Reducing Perceived Waiting Time in Theme Park Queues via an Augmented Reality Game

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Theme parks visits can be very playful events for families, however, waiting in the ride's queues can often be the cause of great frustration. We developed a novel augmented reality game to be played in the theme park's queue, and an in-the-wild study with X participants using log data and interviews demonstrated that every minute playing was perceived to the same extent of about 5 minutes of not playing the game. We articulate a design space for researchers and strategies for game designers aiming to reduce perceived waiting time in queues. With our work, we hope to extend how we use games in everyday life to make our lives more playful.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**;

Additional Key Words and Phrases: Augmented reality, theme parks, waiting psychology, entertainment

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1 INTRODUCTION

If you have ever been to a theme park, you know the frustration of being stuck in queues. While a theme park inherently promises novel experiences and family friendly entertainment, the reality is that customers spend many hours of their day simply waiting for these experiences to begin. In fact, queuing times at popular theme parks can be hours long for a single attraction [30]. Ongoing research and industry developments aim at reducing queue times by carefully structuring the layout of the park to improve customer flow [1], providing queue skipping mechanisms to allow for

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structured load-management [15], introducing timed incentives and information on mobile devices to encourage visitors to alter their paths [10], or scheduling staff rosters and live show times to increase attraction turn-over rates or entice customers away from specific attractions at busy times [7]. However, as with any overloaded system, there is a limit to how much queuing time can be reduced. Additionally, queues can actually be a positive aspect of the theme park experience [30]. They provide additional opportunities to entertain customers [29], allow customers to socialise during the downtime [38], indicate the potential quality of attractions based on the size of the queue [22, 56], and increase sales potential by extending the time spent within the park or requiring revisits to experience the entire park. Thus, rather than (or in addition to) attempting to reduce the *actual* queuing time, theme park managers may instead aim to reduce the *perceived* waiting time. That is, to induce a sense of time passing quickly in waiting customers by improving the quality of the queuing experience [33].

The focus of this article is on improving the queuing experience by integrating novel, purpose-built digital interactive entertainment into the queue environment in order to reduce perceived waiting time. This is done by deriving key factors from commonly discussed queue design and management strategies, integrating them with game design practice, and evaluating the effect that the resulting prototype has on the perceived waiting time of theme park customers. Through this prototyping process, design insights for this novel context are exposed that may guide others in similar work in the early stages of this research field. With additional such prototypes, studies, and debates, a critical mass of knowledge can be accumulated to aid in the formulation of design frameworks targeted towards the creation of in-queue entertainment.

Through this and future work, we seek to move towards an envisioned future where the boundaries between the attraction, the queue, and the greater park are blurred and where entertainment experiences are pervasive throughout the park, rather than the currently often segmented attractions that are divided by intervals of disengaged travel and waiting. We foresee augmented reality (AR) as key enabling technology in this transformation, starting with current consumer devices (such as smartphones and tablets) for pervasive experiences throughout the park. We also envision a not too distant future where emerging dedicated AR technology (such as non-tethered AR head mounted displays) will enable entirely novel mixed reality attractions. In order to do so, however, the aforementioned queue design strategies will need to be implemented in AR game prototypes, resulting in experiences leaping ahead of existing standard games. In this way, AR allows for digital entertainment to be built upon existing park infrastructure to minimise capital expenditure and provides further bodily entertainment that complements the physical and social qualities of the theme park experience. We predict that not only will these new experiences increase perceived value for customers but also continue to cement theme parks as centres of unique entertainment in an increasingly digital world.

Thus, this article is presented for theme park designers and managers seeking to improve their queuing experiences, as well as for user experience designers and researchers who are either looking for a challenging design context to explore with real-world implications or who wish to apply an existing theory or artefact to a novel environment.

In summary, the four primary contributions of this article are as follows:

(1) Identifying 12 queue design dimensions in the categories of *Activity*, *Information* and *Affect* from commonly mentioned strategies in the queue management literature. This is done in Section 2.
(2) Exploring the potential for improving the quality of queues through detailing a prototype AR queue game that is played on a smartphone and was designed through the combination of game design principles and a subset of the queue design dimensions. This is done in Section 3.

(3) Evaluating the effect of in-queue entertainment on customers' perceived waiting time through an in-the-wild study utilising the AR queue game prototype in a popular theme park during peak time. This is done in Sections 4–6.
(4) Formulating four game design dimensions that resulted from our experience in creating a prototype queue game and evaluating it in an in-the-wild study. This includes elaborating on the potentials within the design space to inform future research. This is done in Section 7.

To the best of our knowledge, this research represents a first on multiple accounts:

(1) The first time queue design strategies from numerous sources have been collated and framed as variable factors for in-queue entertainment.
(2) The first time a smartphone-based AR game has been designed for the specific context of in-queue entertainment.
(3) The first time a game has been used in an in-the-wild study on perceived waiting time in a theme park.
(4) The first time design dimensions have been proposed for the creation and further exploration of queue games.

2 BACKGROUND

In this section we first provide an overview of existing approaches to in-queue entertainment followed by a summary of 12 queue design strategies. Many of these are commonly mentioned literature as recommendations for queue management and are subsequently used as an initial guiding framework that we later used in the design of the AR queue game prototype.

2.1 In-Queue Entertainment

Entertaining queue members at theme parks to reduce perceived waiting time is not a new concept. Many theme parks incorporate themed aesthetics and videos into queues to provide customers with visual stimulation, encourage social interaction, outline instructions for the attraction or increase anticipation of the attraction itself [57]. Interactive entertainment is also experiencing a rising presence in theme park queues [34]. Traditional approaches to such interactivity typically include mechanical systems, such as pressing a stationary button to start an animatronic routine or play a line of dialog. However, recently, increased forms of interaction have been explored through the use of digital technology [58]. For example, the shadow play in the queue of the Peter Pan's Flight at Walt Disney World, which combines gesture recognition technology and projected animated shadows to give the guests the sense that they are interacting with magical shadows. However, a common limitation with these mechanical and digital interactions is that they are typically in fixed locations within the queue and therefore are only usable by a small number of people at a time, are short lived within a long queue, and can disrupt the queue flow if customers are slow to move on from the entertainment.

Heger et al. [29] provide a novel solution to this limitation by utilising interactive table tops as the guiding barriers in the queue, effectively allowing for a single multi-player game to be experienced throughout the queue. Here, the game is projected onto the table tops and user input is registered through tracking markers on the customers' hands. We gain inspiration from this work as Heger et al. also target a reduction in perceived waiting time by focusing on providing customers with an activity, a feeling of progress through the queue, and the feeling of being part of a cooperative social group. Their lab-based qualitative study showed that the game engaged participants and promoted collaboration among strangers. We extend this work by augmenting an existing queue structure through smartphone AR rather than requiring significant infrastructure

Table 1. Twelve Factors that Affect Queue Dynamics Drawn from the Referenced Literature, Which Include 1-[37], 2-[29], 3-[33], 4-[45] and 5-[47]

Activity			Information			Affect		
F1	Active Waiting	1,2,3,4,5	F5	Wait Time	1,3,5	F9	Positive Affect	1,3,4,5
F2	Social Engagement	1,2,3,5	F6	Delays	1,3,4	F10	Fairness	1,3,4
F3	Attraction Interest	1,3,4	F7	Progress	2,3	F11	Physical Comfort	3,5
F4	Starting Point	1	F8	Expectations	4	F12	Positive Memories	4

Heger et al. [29] and Ledbetter et al. [33] specifically discuss theme park queues, while the others address service queues in general.

changes to the queue and by testing this experience through an in-the-wild user experiment. By using smartphone AR, we are highlighting an emerging trend of augmenting existing physical theme park structures with dynamic digital content that can be easily modified in future iterations [21, 40] while also making use of widely owned smartphones as an individual input interface in a crowded environment.

Interestingly, a study of some of the most popular theme park queues around the world found no significant link between 'suspended reality' elements present in the queue area and perceived time. A possible explanation for this finding, which goes against intuition, is that those who are affected the most by such elements are children, who were excluded from the study [19].

2.2 Twelve Factors That Affect Queue Dynamics

In this section, we identify 12 factors that affect queue dynamics. We group them into the categories of Activity, Information and Affect to structure our presentation of what we learnt from related work on queues. While many of these are typically framed as strategies or recommendations in related queue design literature [29, 33, 37, 45, 47], we frame them as factors that affect queue dynamics here because (1) many of them can be addressed on a variable spectrum, such as providing no activities in the queue to providing a fully interactive queue, (2) many of them are still debated in general queue management literature, such as how much information about remaining wait time should be given to a customer at any one time and (3) even if there are strong recommendations and supporting literature for standard queues, these have yet to be explored in the context of in-queue entertainment. Table 1 outlines these 12 factors and below is a discussion of each.

2.2.1 Support Active Waiting (F1). This strategy is at the core of our work and of all of the referenced literature. An active wait is one in which individuals are participating in an activity while they are waiting. It builds on the principle that a mind that is unoccupied by any other mentally or physically stimulating activity will increase its focus on monitoring time. By providing an engaging distraction, the mind reduces its focus on time and therefore perceives time as passing more quickly [12]. This also relates closely to the theory of "flow" [18], which discusses the correlation between the level of engagement in a task and perception of time. Finally, experiments have recently shown the role of dopamine neurons on the judgement of time [53], suggesting that rewarding experiences may positively affect time perception. The inclusion of in-queue entertainment seeks to engage active waiting by providing customers with mentally and physically rewarding activities and, similarly to Heger et al. [29], we believe that mixed reality games are a key approach to this.

