Harper, E., Rall, H., Wong, S. and Hodgkinson, G. (2025). Visualising medical information for edutainment through animation: a case study of the Diabetes VR experience "A Choice for Life". *Mutual Images*, 13, 20-36. https://doi.org/10.32926/2025.HRWH

ORIGINAL ARTICLE

Visualising medical information for edutainment through animation: a case study of the Diabetes VR experience "A Choice for Life"

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ISSN 2496-1868

Abstract: Over 10 per cent of the world's population lives with Type 2 diabetes, making it a significant public health concern. In Singapore, the government launched the "War on Diabetes" in 2016, initiating efforts focused on prevention, early detection, and better disease management. A challenge that remains is promoting informed dietary choices within hawker centres - open-air food complexes central to Singaporean food culture - where diverse offerings can complicate healthy decision-making for diabetes prevention and control. This paper presents a case study of *A Choice for Life*, a practice-as-research project developing a virtual reality (VR) experience aimed at educating users on making healthier food choices in hawker centres. Drawing on evidence that VR experiences can influence real-world behaviour, the project integrates insights from medical professionals, animators, and game designers. The discussion focuses on the iterative development of the user interface and innovative feedback mechanisms, including emoji responses that reflect the nutritional value of users' food selections in the virtual setting. Presenting initial findings from prototype testing, it reflects upon the value that immersive experiences hold for the future of diabetes education and plans for the further development of the project.

Keywords: diabetes; edutainment; serious games; Virtual Reality; health games

1. Introduction

Type 2 diabetes is a major international public health concern, a chronic condition which requires patients "to make a multitude of daily self-management decisions and to perform complex care activities" (Powers et al., 2016: 70). Globally, the International Diabetes Federation estimated that there were 536.6 million people with Type 2 diabetes in 2021, representing over 10 per cent of the world's population, with the number rising year on year (Hong et al., 2022: 1). Singapore, where this paper's authors are based, is representative of this wider global trend, with its own specific challenges. Recent decades have seen the country's population undergo significant changes in lifestyle, diet and other environmental influences that are typical of a high-income society, yet which are associated with a rapid ageing and

increasingly sedentary population (Phan et al., 2014: 1). In the 1980s, the rate of Type 2 diabetes amongst the Singaporean population was 5 per cent - this number had more than doubled to 11 per cent by 2010 (Thai et al., 1990: 517; Ministry of Health Singapore, 2011). Hand in hand with the rising prevalence of the disease comes rising costs for public health. In 2010, Type 2 diabetes cost Singapore more than S$1 billion and this figure is estimated to soar to beyond S$2.5 billion annually by 2050 (Saw Swee Hock School of Public Health, 2016). These costs consist of diabetes-related medical treatment as well as productivity losses related to morbidity and early mortality as a result of the disease.

In April 2016, Singapore's Health Minister Gan Kim Yong declared the "War on Diabetes" (WoD) – a series of initiatives and programmes rooted in three key pillars of healthy living and prevention, early detection and intervention, and better disease management (Ministry of Health Singapore, 2019: 1). The "war" aimed to rally the nation as a whole and involved the participation of government agencies, healthcare providers, community-based organisations, industry partners, academics and individual Singaporeans to educate those at risk of, or living with, Type 2 diabetes. Initiatives included public outreach programmes, promotion of healthier food choices and incentive schemes for improved diabetes management (Ministry of Health Singapore, 2023).

However much remains to be done. In a 2021 review of the "war", Singapore's Ministry of Health acknowledged that they were "unable to support at present" the implementation of a system of rating hawker centres based on their provision of healthy food options (Ministry of Health Singapore, 2023). Hawker centres are open-air food complexes that house many stalls selling a wide variety of affordably priced food options (Tung, 2021). Conveniently located across the city state, hawker centres are a unique aspect of Singaporean culture and lifestyle, functioning both as a staple of dietary behaviour and an important place for social interaction and community bonding. Hawker centres are emblematic of Singapore and its culinary culture – in December 2020, Singapore Hawker Culture was inscribed on UNESCO's Representative List of Intangible Cultural Heritage (Tung, 2021). In 2018, 83 per cent of Singaporeans ate at hawker centres at least once a week (National Environment Agency, 2019). However, many of the dishes on offer are rich, fried, and less nutritious, which can prevent a challenge to those living with diabetes and aiming to control their nutritional intake.

