also allow users to customise colours and patterns to their liking.

Q5. Does the app implement aspects of Māori culture appropriately?
Culturally aware care was taken in the selection of mnemonic devices, patterns and suitable memory objects. The available object types represent a selection of objects that are familiar to Māori and other objects that are familiar to non-Māori. The selected patterns are culturally appropriate and have been used respectfully and in consultation with kaumātua. None of the patterns or objects is restricted in its cultural use, and they are therefore suitable for an app.

Q6. Do the Māori cultural aspects contribute to the TBI users' remembering?
To completely address this question, a longitudinal study needs to be carried out with participants who are survivors of TBI and those who do not suffer from brain damage. Our attempt at using Māori mnemonic aids is original. The expert panel believed that using Māori patterns and concepts does make the app more attractive for Māori as well as New Zealanders in general. Contribution to users' remembering may depend on their acculturation within the Māori community. Urban Māori may approach the interface much like any other New Zealander. However, the interface uses concepts that are familiar, and thus is likely to assist with remembering.

Q7. Is the app suitable for both Māori and non-Māori?
The app is generic enough in its use of concepts and visual aids to allow people from many backgrounds to use it. It will be more familiar to people from New Zealand, and most easily recognisable for people with Māori and other Pacific upbringing.

At the end of the expert discussion, it was noted that this is an application of AR for people in their everyday environments. It does not need any special equipment, and users are free to explore it without the help of a health care provider, unlike many other games and practices for TBI survivors. Further, unlike other memory games, the app does not use artificial memories but engages people in reminiscing and practising remembering with their own memories, thus contributing to their well-being and sense of control. It is one of very few attempts to incorporate Māori cultural experience in health care interventions.

Discussion

Culturally aware health interventions

Our work is based on the work of Elder (2013, 2017), who argues that Māori health is a community-based health concept. She developed a paper-based approach to supporting TBI survivors that engaged the whole whānau. Elder recommends taking guidance from Māori culture to best understand the needs of individuals in the context of their community, which has been a central focus of our app development. Unlike our research described here, Elder's work has not focused on digital interventions.

As already noted in the expert review, this project is one of very few attempts to incorporate Māori cultural experience within digital health care interventions. Approaching the

problem of assisting a TBI survivor to remember through learning from traditional cultural mnemonic aids has not been discussed in the literature to date for Māori or for any other Indigenous people. Issues of cultural sensitivity and appropriateness have been considered throughout the development of the app.

Augmented reality on mobile end-user devices

The decision to use AR technology was based on the lack of immersive digital rehabilitation support for TBI survivors that would be available for people in their everyday environments. The decision to use a 2D-based interface for data entry and editing was based on the research of the MyMemory application (Chang et al., 2014). Chang et al. (2014) developed a 2D text entry icon-based interface for their MyMemory app, which we rely on for memory information ingest into our application. We follow them in their argument that TBI survivors prefer a simple design with "enough" functions, avoiding complex interfaces that potentially lead to cognitive overload.

Māori and app development

The extent of currently available apps specifically for or about Māori and Māori culture is limited. Most available apps focus on teaching te reo Māori or tikanga Māori and Māori cultural beliefs. A few apps are about restoring Māori sovereignty and showcasing projects on their native land. To the best of our knowledge, there are no apps that aim to use Māori cultural knowledge in digital health interventions, and the work presented here is unique in its approach.

Shortcomings of current prototype

The AR app software introduced in this paper is a prototype used to explore the mechanics of incorporating Māori traditions within a digital tool, as well as the concept of using AR software for TBI support. Digital prototypes are typically not suited (and not designed) to be turned directly into commercial products. The focus of the development described here was the exploration of Māori cultural inspirations in AR features. Having shown the suitability of this approach, further evaluation is warranted. Further, additional technical improvements, such as increased performance of the AR rendering on mobile phones, are required, as the current prototype is restricted to high-end phones with sufficient computing power.

Shortcomings of current evaluation

The current AR app for TBI has only been tested in a cognitive walkthrough with three experts, and is lacking an evaluation with end users. Such thorough evaluation is planned for the future, and needs consideration of ethical and cultural implications and restrictions (e.g., health of TBI survivors, access to personal data, cultural sensitivities). Planning, developing, testing and performing such an evaluation study will require a larger research team and further funding.

Conclusion and future work

This project aimed to develop a health intervention that supports TBI survivors using an immersive AR interface on commonly available mobile technologies. We incorporated concepts of traditional Māori cultural tools and techniques that have helped Māori people retain and recall past information in an oral culture.

We identified a range of different traditional aids that Māori people use to help them remember past information. The design concepts and techniques used in developing these aids were vast and not all were considered for the development of the current application. We chose the treasure box metaphor of the papahou to implement as an AR interface for our app. This

memory box concept will be familiar to Māori users and is an artefact that will also translate to non-Māori users, who will also be familiar with treasure boxes in their own cultures.

This paper has described the design process undertaken to develop the Maumahara Papahou app. We discussed the design and interaction considerations we explored to develop a mobile app that is appropriate for TBI survivors and their supporters, especially for recall of memories and reminiscence. We showcased the Maumahara Papahou application and explored it using a reflective analysis discussion with three experts.

Contributions and limitations

This paper makes the following contributions: (a) development of an AR concept for memory cues based on Māori concepts, (b) a mobile app prototype using AR for TBI survivors and (c) a viability test using expert walkthrough.

The research has the following limitations: (a) a working prototype with limited computing performance currently restricted to high-end phones and (b) a lab-based evaluation with experts but no in-the-wild tests with user groups.

Future work

Our future work will see the Maumahara Papahou application being tested in a longitudinal study with Māori and non-Māori TBI survivors and their supporters. In this upcoming study, we will be investigating the user interactions with the app as well as the perceived successes in recording and associating memories with AR artefacts. Further developments of the app based on the insights from the expert review will be undertaken, such as extension of the use of colour in the app and further enhancement of the user interface. We also wish to enhance the use of traditional Māori taonga in this immersive AR environment, for example, through incorporating further relevant objects. It would also be interesting to add an interface in te reo Māori to determine whether that assists with usability and improved memorability of TBI survivors.

Glossary

haka	war dance
kaumātua	adult, elder, a person of status within the whānau
kōauau	flute
kōwhaiwhai	patterns
marae	tribal meeting grounds
Maui	Māori fabled hero
mōteatea	Māori chants
papahou	contemporary treasure box
pounamu	greenstone
poupou	carved panels
pou pupuru whenua	landmarks
pūrākau	myths and legends
rākau whakapapa	orator's mnemonic staff
rei puta	whale tooth pendant
tāniko	embroidery
taonga	treasure, an heirloom to be passed down through the different generations of a family
tekoteko	carvings of human figures
te reo Māori	Māori language
tikanga Māori	Māori customs and practices
tukutuku	lattice-work
tūpuna	ancestors
waiata	songs
wakahuia	traditional treasure box
whaikōrero	Māori formal speech/ oration
whakapapa	genealogies
whānau	wider family
wharenui	meeting house

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