2.2.2 Foster Social Engagement (F2). Social engagement with family, friends and even strangers can provide both positive emotions and an active wait as customers focus on the social interaction. It has been shown previously that perceived waiting time is significantly reduced in those that experience a wait in a group [31]. In a queue design sense, this typically translates as providing enough physical space for a group of customers to easily have a conversation, rather than forcing them into a single file. For a queue game, this could be through multi-player gameplay that promotes communication among queue members with friends who have chosen not to queue for the ride. This would engage a wider audience [50] and allow for separated groups to understand where others are in the queue and when to expect them to exit the attraction. It is also important for the gameplay to foster positive social interaction; competitive play, privileged play (e.g., paid queue games) or play that disrupts the movement of the queue could result in negative social interactions.

2.2.3 Maintain Attraction Interest (F3). Customers are willing to join long queues because of the attractions at the end of them. Reminding customers of the attraction they are queuing for by giving them a view of the attraction while queuing or by incorporating the theme of the attraction in the queue design can help to maintain that initial interest [33]. In a queue game, there is also potential to have the current attraction participants influence the in-queue entertainment [51] or by having the queue members influence the attraction itself in a form of asymmetric play. Both of these are becoming more viable with the growing interest in gamified attractions [36] and the integration of virtual reality into roller coasters [28]. Customers are also naturally more willing to queue for a product or service that they believe has value. While this implies improving the attraction itself, we hypothesise that by introducing more in-queue entertainment, cultural perceptions of the queue could be changed such that the queue could be seen as being part of the attraction as well.

2.2.4 Get Started (F4). In multi-stage queues, for example those where customers wait to place an order and then wait for the order to be processed, customers are more likely to accept a long wait in the later stages [20]. This is because customers want to get started; that is, to feel as though the service has begun and that their presence is acknowledged [37]. In a restaurant setting, this is achieved by staging the provision of menus, drinks, taking main orders and the delivery of the food. Converting this to theme park queues is not obvious as these queues typically have a single stage (i.e., waiting to board the attraction). However, it may be that providing in-queue entertainment provides a sense of the service starting and demonstrates that the theme park operators acknowledge the wait time and are taking efforts to alleviate the burden of it.

2.2.5 Control Information (F5). It is becoming more common at popular theme parks to see an estimated wait time displayed to help customers decide whether to join the queue. However, once in the queue, the pathway often weaves through rooms, blocking a customer's view of the queue ahead and hiding the length of the remaining queue. Both of these are forms of information control and there are ongoing studies into the degree of information that should be provided to waiting customers [44]. The compromise may be to provide an indication of the remaining time without providing exact statistics [27], such as the use of static physical signs saying the estimated amount of time remaining from a certain point in the queue. In a queue game though, this could be represented even more indirectly by, for example, showing the queue as an in-game map. This would avoid providing raw time estimates and allow for information to be subtly controlled to enhance the sense of progression of time and position in the queue.

2.2.6 Communicate Delays (F6). This is a subset of wait time information control that encompasses unexpected delays, such as when the attraction is temporarily disabled. Customers are generally willing to accept a wait if they feel it is justified (e.g., only so many customers can be served at one time) but unexplained waits are often seen as being unreasonable [27]. A theme park attraction typically has a regular turnover rate that sets an expected pace for movement in the queue. If this pace is negatively altered, it can induce animosity towards the theme park operators and cause anxiety (see F9), especially if no reason for the delay is communicated [44]. Providing this information can give reassurance to queue members or allow them to decide whether to renege from the queue. Again, a queue game can be used to creatively communicate this delay in an automated manner, allowing for progress to be made in the virtual world even when no progress is made in the physical world (see F7).

2.2.7 Highlight Progress (F7). Similar to perceived time versus actual time, how a customer perceives their progress through a queue can be just as important as their actual progress [44, 54]. Unfair queues (F10) can be perceived as disrupting the normal progress of the queue; and controlling information (F5) can be used to reinforce a sense of progress or potentially highlight the lack of progress if used incorrectly. Digital queue games allow for novel ways of reinforcing progress through the queue, such as introducing new skills and experiences in the virtual game as they progress through the physical queue [26]. A queue game could also provide a sense of progress even when physical progress in the queue is unexpectedly halted by, for example, allowing the player to increase in rank, move onto subsequent levels or explore a virtual environment even when stationary in the queue.

2.2.8 Beat Expectations (F8). Boltz [9] has shown that providing participants with an expected wait time that is greater than the actual wait time can result in the participants underestimating how much time has passed. Thus, the information control strategy (see F5) can be extended to ensure that any wait time information that is provided is an overestimate of the actual wait time. Then, when it is beaten, customers will reflect more positively on the wait time. We believe it is also possible to beat the customers' expectations of the experience through novel forms of entertainment, much in the same way that traditional media can beat the audience's expectations.

2.2.9 Support Positive Affect (F9). Just as a physically fatigued customer can grow tired of standing in a queue (see F11), a mentally fatigued customer can become easily irritated [33] and spread their negative mood to those surrounding them in the queue [45]. By utilising cheerful lighting, images, and sounds and avoiding repetitive stimuli, a theme park queue can encourage a positive affective state in customers and reduce perceived time [2]. Similarly, queue games should encourage positive emotions through achievement, progress, and cooperation while striving to reduce negative emotions, especially anxiety [37, 47]. A lack of information regarding queue length (see F5 and F6), the process at the end of the queue or how physically intense the attraction will be can cause anxiety rather than a positive form of suspense. Because of this, information about the attraction is often provided in illustrations or videos in the queue. This could be further extended into queue games by using the game mechanics to prepare customers for the ride ahead.

2.2.10 Enforce Fairness (F10). When customers do not have differentiable needs (e.g., a shop queue versus a hospital queue), the first-in-first-out (FIFO) queue structure is generally perceived as being the fairest [3]. A single FIFO queue is most often used in theme parks, with the exception of additional fast-tracked queues [15], which, if implemented poorly, can also be seen as unfair, due to favouring those who can afford the service. Similarly, any queue game that requires or encourages customers to alter their position within the queue could be perceived as being unfair. However, this in itself could also be explored as an experimental game mechanic that studies risk management in players with real world consequences or uncomfortable social interactions [5] stemming from negotiating new queue positions.

2.2.11 Maintain Physical Comfort (F11). Physical comfort and fatigue levels can influence a customer's mood, responsiveness, and behaviour and in turn can affect perceived waiting time [4]. This is typically addressed in theme park queues by providing shelter, air flow, soft flooring, consistent lighting, or sturdy railings to lean against throughout the queue environment. While in-queue entertainment can make use of the physical nature of the queuing environment, caution should be used in the design of the entertainment to avoid customers from over-exerting themselves and be designed to accommodate a wide variety of physical abilities of theme park customers. This is of particular importance for mixed reality entertainment that typically requires additional physical exertion over traditional digital play.

2.2.12 Support Positive Memories (F12). Norman [45] argues that the memory of an event is more important than the event itself. This has been observed whereby experiment participants are more likely to overestimate time duration of a current activity over a past activity. People also tend to remember past experiences by a few key events that can cause the memory of the entire experience to be either positive or negative. Thus, customers with positive experiences in a queue have a higher chance of remembering the queue as enjoyable, rather than remembering the long waiting time [8].

Additionally, Norman [45] argues that the start and end of an event are remembered more clearly. In this case, a queue game should attract customers to play through engaging initial minutes of play and then provide a memorable moment of play towards the end of the queue. Allowing guests to continue to play after the attraction and reflect on their positive gameplay moments from the queue may also provide lasting positive memories [23].

3 AUGMENTED REALITY QUEUE GAME

After having identified the above twelve factors, we translated these into a queue game. In this section, a brief synopsis of the game is provided followed by a detailed description of the game design and technical implementation details and a discussion of how the queue design factors were incorporated into the game design.

3.1 Game Synopsis

The game is playable on mobile devices such as Android or Apple smartphones. With their device in hand, the queue members can point the camera towards special AR markers that are placed on the sides of the queue every few meters. While scanning a marker, an AR 'portal' opens up above the marker that can be seen through the mobile device's screen. This initiates the beginning of a level, after which enemies gradually spawn out of the portal. It is the task of the queue members to (individually or in group) tap with their fingers on enough enemies to destroy them before the portal closes again. The game gradually intensifies with more and stronger enemies.

3.2 Game Design and Implementation

The software developed for this project is a game client deployed to smartphones and a standalone server. Both were developed on the Unity 5.5 Game Engine to enable cross platform mobile development, with the Vuforia SDK used to handle the detection of AR markers. The game's client was deployed to eight of the control devices (Samsung Galaxy S5), which were given to theme park guests to play the game while in the queue.

After the brief introduction, players are presented with a real-time video feed of the smartphone camera. This becomes the background of the game world and is stylised to appear black and white, thus adding contrast from the other game elements that are purposely brightly coloured. Elements of the game that are related thematically are coloured in similar colours. For example, enemies are bright pink and thus text, progress bars and other information pertaining to enemies are pink. Conversely, elements that are related to level progression are blue.

Once a player has directed the smartphone towards an AR marker, play can commence. A circular dome that represents the shield of the player and a portal hole expands from the centre of

Fig. 1. Prototype queue game.

the AR marker. The portal and dome are aligned to the plane of the AR marker generating the illusion that the portal is appearing on the floor, wall, or wherever else the marker is located and extending into the surface or air from that point (Figure 1).