Against this backdrop, in 2021 an interdisciplinary project team from Nanyang Technological University and the National Healthcare Group, Singapore was assembled with the aim of considering new ways of informing patients about the impact of diet on diabetes management through the development of an interactive animated VR serious game, designed to be used in conjunction with traditional forms of physician-led care which are rooted in the specific medical histories of individual patients. Of note is this project's intention to work towards a virtual representation of consuming hawker food as a characteristically Singaporean model of dietary behaviour which presents a specific challenge to those attempting to make healthy, informed food choices, which is absent from existing VR games created elsewhere in the world for diabetes education. The project aims to leverage upon immersive animation's potential to create a sensory perception of reality in which participants are physically and mentally fully immersed within a computer-generated 3D world (Rall et al. 2024: 111). However, it also needed to represent the "invisible" in the form of nutritional information and the health consequences of poor food choices on diabetes management in both the short and longer terms.

The need to represent these somewhat intangible elements was closely linked to the challenge that presented itself with the project more broadly – how to best leverage on the knowledge and experience of the cross-disciplinary team to use creative design to support and enhance medical messaging with the aim of enacting real world behavioural change. The experience needed to be engaging, visually appealing and technically sophisticated, yet underpinned by verifiable medical facts and knowledge that could be transferred to players' real-world experiences and daily lives, specifically related to choosing food in a hawker centre environment.

This paper will outline the development process of this experience – titled *A Choice for Life* – with a particular focus on how the production of the initial prototype integrated creative design with medical knowledge. Particular attention will be paid to one specific aspect of the project, the emoji responses which the player receives as part of the evaluation at the end of the experience. These emojis function to provide the player with feedback and guidance on their food choices within the game which can be transferred into life outside the virtual world. They also represent a moment in the project development that required particularly close collaboration and conversation between doctors, dieticians, technical developers, illustrators, and animators. It is hoped that this discussion will provide an insight into the process of practice-led-research at the heart of the project and offer broader recommendations for mediating medical science through animated immersive media.

2. VR for Diabetes Education

A January 2024 paper by Neil Vaughan provides a comprehensive overview of VR and AR (augmented reality) applications in diabetes. Vaughan (2024: 810) outlines that "for diabetes training, VR is particularly suitable, because the physiological characteristics are especially responsive to patients' lifestyle, physical and cognitive change," categorising applications as focused around either education, prevention, or treatment.

He further states (2024: 817) that:

> *'For VR patient education of diabetes, VR simulators provide the immersive platform on which to deliver real-world scenarios and information for training patients in self-management behaviors which can be experienced anywhere, anytime in a safe training environment without risk to the patient.'*
>
> *(Vaughan, 2024, p. 817)*

In creating an environment that simulates and represents the "real world", VR allows patients to experiment and make health decisions without facing real-life health consequences on their real-world physical bodies yet also allows them to test out decisions and behaviours which they can then easily translate into their lives beyond the VR environment. The benefits of a virtual environment for diabetes education are also highlighted by Johnson et al. (2014) in their discussion of the creation of a Second Life virtual diabetes community – which, despite taking place on a 2D computer screen, further reinforces the idea that such environments can offer platforms through which healthcare providers can "promote skill building via interactive simulations and scenarios."

Recognising the value of VR for diabetes education, several existing projects have been developed which have made use of the medium, leveraging specifically upon the fact that Type 2 diabetes can be prevented, controlled or even reversed through changing dietary and exercise habits. Examples of VR education for adults with diabetes include Neira Tovar and Elizondo Elizondo's work in Mexico to develop a serious game to promote

physical activity through a combination of VR and movement sensor technology (2018); a project at the University of Exeter, UK in which a prototype VR diabetes training platform for people with diabetes offers patients the chance to learn about exercise, carbohydrate counting, blood glucose testing and monitoring, (Vaughan, 2024: 812), and The Boston Medical Center/University of Massachusetts Medical School's pilot project *Women in Control*, which delivered an education programme to African American patients with diabetes or pre-diabetes through interactive sessions within a virtual world (Rosal et al., 2012: 1).