Information pertaining to the current level is shown to the player such as the level number, the required number of collectable blue cubes dropped by enemies to pass the level and the limit of escaped enemies to fail the level. We discovered having GUI elements on the smartphone was distracting players from the augmented game world. Therefore, most of the GUI is projected around the peripheral of the portal to direct the focus to the AR game world rather than the smartphone.

After a short countdown, thumb-sized circles appear on the screen as the player's laser turrets. These turrets are draggable and can be positioned anywhere on the smartphone screen and are only active if a finger is touching them. Whenever a point on the smartphone screen is pressed, a laser beam is fired from each (active) turret towards the touching point (in the virtual world). A laser beam is fired from each circle towards a point projected into the AR game world whenever the smartphone screen is tapped. However, each circle is required to be held down by another finger for this to happen. Initially, players begin with one laser turret and every fifth level they are given an additional one, thus encouraging more social cooperation in later levels to successfully activate turrets and tap on enemies.

Enemies appear and spawn at random locations in waves. The number of waves, enemies per waves, and enemies' speed and health increase as players advance in levels. They fly towards the centre of the portal location beyond the shield dome. Enemies are considered to have escaped if they reach and collide with the shield dome. The level is considered failed if more than a certain number of enemies successfully escape. A blue cube may appear after an enemy is destroyed and players can collect them by dragging laser turrets over them. Once sufficient cubes have been collected, the player passes the level and is prompted to proceed to a higher level.

Table 2. Specific Design Elements of the AR Queue Game and the Queue Design Factor that Were Considered in Relation to Them

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10	F11	F12
Novel and accessible queue entertainment	x		x					x	x			x
No major penalties for failing a round									x			x
Casual gameplay with colourful visuals	x								x		x	x
Mechanics encourage multi-user on a single device	x	x										
Synchronized boss battles with central large marker	x	x										
Game does not affect position in the queue										x		
Players can start from any marker and skip markers	x			x			x		x	x	x	
AR encourages awareness of surroundings		x							x	x		
AR encourages bodily movement	x										x	
Markers distributed throughout queue	x			x			x				x	
Markers placed at different heights											x	
Progress in game without progress in the queue	x						x					
Player can seamlessly transition between markers	x						x			x		
Player must move to a new marker after a boss battle							x			x	x	
Non-AR gameplay after boss battle and before next marker	x											
No information or representation of queue length					x							
Game linked to attraction theme and style*			x						x			
Boss battles triggered by cart departure at head of queue*	x		x		x	x	x					

Starred items were designed and implemented though not applicable to the reported user study.

Normal gameplay will be periodically interrupted by a message that a 'boss' enemy is appearing. Players are then required to locate a special boss AR marker with the smartphone camera. A separate but similar portal with another shield dome is augmented over the boss AR marker. The boss is represented by a large single enemy that slowly flies towards the shield at a slower rate compared to normal enemies. Unlike the standard enemy portals, all players in the queue will see and attack the same boss regardless of which boss AR marker they are viewing and advance a level if the boss has been successfully defeated by the collective effort. The boss is defeated if it receives sufficient laser taps from all players present in the queue before reaching the shield. The number of taps required to defeat the boss dynamically scales with the number of smartphones actively playing in the queue and are triggered every time an attraction carriage is launched at the head of the queue in order to link the progression of the queue to the progression of the game.

The server is a standalone application deployed onto a laptop and handles the collection of queue data and the triggering of boss levels. The server, like the client, is also built using the Unity 5.5 game engine and relies on the Unity High-Level API (HLAPI) networking code to transmit events and messages. The server broadcasts a signal over WiFi to invite smartphones to connect to it. Once connected, clients are identified by a unique smartphone ID. The ID is reset by our staff using a specific AR marker that also clears all player progress data; this operation is done when players arrive at the end of the queue and the smartphones are returned to the staff, ready to be deployed again to new players at the start of the queue.

3.3 Application of Factors of Queue Design

Table 2 shows some key considerations that arose during the design and development of the AR queue game and the queue design factors that relate to them. As active waiting (F1) is the core of queue design, so it is the core of the AR queue game with many of the design choices made towards keeping the players actively engaged while also physically comfortable (F11) and considerate of others in the queue (F9, F10). The game was designed to be casual, colourful and social, with few penalties for failure within the game to encourage participation (F1), social interaction (F2), positive affect (F9), and an overall more positive memory of the queue and the attraction (F12) that aims to beat participants' expectations of what a queuing experience can be like (F8).

An important challenge of the game's design was the dynamic nature of a queue. At peak times, the queue might be tightly packed for a 100 m, while at other times people might form a loose queue for a few dozen meters. It is challenging to map all possible queue configurations such as these to tightly structured game mechanics. For this reason there is no order to the markers and they are not directly linked to specific levels in the game. Thus, players can get started at any marker no matter how short or long the queue is (F4) and they can skip markers if they wish to do other activities (F9) or are fatigued from the game (F11). Furthermore, though players can play by themselves, surrounding queue members can help tap on the mobile device to destroy enemies (F2). In the game, there are also multi-player upgrades available (e.g., double barrel gun) that make it advantageous to play with more than one person. As there is no specific order to the markers, the use of AR encourages players to be more openly aware of others in the queue (F2) and the movement of the queue, especially for the benefit of those who are not playing the game (F9, F10). Additionally, because the markers are spread throughout the queue, queue members need to walk from one point to the next in order to continue playing the game. This reinforces the sense of progression as players move to new markers (F7) as well as causes the players to switch between mental tasks in the digital and physical world and therefore increasing their active wait (F1) while not interrupting gameplay too much. Furthermore, the angle and position of how a mobile device is held determines how a portal is seen on the device's screen. Thus, with queue markers being at various heights and angles, queue members often benefit from moving their upper torso, arms and hands to get the best shooting angle on the enemies when they come out of the portal. We hope this keeps players physically active as well as mentally involved in the game and helps with shifting body positions to maintain comfort (F11).

Further in the interest of physical comfort (F11) and queue progression (F7, F10), the portals only stay open for a small period of time and there are cool-down periods between rounds. This is also reinforced by boss battles that ensure that a player moves on from the current marker and gives them other activities to do in the game in the meantime, keeping them actively engaged (F1) while reducing the intensity and allowing for physical recovery (F11). The closing and opening of the portals, as well as the accumulation of weapons and upgrades, also provide a sense of progress (F7) to queue members even when the queue is not moving.

The factors that were least considered in the design of this game are those that relate to information (F5) and communicating delays (F6). The game is purposely light on information regarding the remaining length of the queue as, from the previous section regarding the queue design factors, there are strong arguments in the literature for hiding the length of the queue. Instead, much of the game design encourages a sense of progress (F7) without directly indicating how long is left in the queue. However, information about the queue's movement and the potential of a delay can be interpreted through the link between an attraction cart leaving the docking station at the head of the queue and the start of a boss battle. This not only reminds the player of the attraction they are queuing for (F3) but also indicates that progress is being made in the queue as a whole (F5, F7), suggesting that there are no delays such as the ride undergoing maintenance (F6), and preparing players to move forward in the queue (F10). Unfortunately, due to technical and logistical issues on the days of the experiment, this functionality was not incorporated and instead boss battles were triggered on a periodic basis. Similarly, the game was linked in theme and style to a specific attraction (the Justice League ride at Movie World, Gold Coast) to engage players with that attraction

(F3) and set expectations of what the ride would be like (F9). Again, though, the actual attraction that the game was deployed at had to be changed on the experimental day due to practical logistic reasons.

4 EXPERIMENTAL SETUP

In the following section, we provide details of an in-the-wild user study that utilised the prototype in a real world theme park queue. A public study was chosen over a controlled user study because we are targeting perception of waiting time in the context of theme park queues and members of these queues embody specific emotions and expectations. Synthesising a controlled queue from recruited participants would impact the results of the study due to the different state of mind of the participants.

4.1 Study Site and Demographics of Participants

The study was conducted at the Movie World theme park on the Gold Coast, Australia. The study was run over 3 days from Friday 6th to Sunday 8th of January, 2017. These dates were chosen to gain access to peak crowds during the Australian primary and secondary school summer holidays. The experiment was run during the entire 9 am to 5 pm operating hours of the theme park. However, due to queues being too small at some periods of the day, data was primarily acquired between 11 am and 4 pm on all 3 days.

While the prototype was designed for the queue of the sci-fi themed Justice League attraction, the experiment was instead conducted at the western themed Wild West Falls attraction. This was due to operational concerns during the chosen dates, including a larger expected queue at the Wild West Falls attraction. While feedback from a few participants and non-participants indicated that the clash in theme was noticed, it did not appear to significantly impact the experience of the participants, as detailed in Section 6.

In total, 100 groups of participants played the game and 25 of these groups conducted the post play interview. While we did not formally collect demographic data, we observed that most groups of players were young families with at least one member under the age of 18 and that almost all participants were fluent in English. This aligns with the family oriented nature of the Movie World theme park and general park admission statistics that identified roughly 60% of guests as being local Australian residents. On average, groups played for 15 minutes and 10 seconds, while the median value is 13 minutes. Figure 2 shows the distribution of the waiting times.

4.2 Experimental Design

The prototype was installed onto eight Samsung Galaxy S5 phones that were reused throughout the three experimental days. The prototype included instructions on how to play the game as well as information for participants regarding the experiment. These devices were connected to the local server via WiFi to coordinate boss battles and to store survey results. The devices were locked such that participants could only play the game on the phone and not use it for any other purpose. Each device was given both a physical identifier (marked on the back of the phone) and a digital one.

Participants fell into one of two groups; players and non-players. Players were recruited by the investigators by occasionally approaching the back of the queue, where they would demonstrate the game and describe the experiment to the last group of guests in the queue and ask whether they would like to participate. If surrounding groups enquired about game, they were also presented with the opportunity to participate. Signage was also posted around the entrance to the attraction to advise theme park guests of the experiment. Only one device was provided to each group of family or friends and they were encouraged to play together on the one device. Players were told

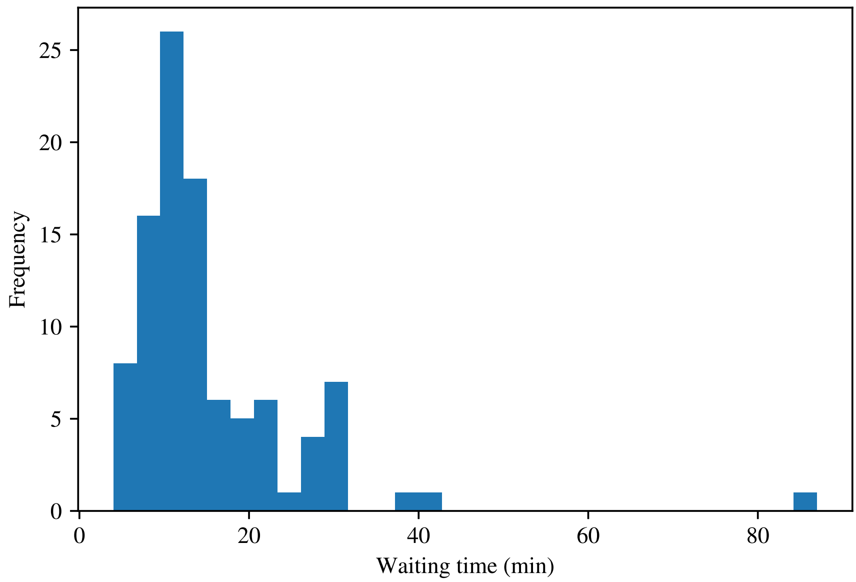


Fig. 2. Distribution of waited time in our sample.

that they could play the game as little or as much as they liked and were requested to return the device to another investigator located at the head of the queue just before they got on the attraction. The recruiting investigator then recorded the device identifier and the time that it was provided to the players.

At the head of the queue, when a device was returned to the investigator located there, a 10 question Likert-style survey was loaded (see Section 5.4) on the device and the players were asked to complete it as a group, with the results being registered against the device digital identifier and stored on the game server. After the survey was completed, the investigator asked the group to estimate, without looking at a clock, the amount of time that they had been in the queue since they were provided with the device. Where estimations within the group varied and no consensus was reached, each estimation was recorded. These estimates, along with the device identifier and the time that the device was returned, were then recorded.

The players were then provided with a new unique identifier (recorded against the earlier time estimates) and asked to approach another investigator located at the exit of the attraction to complete a brief interview. This semi-structured interview was audio and video recorded after gaining permission from the group.

Non-playing participants were recruited in a similar fashion to playing participants but instead of being provided with a device they were simply provided with a token with a unique identifier on it and asked to return the token to the investigator at the head of the queue. Once at the head of the queue, the non-players were also asked to estimate their wait time since being given the token and these details were recorded similarly to the above. Non-players did not answer the survey nor they participated in the interviews as most of the questions in these were aimed at qualitatively analysing the queue experience in relation to the gameplay experience.

4.3 Data Collection and Analysis

Actual wait time is calculated by taking the difference between the time when the participant is at the back of the queue and the time he or she is at the head of the queue. The degree of time

Table 3. Statistical Metrics of Perception Error for Players and Non-Players

Group	Count	Mean (%)	Std. Dev. (%)	Median (%)	Mean (min)	Std. Dev. (min)	Median (min)
Non-players	100	40.9%	67.2%	25%	3.74	6.74	3
Players	100	7.7%	46.1%	0%	−0.41	8.53	0

The two groups both count 100 participants, but these round numbers were not planned and are a coincidence.

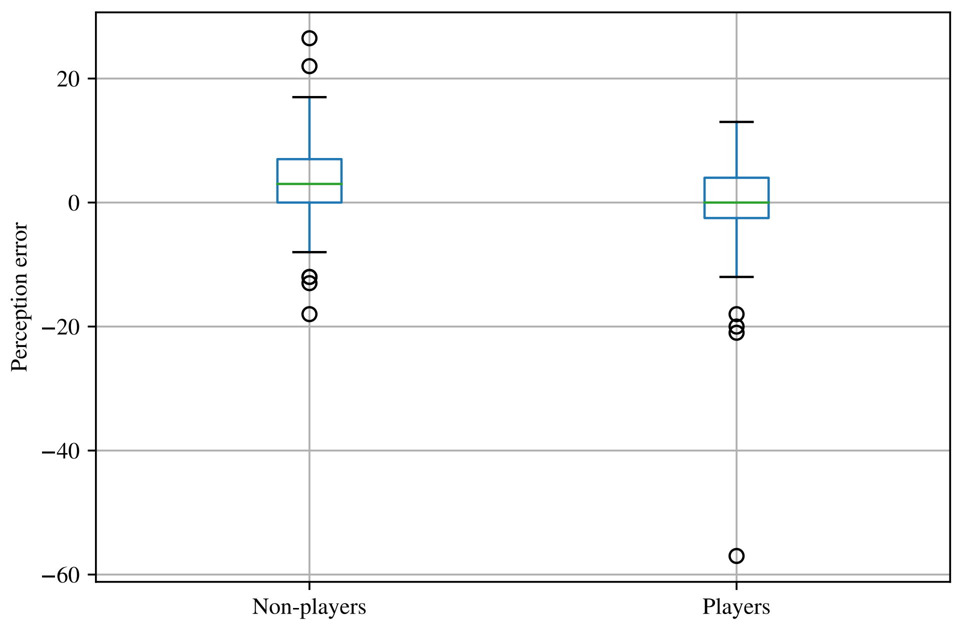


Fig. 3. Box-plot of perception error for players and non-players.

misperception is then calculated as the difference between the actual wait time and the perceived wait time (participants' time estimations). The game also recorded how long players were interacting with the game during their total time in the queue, giving a measure of engagement with the game.

Non-player participants provided a baseline and by comparing the degree of time misperception of the two groups we determine the impact that our prototype had on perceived waiting time. Additionally, survey data provided a quantifiable perspective on the player experience while the interviews allowed for more expressive and open ended qualitative data to be collected. The results are provided in the next section.

5 QUANTITATIVE ANALYSIS OF EXPERIMENTAL RESULTS

Our hypothesis is that playing with our game while waiting in line makes players perceive time as passing more quickly. To test this, we computed the perception error for players and non-players, as described in Section 4.3. Table 3 reports statistics for the samples and Figure 3 shows a boxplot of their distribution. Notice that the mean/median perception error is more negative in players than in non-players. In the following sections, we analyse the statistical significance of this difference and we present other evidence supporting our hypothesis.

Table 4. Results of Statistical Significance Tests and Effect Size Test

Test	Result
Mann–Whitney rank test	$p < 0.001$ ($Ua = 6681.5$)
Cohen's d	$d = 0.54$

Table 5. Outcome of Pearson's Correlation Test on Score- and Playtime-Related Variables and Time Perception Error

Variable	Result
Time actually played vs Perception error	$r = -0.33$ ($p < 0.01$)
Time the game was running vs Perception error	$r = -0.30$ ($p < 0.01$)
Total Score (total score obtained on all levels) vs Perception error	$r = -0.35$ ($p < 0.01$)
Final Score (score obtained on the last level) vs Perception error	$r = -0.34$ ($p < 0.01$)

5.1 Statistical Significance and Effect Size

We compared the perception error of players and non-players using a two independent samples *t*-test and a Mann–Whitney rank test. Both tests reported *p*-values < 0.001, indicating that the difference observed is very likely not due to chance. We also computed Cohen's d coefficient to estimate the effect size of playing on time perception error (using the formula provided in [14]). The value found indicates that the effect size is medium, suggesting that the difference found is of concrete significance. Table 4 reports the results of these tests in detail.

5.2 Correlations

To verify whether some of the variables we collected correlate with time perception error, we computed the Pearson's correlation coefficient r for some pairs of variables. This coefficient tests for linear correlation and can range between −1 and +1, it gives an indication of how well the data fits into a perfect line, where −1/+1 indicate a perfect negative/positive correlation and 0 indicates no correlation at all. We found some correlations to be statistically significant, which are shown in Table 5. All the variables we found to be significantly correlated to time perception error are proxies to how much attention a participant dedicated to the game over time. The fact that all these correlations are negative seems to indicate that an increase in attention to the game correlates with a more negative perception error; that is, a lower estimate of elapsed time. Figures 4–7 show scatter plots of the correlations. Although this correlation is not large, it is statistically significant; this is in agreement to the outcome of the statistical significance and effect size that were reported in the previous section.