The discussion of games within the context of VR diabetes education is largely limited to projects targeted at children. This is despite a widespread acknowledgement that

> *'Digital games for teaching about T1D [Type 1 diabetes] and T2D [Type 2 diabetes] can help children, adolescents, and adults with diabetes to better cope with their lifelong condition. This demonstrates the potential of diabetes VR integrating gamification…to motivate and educate patients to positively change behavior and lifestyle.'*
>
> *(Vaughan, 2024, p. 813)*

'Gamification' here refers to "the use of game design elements in non-game contexts" (Deterding et al., 2011: 9), a process which has been demonstrated to facilitate "significant, positive effects" on "cognitive, motivational, and behavioral learning outcomes" (Sailer and Homner, 2020: 77), "since it is motivating and fun and consequently, more efficient for the learning process and the management of the disease" (Martos-Cabrera et al. 2020: 2). Existing studies have demonstrated that:

> *'Gamification offers the advantages of enhancing patient care without face-to-face contact and with flexible timing, thereby reducing transportation time and cost for patients with T2DM [Type 2 diabetes melilites]. Virtual gaming also provides a novel way for the DCES [diabetes care and education specialists] to engage with patients to provide education and assess the attainment of knowledge.'*
>
> *(Brady et al., 2023, p. 510)*

It was with this in mind that this project aimed to not only create an entertaining educational experience in VR for adults but to incorporate ideas drawn from game design and development throughout the project development process.

3. Project Development

Vaughan (2024: 810) states that "when future VR systems are being developed for diabetes, they should include a wide range of stakeholder inputs, including from people living with diabetes, pharmacists, practitioners, and diabetes educators." Our project not only integrated the opinions of medical professionals throughout and brought in the feedback of Singaporeans with diabetes at the prototype testing stage but also closely involved animators and game designers within the development process. This collaboration aimed to bring together expertise in topics ranging from data visualization and information graphics to visual and interactive storytelling to enhance the educational experience and harness the visual and technical possibilities offered by VR.

While a VR simulation can be extremely immersive and as a result demonstrate benefits for engagement and education, *A Choice for Life* was conceived of throughout as a serious game rather than simply a simulation experience. The application of game principles such as interface, interaction, feedback, navigation, engagement and reward creates an enhanced experience for the player as they move within the experience (Hodgkinson,

2023). When combined with a stimulating animated visual environment, the VR experience becomes invigorating, loaded with significant learning outcomes within the context of healthcare. This project represented a somewhat unorthodox approach to game design – the design team were available immediately from the start of the project, meaning that characters and environment could be developed before the central game mechanics – the procedures and rules which structure the game experience and the player's expected behaviour – were established (ibid). This placed the interaction between designers and medical experts at the centre of the project from the outset.

The narrative at the heart of *A Choice for Life* follows the player as they find themselves within a virtual hawker centre. They are free to explore the environment, which includes a minimart, food stalls and vending machines. Upon moving towards the stalls, they can interact with the hawker and select the food they would like to order. They can choose not only which food elements to consume, but also portion sizes, in the same way they might do so in a real-world hawker centre. The food is then plated, and the player is guided to a table, where they sit and consume their selection. After the food has been consumed, players are presented with an evaluation of their choices. This evaluation highlights positive elements as well as making suggestions on adjustments that they could make to improve their diet and as a result improve their diabetes control.

3.1. Integrating Medical Knowledge: Behavioural Change

The foundation of the *A Choice for Life* project is the idea that experiences in a virtual world can encourage real-world behavioural change (Wong, 2023). This idea is founded upon theories drawn from medical psychology and is of particular relevance to diabetes care. Diabetes self-management education (DSME) relies upon

> *'…the transfer of knowledge and addressing and supporting behavioral change to improve clinical and health-related outcomes. The outcome of DSME is "behavior change," which is evaluated based on…healthy coping, healthy eating, being active, taking medication, monitoring, reducing risk, and problem solving.'*
>
> *(Brady et al., 2023, p. 493)*

Michie et al. (2011: 4) propose that behavioural change interventions be conceptualised according to a framework based upon a behaviour system involving three essential conditions: capability, opportunity, and motivation (what they term the "COM-B system"):