5.3 Linear Regression

We fit a linear model to compute the magnitude of each contribution to the overall time perception under the assumption that the contributions are linear and independent. The results suggest that time spent playing and time spent not playing contribute to different degrees to the overall perceived time. In mathematical terms, we compute A, B and C so that the following formula was as accurate as possible:

$$A \cdot \text{non-playing time} + B \cdot \text{playing time} + C = \text{perceived time}. \tag{1}$$

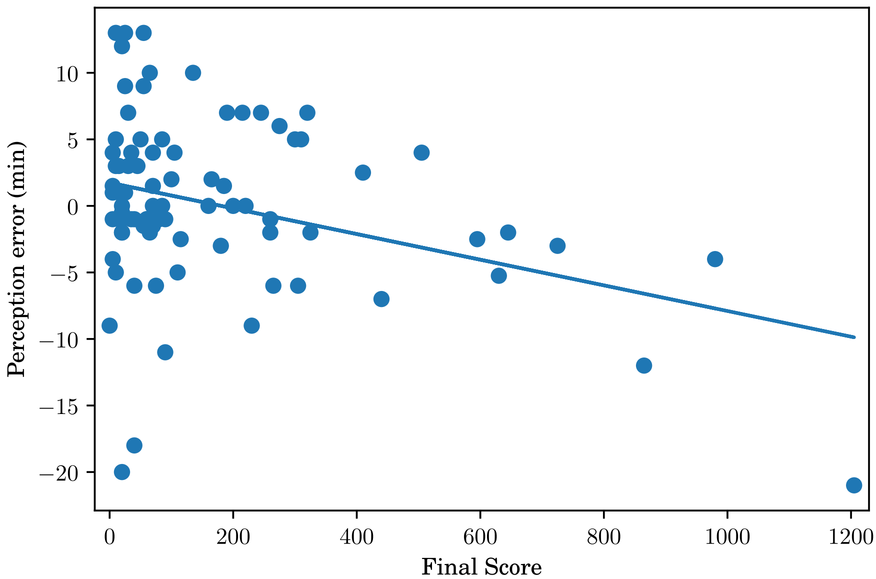


Fig. 4. Correlation between final score (score obtained on the last level) and perception error.

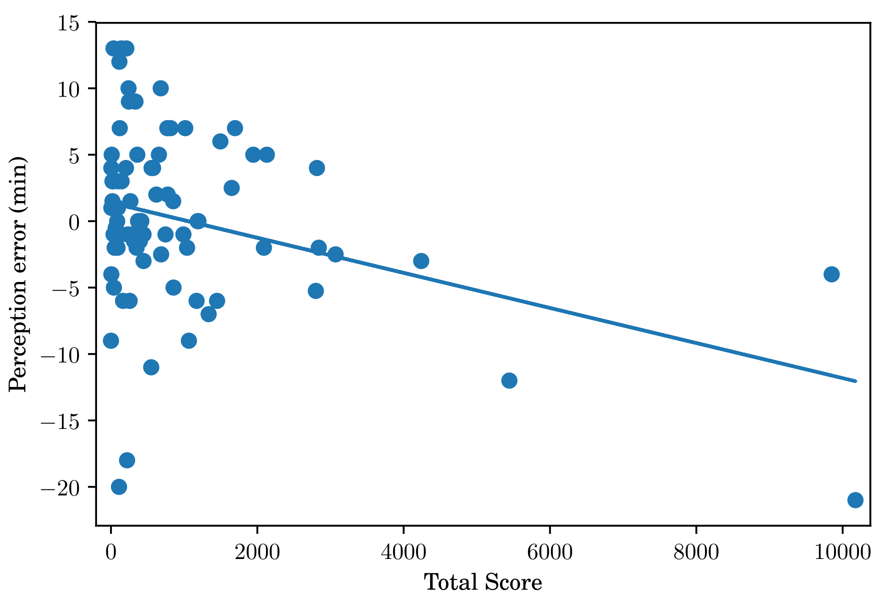


Fig. 5. Correlation between total score (total score obtained on all levels) and perception error.

To do this, we performed a basic linear regression. The coefficients can be interpreted as follows: every minute not playing (while in the queue) is perceived as A minutes; every minute playing is perceived as B minutes; people usually always perceive a wait of at least C minutes (that is, C is the intercept in the linear formula). We computed the three coefficients using three sets of data: players only, non-players only, and both players and non-players together. The three sets of coefficients we found are reported in Table 6, along with the R-squared statistic, which is a statistical measure

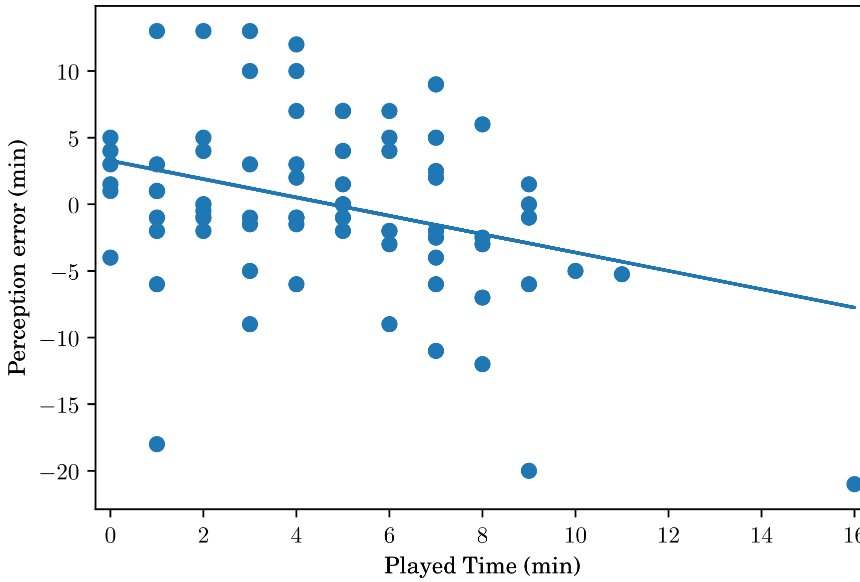


Fig. 6. Correlation between played time and perception error.

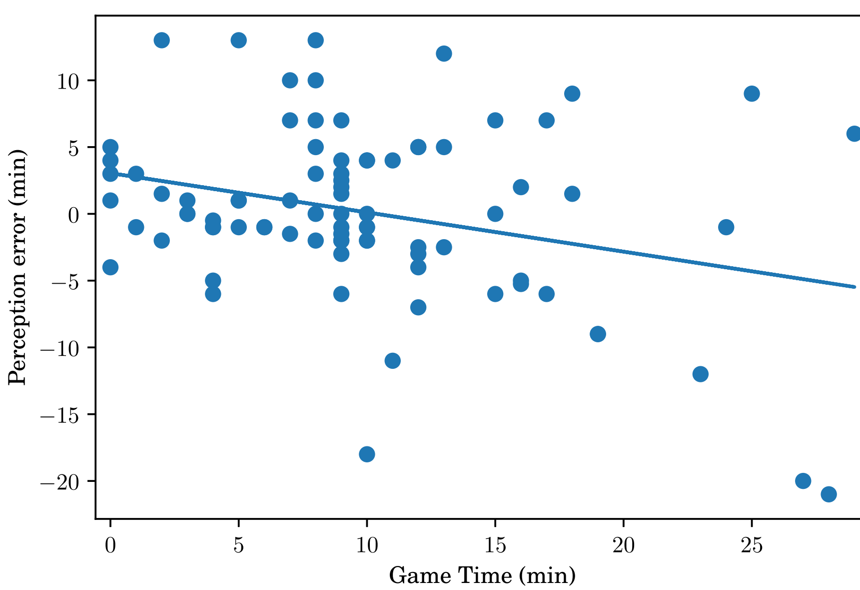


Fig. 7. Correlation between game time and perception error.

between 0 and 1 indicating how closely the data matches the formula. Even though these findings are limited by the strong assumptions made and by the average R-squared statistic, the numbers suggest that, when estimating perceived time from playing/non-playing time, the contribution of the time spent playing to the overall the perceived time is many times lower than the contribution of the time spent not playing. Using the data from both groups, we found that the same amount of actual time was perceived roughly 5 times longer by non-players than by players. That is to say, non-players perceive 5 times as much time passing as players do.

Table 6. Results of the Linear Regressions Conducted

Using	A	B	C	R^2	Ratio A/B
Players and non-players	0.87	0.17	5.49	0.6	5.24
Non-players only	0.94	0	4.73	0.64	N/A
Players only	0.75	0.24	6.27	0.5	3.15

A and B are, respectively, coefficients for non-playing time and playing time; C is the intercept. $0 \leq R^2 \leq 1$ is a statistical measure indicating how closely the data matches the formula A * non-playing time + B * playing time + C = perceived time.

Table 7. Statistics of the Survey Responses that We Collected

Question	Mean	Std. Dev.
I played the game as much as possible in the queue.	3.92	1.17
Playing the game made time pass more quickly.	4.09	0.92
I enjoy waiting in long queues.	1.76	1.13
I often use my mobile phone while waiting in long queues.	3.72	1.28
I would appreciate a game like this being available in other long queues.	3.87	1.02
I would rather play my favourite mobile game in a queue than the game that was provided.	3.4	1.07
Playing this game with a group makes time pass more quickly.	3.98	0.99
I/we explored different strategies in the game.	3.48	1.06
Progressing in the game made me feel better about my progress in the queue.	3.72	0.97
I would play this game again if I re-entered this queue.	3.78	1.19

Responses, in a Likert scale, are assigned values 1 to 5, which represent, respectively, strong disagreement or strong agreement.

5.4 Survey Analysis

After playing during their wait in the queue, players were asked to complete a 10 question survey, each answer being given on a Likert scale; we used a five step Likert scale, including ‘Strongly disagree’, ‘Disagree’, ‘Neutral’, ‘Agree’, ‘Strongly agree’, along with an extra option ‘Not applicable’.

Table 7 shows mean scores for every question. Players seem to agree on the positive impact of the game, with high mean scores on questions such as ‘*Playing the game made time pass more quickly*’ and ‘*I would appreciate a game like this being available in other long queues*’. However, some players stated that they would prefer playing some other game. The data seems to support that some of the queue design factors are indeed effective, such as playing in groups and giving players a sense of progression. Figure 8 shows the distribution of answers to selected items of the survey.

6 THEMES DESCRIBING PLAYER EXPERIENCE

Over 100 participants played the game and their general belief was that the perceived waiting time while playing in the queue decreased. One family who played the game said, ‘*It did make us feel that we were waiting for lesser time in the queue. This was due to the fact that we were waiting to move on to the next marker to continue playing the game*’. To add to this thought another family said, ‘*Because the game helped us shift the focus of our mind from the time of waiting in the*

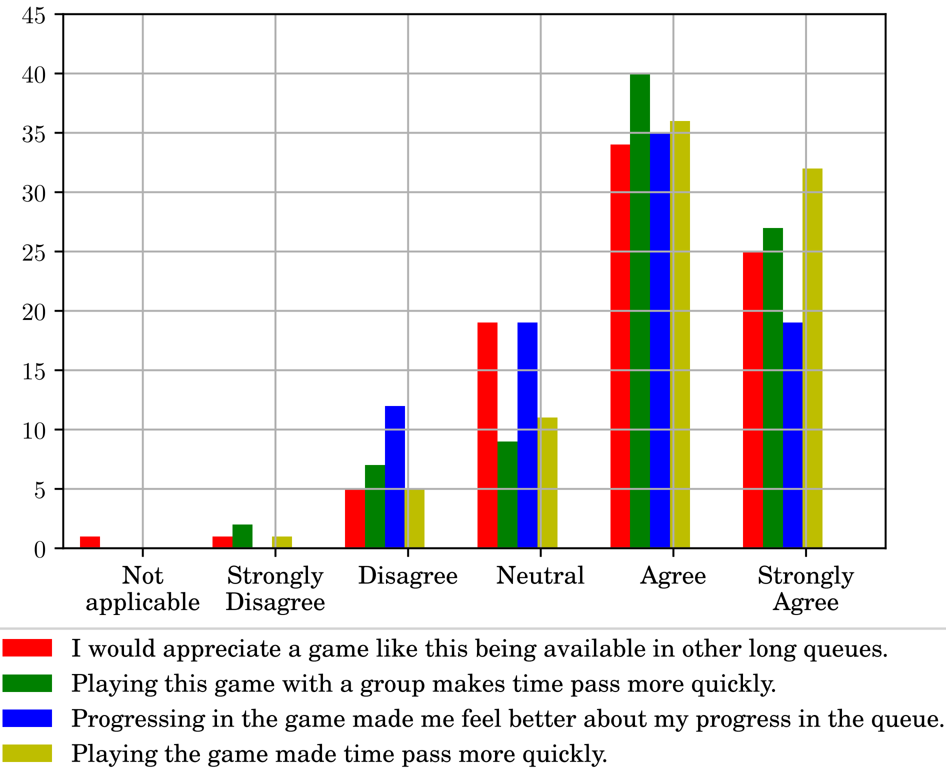


Fig. 8. The figure shows the distribution of answers for selected questions of the survey administered to participants.

queue to the playfulness of the game, we felt that our waiting time was much lesser, almost by about 15 minutes'.

An analysis of the interview data helped us come up with three overarching themes as follows: (1) Designing to Support Simultaneity, (2) Social Engagement through the Design of Queue Space, and (3) Technology to Foster Flow.

6.1 Designing to Increase Player's Sense of Simultaneity

Simultaneity is described as the relationship between two events happening at the same time in the same physical space [25]. In the context of our queue game, we describe the relationship between two events happening while playing the AR game as follows: (a) the player playing the game, and (b) the perception of time moving faster. This theme describes participants' discussion on how they relate their experiences while playing the game and their perception of time. A total of 186 of the total 422 units of data were described by this theme, which consists of the following two category codes:

(1) Cognitive shifting (mentioned in 107 units), and (2) altered sense of time (mentioned in 79 units).

6.1.1 Cognitive Shifting. Cognitive shifting is a method used in awareness management. It is described as the mental process of redirecting one's focus of attention away from one fixation and towards a different focus of attention [24, 55]. Participants described how the game helped them redirect their focus of attention from waiting in the line to playing the game. Participant p3 from a family playing the game said: '*It helped us get distracted from the fact that we were waiting in the line and helped us become excited from being the state of being bored*'. Another family said: '*We liked playing the game as it helped us cope up with the boring aspect of waiting in a long line*'. These aspects described by the participants help reaffirm the factors F1 and F9 (Section 2.2). Participants also described the initial hindrances they faced with the camera's focus when they started to play the game. This was not a conscious design decision, however, participants had to work around some technological limitations before they could play the game. Participant p19 said: '*Although I would have been irritated elsewhere, the fact that it took us some time for the camera to focus on the poster helped us kill some time; I feel like this because it is better to do something interesting in the line rather than nothing*'. We believe that this unconscious design decision contributed to F5, i.e., control information presented to them in the queue by restricting the amount of time it took participants to start the game. Some participants were playing an AR game for the first time and this helped them shift their focus away from the waiting time in the line as well. Participant p8 said, '*I was playing an AR game for the first time. While adapting to the gameplay, the required distance between the poster and the camera was irritating, it did consume time and helped me feel that I was waiting for a lesser amount of time in the queue*'. Participants played the game for as long as 10 to 15 minutes and this helped them feel that they were waiting for a considerably shorter time in the queue. Participant p26 said, '*I am sure I must have waited for about twenty-five to thirty minutes in the queue, however, as I was playing the game for ten minutes or so, it made the time go by faster*'.

6.1.2 Bursts of Time Distortion Due to Staged Level Design. A person who is completely absorbed in performing an activity might reach a state of flow, a mental condition that is marked among other characteristics by a distorted sense of time [17]. Such flow experiences are often reported by people who play computer games [13, 59]. We designed our game to be staged, with each level being entirely played at one marker, as discussed in Section 3. While staged gameplay is common in the design of games, factor 7 informed this design as we wanted to inform participants about their progress. We learnt that participants felt that the time was moving faster while they were waiting in the queue as they were eager to play the next level of the game ahead in the queue. Participants also discussed about how the staged design helped them sustain their interest in the game throughout their waiting period. Luthman et al. say that time perception affects gamers uniformly based on the theory of flow [35] during play and up to 10 seconds after the game session ends. Participant p15 said: '*We were playing as a family and we liked how the posters were arranged in the queue. The game felt progressive and I rarely felt that I did not have anything to do while waiting in the queue*'. Further, participants also liked how the gap in the placement of the posters helped them perceive time. Participant p23 said: '*[…] I played one level and it excited me and I felt that the time was moving faster […]. I had to wait in order to play the next level. During this waiting period, which was lesser than 15 - 20 seconds, I thought that the time was passing by faster as well.*' Participant p32 further explained this phenomenon: '*As there was a gap in the placement of levels in the queue, we felt that burst of excitement continue even when we were not playing the game and waiting to play the next level. When we felt that the excitement levels were dropping, we were at the next level and ready to play and the excitement continued. Although this was the case with a few levels, some levels were gapped too far I suppose and that irritated us as it made the time go slower.*'

6.1.3 Design Implications—Consider the Usage of Multiple Fingers on the Screen to Support Social Inclusion and Increase Social Collaboration. Our results with theme 1 suggest that participants liked playing by collaborating either with their family or friends by having each of them take responsibility for a certain activity on the screen. Researchers [16] developed a set of collaboration patterns that can be used as design principles to create games that enhance social engagement. Using principles of Cognitive Behavioural Therapy (CBT) that encourage or require joint-engagement they developed games that encouraged social collaboration. In one of their games they used 'Objective pattern' as a way to facilitate collaborative play. In objective pattern, collaboration is facilitated because the participants have ownership of different objects that need to be negotiated. As discussed earlier, collaboration in our game happens because various parts of the game on the screen need fingers placed in different positions. This is possible because of social collaboration between a family of players waiting in the queue. Based on our theme discussions, we therefore extend the notion of 'Objective pattern' to the design of AR queue games and recommend game designers to encourage the use of multiple features in the game that require collaboration between multiple people waiting in a queue to facilitate joint engagement and social collaboration. Our results have shown that this in turn would help in the reduction of perceived waiting time in a queue for theme park visitors.

6.2 Social Engagement through the Design of Queue Space

This theme describes how playing the AR game helped participants' increase their social engagement while waiting in the queue. A total of 177 of the total 422 units of data were described by this theme, which consists of the following two category codes: (1) Fostering social inclusion while playing the game (105 units), and (2) increasing social curiosity prompting others to play the game (72 units).

6.2.1 Fostering Togetherness While Playing the Game. Togetherness is defined as the idea of people staying close to each other not just physically but emotionally as well [49]. Participants discussed how the game helped them share and participate in a play experience as a family. This experience of the participants reminds us of the factors F2 and F12. Participant p17 said, '*I discovered that I can play this game while waiting in the line and I called upon my brother and sister to play the game along with me. Eventually we dragged our parents to play the game along with us. It was much more fun playing the game together*'. When we enquired about what prompted this behaviour, participant p19 said, '*I quickly realised that the game was cooperative in nature and more fingers on the screen means more fun and more win. The game nudged me to play the game together with my family.*' Participants also liked how they could distribute the controls of the game amongst themselves while playing the game together. Participant p26 said: '*[...] my dad and I were shooting the black hole portal in the game, and my mum was responsible for collecting the points [...]*'. Parents were discussing about how they got to have some fun time with their kids by playing the game while waiting in the queue. Participant p14 said: '*I am glad I played the game as it helped me bond with my son and daughter for a little bit while waiting in the line; if not for the game, the time would have been spent fidgeting with our individual phones while getting bored in the line*'. Participants also discussed how the cooperative design of the game pushed them towards playing the game together with family and friends. Participant p26 said: '*I started playing the game and soon realised that I need more fingers on the screen to score more points and therefore I pulled my dad and mom to play the game along with me*'. The entirety of this experience was summed well by a one of the family that played the game. They said: '*We knew we were moving quickly in the line, but we never realised how quickly we were at almost the front of the line*'. The social experience that the game created while maintaining their interest in the ride helped them exceeded their own expectation of how quickly the time passed by in the queue emulating F8.