> *'In this 'behaviour system,' capability, opportunity, and motivation interact to generate behaviour that in turn influences these components… Capability is defined as the individual's psychological and physical capacity to engage in the activity concerned. It includes having the necessary knowledge and skills. Motivation is defined as all those brain processes that energize and direct behaviour, not just goals and conscious decision-making. It includes habitual processes, emotional responding, as well as analytical decision-making. Opportunity is defined as all the factors that lie outside the individual that make the behaviour possible or prompt it… Opportunity can influence motivation as can capability; enacting a behaviour can alter capability, motivation, and opportunity.'*
>
> *(Michie et al., 2011, p. 4)*

Studies within a range of fields with an interest in human behaviour have established the link between experiences in VR and real-world behavioural change. In a 2021 review of existing literature concerning the use of VR in consumer research, Taufik et al. (2021: 1) state that:

> *'VR can potentially be validly used in consumer research aimed at behaviour change in a consumer setting, as findings in real-life were mostly replicated in VR (or vice versa)... Studies which used VR as a behaviour change tool were generally effective in changing consumer behaviour in desired directions, more so than when less immersive (2d), equivalent treatments were used'.*
>
> *(Taufik et al., 2021, p.1)*

The work of Morina et al. (2015) has demonstrated that this conclusion is also applicable when the intention is using VR in psychological treatment. Their case study, based around the use of virtual reality exposure therapy (VRET) to treat patients diagnosed with anxiety, demonstrated that virtual reality interventions can indeed lead to behavioural change in daily life, and that virtual reality interventions for specific phobias are as effective as traditional behaviour therapy methods. What these examples demonstrate is a cross-disciplinary acknowledgement of the potential that VR holds for influencing behaviour in the real world.

Figure 1 outlines how specific elements of our VR experience were selected to create particular responses on the part of the user, which function to facilitate behavioural change. It also explains how this relates to Michie's COM-B behaviour system discussed above.

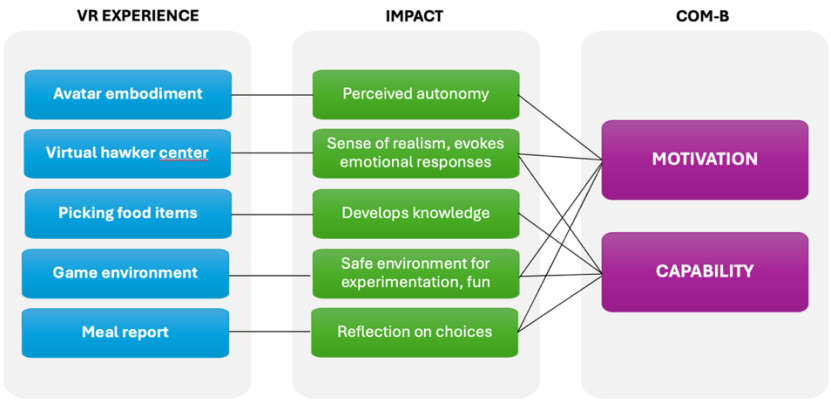

Figure 1. Diagram showing relationship between aspects of our VR experience and models of elements of behavioural change drawn from the COM-B model.

Having established the precedent on which our VR experience is constructed, we now move on to a discussion of a case study which demonstrates how creative design and scientific medical knowledge were integrated when designing the prototype version of our VR experience.

3.2. Subverting Expectations: A Stylised Approach to Design in VR

Many discussions of the ability of VR to enact behavioural change attribute its success to its ability to closely "simulate" players' everyday lives and experiences. However, arguably empathy and authenticity can be created by adopting a stylised, non-photorealistic (NPR) approach to visual design rather than a photorealistic depiction. Whilst some existing virtual diabetes education projects, such as the Second Life virtual community created by Johnson et al. (2014) have leveraged upon virtual environments' ability to closely replicate the real world, others, including the app games discussed by Alsalman et al. (2020) which require a player to interact with a cartoon bear, dragon or other character instead leverage animation's potential for abstraction. Earlier research by this paper's second author has demonstrated how empathy and authenticity might be created in VR