6.2.2 Increasing Social Curiosity Prompting Other to Play the Game. The desire to acquire new information about other people and the resulting exploration of the social environment is described as social curiosity [48]. Participants discussed how playing the game prompted other people in the queue to speak with them and seek information about the game. Participant 22 said: '*I was waiting in the line playing the game. In order to start playing the game, I had to lift my phone up in the air to read the AR marker on the poster*'. Placing the tags above the height of an average man was a queue design decision that we took deliberately in order to foster social curiosity. While this design decision was advantageous to foster social curiosity, we observed that it was difficult for the kids playing the game. Participant p5 said: '*The posters were a tad higher for my height and it would have been nice to have the posters at eye level*'. Although this design decision seems to be straightforward, we had difficulty implementing it due to the tight layout of the indoor facilities, funnelling the queue to the attraction. Participants discussed how they were enticed to play the game seeing others play it while waiting in the line. Participant p9 said: '*I was really curious to play the game as people playing the game seemed to be having a lot of fun and this urged me to play the game along with my family as well!*' Some participants even spoke about how they felt the time was moving faster while watching others play the game. Participant p21 said: '*I generally watch my little brother play games and that entertains me. I did the same thing here, I was watching other people play the game and that gave me a sense of joy somehow and I felt that I waited for a lesser time in the queue*'. Participants (except for children) also suggested how the physical assets in the queue helped them stretch their body to reach them and how this was a pleasurable experience. Participant p11 said: '*I was not tall enough to point my phone at the physical asset, so I had to stand on my toes to just get it into focus. Although it felt uncomfortable at first, the stretch gave my muscles an amazing feeling. I guess they became sore waiting in the line. However, I feel for my little brother [giggles], my parents had to lift him!*' These experiences suggest that by designing to facilitate social engagement (F2), we can keep the participants in a cheerful mood (F9) and sustain their enthusiasm about the ride (F3) to reduce their perceived waiting time in the queue (F1).

6.2.3 Design Implications—Consider Placing Physical Assets Higher Up in the Queue Space to Nudge Performative Play and Foster Social Curiosity. Our results with theme 2 suggest that participants liked it that the physical assets were higher up in the queue and that this feature enabled them to interact with other people waiting in the queue. Moreover, others mentioned how this aspect of design helped them stretch their body to play the game that gave them a physical boost although it was inconvenient at first, reflecting factor F11. Sheridan et al. say that a key element of interaction at festivals and events with large crowd is performative interaction. Performative interaction focuses on the often shared, anarchic and spontaneous play found in improvisation—it is social in nature, and happens anywhere, for any duration. Based on our results with the AR game, we found that placing the posters (physical assets) higher up pushed the participants to lift their hands up in the air to point their phones to the AR marker on the poster to start playing the game. People standing behind these participants viewed these performative actions and became curious to know more about what was happening. This increased curiosity pushed the observers to become players by seeking information about the game from those already playing it (the performers). Therefore, we extend the notion of performative play to the design of AR queue games and recommend game designers to place physical assets that participants need to interact with at a higher level in the queue space to foster social curiosity and convert the observers to become the performers. This in turn would help both the performers and observers to reduce their perceived waiting time.

6.3 Technology and Physical Game Assets to Foster Flow

In this theme, we describe about the technology and the physical assets used in the design of the game and participants' discussion of how it fostered flow while waiting in the queue. A total of 59 of the total 422 units of data were described by this theme, which consists of the following two category codes: (1) Using AR to transport players into a different world, and (2) using wall space in the queue for uninterrupted play

6.3.1 Augmented Reality to Transport Players into a Different World (Time World). In this theme, we discuss how AR helped participants transport their minds into a different world while playing the game. Participants reported how the superimposing feature of virtual elements such as the portal and the stars helped them believe that the time was moving faster in the queue. Participant p13 said: '*[...] while I knew that I was standing in the real world, the technology helped me believe that I was in another world and I thought that the time was moving faster here*'. Participants also suggested how they were able to share this experience of this different time world along with their family. Participant p19 said: '*[...] standing in the line and playing the game put me in an illusion of a different world and sharing this time world (with the usage of multiple fingers) along with my family was so much more fun and helped me believe that I was moving faster in the queue*'. These experiences of participants remind us of factors F1, F2, F7 and F12.

6.3.2 Wall Space in the Queue for Uninterrupted Play. In this theme, we discuss how participants used technology in an unexpected way to play the game in the queue without interruptions. While a lot of participants had to move on in the queue before they could complete the level, a lot of them completed the level and were waiting to move on to the next. A few of the participants who finished their level and waiting to move on to the next played the game in unexpected ways. They used the zoom feature of the camera to focus onto the next portal a fair way away to access the portal and play the next level. Participant p18 said: '*[...] I think the best thing was we were able to zoom into some of the posters and tried to play the next levels [...]*'. Participants thought that this feature helped them to think that time was moving faster than it already was for them as they were eager to play the next levels. Participant p22 said: '*[...] Once we figured out we could zoom into the posters to open the portals, we tried to play the game even faster as it was getting addictive and since we had a good phone we were able to zoom in more I guess and in no time it was time for our family to get onto the roller coaster*'.

6.3.3 Design Implications—Consider Designing Stages as the Queue Progresses to Foster Bursts of Time Distortion and Facilitate Flow. Our results with theme 3 suggest that participants liked the increasing difficulty levels. Participants also liked how they could zoom into the AR marker far away to play the next level. When people are in the flow state, they become absorbed in their activity and perceive that time is moving faster . Therefore, we extend this notion of flow to the design of AR queue games and recommend that game designers to consider designing in the following ways to help sustain the state of flow in order to reduce perceived waiting time. We do so by designing levels with increasing levels of difficulty as players progress through the queue; also, we design the QR codes on the physical posters at a size that would enable players to zoom into it even though it is a fair bit away from them in order for them to continue playing the next level.

7 DESIGN SPACE FOR GAMES IN QUEUES

The key design challenge we have found while engaging with the theme park, developing the game and conducting our study is to find the right balance between engaging the players (i.e., engaging with the 'virtual world') and allowing them to progress in the queue (i.e., engaging with the 'physical world'). In other words, designers should help players become so engaged that time perception is altered [17], yet not so much that they are unable to move forward in the queue or miss out on the anticipation created by the ride, as such, these aspects need to be carefully integrated. The need for such an integration has already been articulated by Montola et al. [41] in

Fig. 9. Dimension of integration between the game and the spatial movement of the queue.

the context of pervasive games where designers also need to carefully integrate any requirements of the physical world into the game.

In order to discuss this need for integration and in regards to our findings and our initial 12 queue factors, we now articulate a set of 'integration' dimensions for the design of games in queues. We note that the design dimensions are to be understood as a proposal based on this initial study, while future investigations may provide further insights.

7.1 Dimension 1: Extent to Which the Game is Integrated with the Spatial Movement of the Queue

Our first dimension is concerned with the extent to which the game is integrated with the spatial movement of the queue (Figure 9). Traditionally, digital games did not make use of the physical space around players, however, this has changed with games such as Geocaching or Pokemon Go that utilise GPS in order to guide players through their physical environment. With games in queues, such physical movements are severely constrained, nevertheless, players are moving, in fact, they are moving in a very structured manner: always forward, and within the constraints of queue barriers, making the start and end location very specific and known to designers.

Knowing these constraints can be useful for designers, especially when considering how to implement 2.2.4, for example, designers could take the knowledge of estimated wait time and use this to introduce 'stages' into the game that then align with the progress in the game based on location data.

We identify four broad aspects of how a game could integrate with the spatial movement of the queue, which in turn could affect how people perceive their time in the queue.

7.1.1 Conflicting. Games could conflict with the movement of the queue, by that we mean that the game requires players to move in a manner that hinders the movement of other people. For example, let us imagine a game that uses the sensors in a phone, such as 'guiding a ball through a maze'—game. This can be played in a queue easily, however, once the queue moves, the player is expected to move along, but she/he might be hesitant to do so, as the walking will negatively affect the ability to do well in the game. Such challenges have been previously highlighted [39] in the context of operating mobile devices while moving. Here, we extend this work by highlighting that game designers need to consider if there is a conflict between the player's movements in the game and in the queue; this could ultimately lead to physical discomfort (see 2.2.11).

7.1.2 Indifferent. Games could also be indifferent to the spatial movement of the queue by not incorporating any spatial or contextual cues. A large selection of mobile phone games fall into this category. One might think these games are very suitable for queues, as they provide players with entertainment and as such have the potential to support F1 ('Support active waiting'). However, these games can 'draw' [32] the player in to such an extent that the player does not become aware of when the queue is moving, resulting in people behind the player asking to move along, or even worse, passing by the player and negatively affecting social engagement (see queue design factor F2: 'Foster Social Engagement')

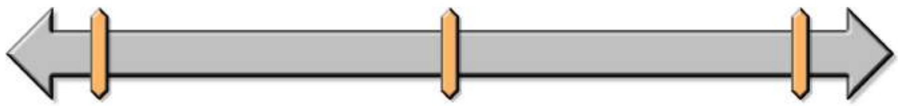


Fig. 10. Dimension of integration between the game and the queue time.