through the adoption of a stylised animated approach. Stylized animation "reveals its artificiality instantly… The spectator is alerted to a constructed reality with fictional elements that might very well be based on correct facts, yet does not force a suspension of disbelief" (Weber and Rall, 2019), with the artistic subjectivity that this approach creates adding new layers of truth, and in fact serving the concept of authenticating facts. Indeed, previous research has demonstrated that stylised characters can evoke or even heighten empathy or emotional engagement on the part of the user when compared to photorealistic approaches to design. Work by Park et al. focusing specifically on character design found that users did not empathise or sympathise more with more realistic designs, and that "the lack of significant difference in sympathy and empathy ratings between character types suggests that the cost/benefit ratio for iconic characters may be best for situations in which the animator is seeking to elicit emotional responses from the viewer" (Park et al., 2019: 486). Van Rooij (2019) has further demonstrated how a shared style of character design, combining aspects of lifelikeness with deliberate abstraction, contributes to audiences' emotional response to, and the resulting success of, American animation films by leading studios including Pixar, Disney and DreamWorks.

What is important to take from this is that stylized animation can indeed create empathy in viewers. In the context of this experience, empathy between user and in-game character is considered desirable for the way that it allows for us to "transform visual in-formation about someone else's emotional state into similar emotional dispositions of our own" (Morrison and Ziemke, 2005: 73), thus heightening the real-world impact and translatability of the lessons learnt within the context of the virtual environment. The effectiveness of empathy induction is arguably influenced more by the narrative and expressive behaviours of characters rather than their visual style. Simple and iconic designs can be as effective as realistic ones, and congruence in appearance and facial expressions enhances emotional engagement. While challenges exist in conveying genuine emotions through animated characters, the strategic use of design principles and expressive behaviours can overcome these hurdles, making stylized characters powerful tools for evoking empathy. Although computer generated animated characters do not possess experiences or emotions which can be drawn upon to create a performance in the same way that human actors do, "when an outstanding animated performance is married to classic cinematic principles the emotive power of animation… can be genuine and powerful" (McIntosh, 2018: 557).

A Choice for Life aims to explore whether a gamified experience can lead to real-life behavioural changes, and as such cannot abandon all sense of reality, however this does not necessitate a reliance on photorealism. The project thus adopted an approach which incorporating medical facts into a stylised approach to design to allow the lessons learnt in the virtual world to be enacted in the player's life beyond the game.

Makhlysheva et al. (2016: 422) state that a successful VR health game needs an "attractive design… to more deeply immerse a player into the game." Considering how to create this attractiveness was thus a fundamental concern of the design approach, particularly when attempting to visualise abstract or serious elements such as nutritional categories and health consequences. When approaching environment design, the aim was to create something that was recognizable to the Singaporean audience of our game design in the form of a hawker centre, yet also functioned as a visually innovative, whimsical environment that prompts the player to explore and interact. Stalls offer cuisines and menu choices that are immediately recognizable to a Singaporean audience, yet presented in an exaggerated, stylized way to increase the playfulness and abstractness of the

environment and the interactions that occur within it. It was also important to incorporate the requirements and demands of user experience in VR, for example by reducing spaces between stalls, and enclosing the hawker centre space to limit the zone which the player can explore to enable them to remain focused on their overall objective of making dietary choices.

In our designs for items within the hawker centre environment we aimed to create a sense of both relational and personal authenticity by evoking recognisable items despite stylized visual forms, based on the assumption that Singaporean game players will respond to the items in a particular way and relate them to their real-world experiences. This draws upon the concept of "existential" authenticity – experiences within the game environment are deemed authentic as they are connected to personal emotions, bodily feelings and emotions whilst engaging in specific activities, an emotional and creative experience defined by the individuum rather than something that relies solely on objective facts and realities (Rall et al., 2024: 113). The experience incorporates playful re-interpretations of well-known brands and food items, thus creating a response reliant on the players' instinctive, feelings-based reaction to the virtual items. Van Rooij (2019: 196) states that major animation studios generate empathy by adopting a visual style that sees characters depicted as "clearly human, displaying all the basic physical indicators; however, their features are often caricatured. In general, they have disproportionally large heads for their bodies and large eyes for their faces, and they often seem to miss certain details such as small lines, hairs and blemishes." *A Choice for Life* thus aimed to create empathy and authenticity in its visual style through the adoption of an approach that clearly resembled the real-world elements that the game is meant to represent (the hawker centre environment, the human characters, and the food items) through the inclusion of basic physical indicators, yet were suitably caricatured and stylised to hit what Van Rooij (2019: 203) terms the "sweet spot on a scale of lifelikeness and abstraction, while generating the highest levels of empathy from the audience" (figure 2).

Figure 2. Illustration demonstrating visual style of characters and environment in *A Choice for Life*.

4. Case Study: Emoji Design

Makhlysheva et al. (2016: 421) state that "interactive, visualized game feedback on a player's action in the game contributes to the player's experiential learning," and considering how to represent this feedback was the most important way in which our project engaged with the idea of representing abstract concepts in visual form. The game required medical information in the form of nutritional data and the consequences of poor food choices to be presented to players to fulfil its educational intentions, yet in line with its overall framing as an enjoyable virtual experience hoped to avoid overwhelming players with large amounts of data or make them feel as if they were being lectured about or punished for poor dietary choices. Taking this into consideration, the decision was made to create of a series of emojis which informed the player of the nutritional value and health impact of the food choices made within the virtual environment during the final stages of the experience.

The issue of emoji design thus emerged as the most important collaborative element in our project, requiring constant dialogue and revisions to approaches to illustration and animation design based on suggestions of medical professionals. Work by Rodrigues et al. (2018: 401) based on the Lisbon Emoji and Emoticon Database (LEED) has established that emoji are perceived as "aesthetically appealing, familiar, clear, and meaningful", high in "familiarity, clarity, arousal, and meaningfulness," with their appeal and relatability linked to their close proximity to human facial expressions. Emojis should be clear and easy to understand, and whimsical and playful in design in keeping with the approach to stylization, realism and empathy discussed above. Effective emoji design requires balancing these factors to create symbols that are inclusive, meaningful, and functional, aiming to avoid any misrepresentation or subjectivity in terms of emotion being conveyed.

The initial approach to emoji design saw each emoji linked to an emotional state – health, hunger, happiness, energy and desire. This was rooted in the idea that an emotional response is fundamental to the enactment of behavioural change.

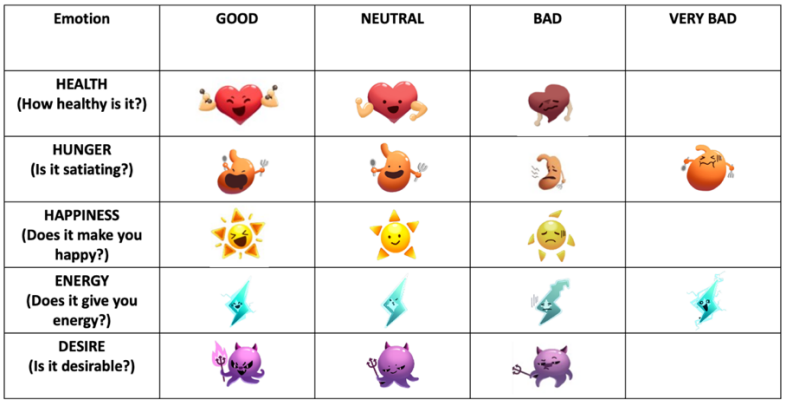

Figure 3. Categorisation of emoji designs reflecting emotional responses to food consumed in-game.

The emoji designs created were chunky and bold, as current consumer VR headsets offer limited resolution, with bright colours and simple shapes used to distinguish each of the five designs (figure 3). It was important that the emojis were readable as thumbnails within the wider user interface (UI), immediately suggesting the intended meaning. The overall design of the UI was bright, clear and simple to understand, however, the adult audience of

the project also needed to be considered, and the typography and interface designed in a way that avoided appearing overly childlike or patronising (figure 4).

Figure 4. In-game screengrab demonstrating initial design for UI within virtual hawker centre environment.

Playful, whimsical animation loops helped to further clarify the positive and negative associations of each emoji, with their style creating a sense of amusement rather than emphasising the serious negative health consequences of poor dietary choices. The emojis were designed to be present in their "neutral" state at the start of the game and reacted to the points assigned after each dish was consumed (figure 5). The overall state of each emoji is presented on a final evaluation screen alongside qualitative comments on a participant's dietary choices.

Figure 5. Preliminary layout design demonstrating proposal for displaying emoji responses to food consumed within the virtual environment.

Once the designs had been produced, they were presented to the medical professionals on the team. Whilst the overall response to the visual approach was positive, they questioned the appropriateness of the system of emoji categorisation. In particular, they stressed the subjectivity of ideas such as fullness, happiness and based on individual preferences and biology.

They furthermore highlighted the importance of improving knowledge of nutritional content in diabetes education, something that was overlooked in this initial approach to narrative and feedback. As such, the decision was made to replace the subjective emoji categories with nutritional groups – protein, carbohydrate, sugar, fat and salt. The design for the emojis was slightly revised so that they could be transferred from representations of emotional states to representations of specific nutritional categories – e.g. the emoji representing hunger was reconceptualised as protein, and the design adjusted to more closely resemble a bean.

Dieticians and doctors provided feedback on the nutritional information of each individual food element present in the game, which then allowed for a total amount of carbohydrate, protein, fat, salt and sugar to be calculated for a combination of food elements that together comprise a dish. Calculations using the recommended daily intakes of each of these food groups were used to create thresholds at which a meal might be considered "good", "neutral" or "bad", which in turn corresponded to the reactions of the emojis in response to a player selecting a particular combination of food elements. Thresholds were coded for both male and female patients, offering a limited level of customisation of the feedback within the game experience based on the gender of the patient participant. For the final evaluation screen, the responses of each emoji are totalled up to calculate a star rating out of 5 which is presented to the player at the end of the experience – 5 stars reflecting a full set of "good" nutritional categories and representing a nutritionally complete, healthy meal, and 1 star reflecting an unbalanced unhealthy selection that has been graded "bad" in most categories. This was presented as part of a broader two stage "report card" which provides a detailed nutritional breakdown of the food consumed, and an overall statement evaluating the players' choices and making suggestions for simple adjustments that could be made to improve their selections from the perspective of diet and diabetes management (figure 6)

Figure 6. Design for UI screen providing player with feedback on nutritional content of food consumed.

Interaction between medical professionals and creative practitioners was thus placed at the heart of the design process. This included a continuous feedback loop to find the right balance between immersive entertainment and communication of medical authenticity, in which both

design decisions (e.g. font sizes and emoji styles) and the data that underlay the visualisations were passed by medical experts to gauge their feedback on comprehensibility and patient sensitivity. And guarantee the correctness of the nutritional information.

By doing so, we built upon existing methodical frameworks for our own specific purposes. In his triadic framework-approach Harteveld (2010) emphasizes the need for balance between fun, learning outcomes, and medical authenticity when creating a serious game, whilst Vanden Abeele et al. (2012: 82) highlight that collaborative effort is required among game designers, programmers, artists, and domain experts throughout the process of game development. *A Choice for Life* has expanded upon these frameworks by focusing on storytelling and aesthetics to enhance player engagement while maintaining scientifically accurate information at all times, forming a Medical Game Design Iteration Loop (MGDIL) for serious game development.

5. Prototype Testing and Feedback

The VR prototype underwent a first round of pilot study testing in November 2023 and January 2024. 12 patients with Type 2 diabetes experienced the VR prototype and provided feedback through pre- and post-participation questionnaires and a semi-structured interview conducted immediately after experiencing the prototype. Participants were between the ages of 34 to 52 and represented both males (66.7 per cent) and females (33.3 per cent) and a range of ethnicities (Chinese, Malay, Indian) representative of the Singaporean population more broadly. For this prototype, the hawker centre environment was fully modelled (figure 7), however only one stall was "open" for players to interact with. In addition, the UI discussed above was not fully implemented, with the emojis appearing only on the final evaluation screen.

Figure 7. Screengrabs of prototype VR experience showing hawker centre environment and Yong Tau Foo stall.

The stall available in the prototype offered Yong Tau Foo – a Chinese dish based around stuffed tofu – which was selected due to the multiple options that customers can select from and thus allows for the construction of meals that are extremely varied in their nutritional content. Users were required to move towards the stall and interact with the hawker stallholder via an in-game interface to select a maximum of 10 items which were combined into their bowl.

They then were instructed by the UI to walk over to a nearby table, where they sat down and "consumed" the prepared dish. After indicating that they had finished eating via a pop up, they received feedback on their dietary choices using the emoji system outlined above, as well as a numerical breakdown of the nutritional information which their selection contained. After completing the experience for the first time, players were offered the chance to repeat the experience and implement the feedback received to improve their score.

Overall, responses to the experience were positive with regards to both the VR experience and its potential for educational messaging that enacted dietary change. Several participants expressed dissatisfaction with traditional methods of dietary education offered by nutritionists and dieticians and suggested that VR offered the possibility of user-directed learning and facilitated more vivid memorisation of educational content. In the words of one participant "using this VR, I'm the one experiencing it, I'm the one who take the stuff and everything. So basically, I'll remember it because I'm the one who play the game, I'm the one who go through the experience." With the exception of one participant who stated that a "more realistic [visual approach] would be more enjoyable," participants overall responded positively to the design approach and visual style of the experience, stating that they "enjoyed the look" and overall aesthetic approach of the VR experience. One participant praised the way that the simplified, stylised design approach helped to remove any sense of disorientation and overwhelm associated with VR, making the required movement and interaction "easy for you to do".

The importance of the emojis was highlighted through several comments which reported difficulties in reading the text in the final evaluation screen. Words were described as "not sharp" and "blurred" and the UI pop up was criticised for appearing too close to the user's face which made legibility challenging. Whilst on the one hand this suggests an area that must be improved in future versions of the game it also highlighted the important role played by the emojis in offering a clear, visual form of feedback that is immediately understandable in contrast to the text-heavy nutritional data.

This initial testing also suggested that the experience in its current form provided useful insights that improved patients' dietary knowledge. Multiple participants expressed surprise at learning about the high sodium content of the items they selected and stated that this information would prompt them to make different decisions when choosing food in a real-world hawker situation. In contrast, pre- and post-participation surveys indicated that there was little evidence that participation in the experience had an impact on the dietary fat and fibre consumption of participants. This was likely attributable to the fact that the evaluation screen did not include a category for fibre, focusing instead on fat, protein, carbohydrate, sugar and salt, and again highlights that the information included in this evaluation

section, and its visualisation, is an important component in the creation of an experience which aimed to achieve behavioural change.

The prototype testing also raised several valuable suggestions relating to potential improvements to the experience which we plan to use to drive the project forward. Participants were divided over whether adding more interactive game elements would enhance the experience or create an unnecessary distraction from the task of selecting food which lies at the heart of the experience. We will also revisit the possibility of having players experience the virtual environment through the persona of an avatar, an idea which was raised earlier in the project yet ultimately not included in the initial prototype due to development constraints. In line with ideas discussed above regarding the relationship between VR and behavioural change, several participants raised the possibility that playing as an avatar would increase their willingness to experiment and make decisions within the virtual environment. However, others felt that this extra layer of mediation was unnecessary, and that playing as themselves within a first-person VR experience was more effective in creating a sense of empathy and identification that would translate to real-world behavioural change. Indeed, it is possible that the level of personalisation required for an avatar to reflect the specific medical histories and physiological complexities of a patient with diabetes is beyond the scope of any game.

6. Conclusions

A Choice for Life provides a case study that demonstrates how complex and detailed nutritional data can be integrated into a visually appealing and user-friendly animated interface, as well as prompting reflections upon the value of interdisciplinary collaboration within the iterative design process. By outlining the collaborative development process behind the creation of the VR experience's UI and emoji design this paper has provided an insight into how "invisible" medical information might be visualised and depicted within the context of an immersive experience for diabetes education.

Moving forward, the next stage of this project hopes to further develop the initial prototype in line with suggestions drawn from the participant testing stage. Funding applications are in progress to extend and expand the scope of the project to introduce new stalls to the virtual hawker centre, refine the UI and in-game elements, and populate the virtual environment with additional interactives to create a fuller game experience. Once a more developed version of the experience has been created, we hope to carry out further patient testing to increase the sample size and thus the representativeness of our findings. We also hope the track the dietary habits and diabetes management of participants over a longer period, and allow for further quantitative analysis alongside the qualitative feedback provided by the semi-structured interviews carried out to date.

Other Information

Funding: This project is supported by the Ministry of Education, Singapore, under AcRF T1 grant RG125/20 "A Choice for Life - Education about Diabetes in a Fully Immersive Environment (VR)"

Acknowledgments: Visual and technical development for this project was carried out by Rachel Chan, Gelissa Loh, Lye Hui En, Sulaiman Bin Abdul Rahman, and Jasper Teh. All images courtesy Hannes Rall/Nanyang Technological University.

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