7.1.3 Aware. Games could also allow players to become aware of the queue's movement outside of the game. For example, a game could offer breaks that allow looking up to determine any movement in the queue. Our design aimed to support this through rather short levels and a results screen that did only advance upon pressing a button, not punishing the player if wanting to take a break when moving along. This aimed to support F4 (2.2.4).

7.1.4 Integrated. Lastly, the game could be integrated with the spatial movement of the queue. By this we mean that the game knows about the movement of the queue, for example through the use of sensors, and integrates this meaningfully into the gameplay. We tried to facilitate this through several design features: Firstly, players could only play the game in the queue, making it site-specific and therefore unique to the queue. This aimed to contribute to F3 ('Maintain attraction interest') through making the overall attraction more appealing by providing a unique, enjoyable experience in the queue. Secondly, the AR markers were sorted in a way that progressing through them towards the head of the queue was aligned with the difficulty of the game. In other words, moving from marker to marker did not only provide players with a perception of passed time through physical movement, but also through the experience of reaching more and more advanced levels (F7: 'Highlight progress'). Thirdly, players were asked, through specific commands such as 'Go find the next marker' to look out for what is ahead of them in the queue. This appeared to support players in anticipating what they will encounter next when the queue moves, 'breaking down' the excitement that usually is only fulfilled at the head of the queue into smaller pieces, similar to a 'divide and conquer' approach (see F7: 2.2.7).

7.2 Dimension 2: Extent to Which the Game Time is Integrated with the Queue Time

This dimension describes the extent to which the game time is integrated with the queue time. On one end of the dimension games are situated where the game time is conflicting with the queue time (Figure 10), and on the other end where game time and queue time are fully integrated.

7.2.1 Conflicting. Most common mobile phone games if played in a queue would not be integrated—in fact conflict—with the queue time: players might start playing them when entering the queue, but the game might not be finished when the player reaches the head of the queue, resulting in an aborted game. This would probably be detrimental to any 'positive affect' (F9), diminishing any opportunity for supporting 'positive memories' (F12).

7.2.2 Indifferent. Game time could also be independent and hence separate from queue time. For example, a non-timed game of chess played on a mobile game would allow playing when standing in the queue, and if movement is required (i.e., the queue progresses), the players could simply put the phone down, move forward and put their attention back to the game, supporting F1 ('Active waiting').

7.2.3 Integrated. Game time could also be tightly integrated with queue time. In our game, we implemented a 'pause' button that allowed players to pause the game when the queue was moving.We also chose a rather fast action game style in order to highlight how fast time can move. We could have possibly implemented additional features to respond to F5 ('Control information'),

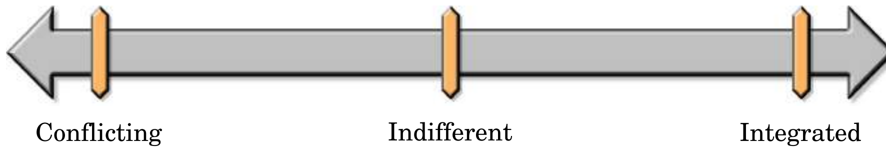


Fig. 11. Dimension of integration between the game and the social affordances of the queue.

for example, using sensors that detect the length of the queue, which would expedite or slow down the game levels in a way that when reaching the head of the queue, the game also ends. However, here we stress the potential to integrate game time with the time perceived in the queue as a way to 'beat expectations' (F8).

7.3 Dimension 3: Extent to Which the Game Integrates the Social Affordances of the Queue

A queue is only a queue because multiple people come together, hence every queue has a significant social aspect to it: people are standing very close to each other, sometimes for hours. Due to cultural norms, even though people are so close to each other, it is socially accepted not to talk (people generally do not say 'hi' when joining a queue). These phenomena make queues interesting social encounters, and we highlight the fact that games can draw on this in order to reduce perceived waiting time. Our third dimension is therefore concerned with the extent to which the game integrates with the social affordances of the queue (Figure 11).

7.3.1 Conflicting. Games could conflict with the social situation of a queue: for example, movement-based games might encounter inhibition from players not comfortable performing in front of other people in the queue. We noticed this in our work as some people did not want to play our game when asked if they wanted to participate in our study, possibly because they might have disliked 'performing' in front of strangers being so close by; however, we cannot say for certain as we did not ask them why they did not want to participate as per our ethics approval agreement. We highlight here that this 'social engagement' (F2) should be considered, in particular, we refer to prior work that has identified that creating socially uncomfortable interactions can also have benefits [6].

7.3.2 Indifferent. Games can also be indifferent to the social situation of the queue. For example, most current mobile games fall into this category, as they can be played in a queue, with the game not being aware of the social context, nor do the players feel socially inhibited or nurtured. It might be the case that other family members might be feeling left out and annoyed if their family members interact with their phones in the queue, leaving them with no conversation partner; however, we did not observe such situations much, as most times if one person operated a mobile phone, all other family members simply took out their own phones to keep themselves busy.

7.3.3 Integrated. There are several ways how games can integrate the social situation of the queue, we highlight the following.

In theme parks, most visitors come in groups, often families. These groups attend to have a shared experience, evidenced by the fact that we have been asked numerous times while manning our study station how many people the carriage carries in order to allow families to experience the ride together, rather than in separate carriages. Games can support this social aspect of the group experience. In our game, we aimed to facilitate this by supporting families to play the game together (F2: 'Social engagement').

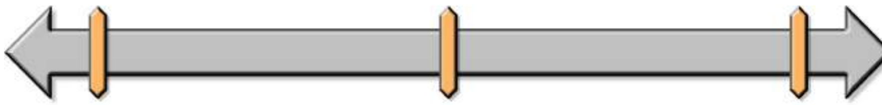


Fig. 12. Dimension of integration between the game and the bodily aspects of the queue.

In particular, our game asked players to share a device while pointing at the AR markers, resulting in bodily movements where multiple arms pointed at various locations along the queue. These often humorous (F9: 'Positive affect') shared bodily movements not only appeared to align with the strong social bond that families exhibit and want to portray, it also provided a small spectacle for the people immediately around them [43]. Our interviews suggest that we were able to achieve the notion of public performance [52] yet did not make people too socially uncomfortable. In addition, this enabled arriving people to see queue participants playing, eliciting curiosity of what their movement actions are about (F4: 'Get started').

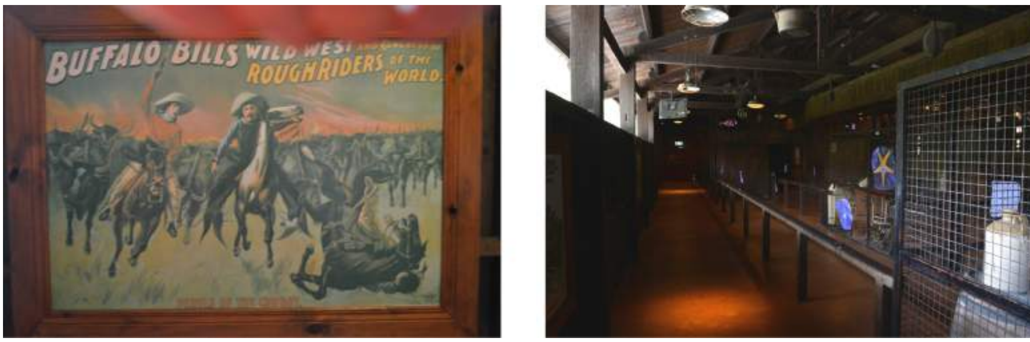
7.4 Dimension 4: Extent to Which the Game Integrates the Bodily Aspects of the Queue

Queuing is not only mentally taxing, but also physically demanding, as almost all queues require standing for a long time (see F11: 'Physical comfort'). Furthermore, queuing can also result in uncomfortable situations when one has to attend the restroom, with people often fearing the loss of their place in the queue (see F10: 'Enforce fairness'). Additionally, theme park queues are often outdoors, and in summer it can get very hot standing in the sun. Our final dimension is therefore concerned with the extent to which the game integrates with the bodily aspects of the queue (Figure 12).

7.4.1 Conflicting. Games can be conflicting with the bodily aspects of the queue: most mobile games require players to squint their eyes when playing in bright sunlight for example, instilling further strain on bodies. We acknowledge that such bodily effort can also be an intriguing game element [42, 43], however, we believe most such bodily effort is incidental, rather than beneficial to the game experience.

7.4.2 Indifferent. Many games people play in queues today are rather indifferent to the player's bodily experience: they do not make it easier for the player to be in the queue from a bodily perspective (such as suggesting stretching exercises) nor do they make it particularly harder (for example by requiring players to do kicking actions (like the AR football kicking game [46] that could result in players kicking other queuers leading to injury).

7.4.3 Integrated. We propose that games can be integrated with the bodily aspects of the queue. For example, games could sense when players have been standing too long in the same position, suggesting through gameplay simple stretching exercises. We can also envision games that draw on vertigo (such as proposed by Byrne et al. [11]) in order to maintain participants' interest into the vertigo ride (F3: 'Maintain attraction interest'). In our work, we aimed to make the standing experience a bit more varied by promoting bodily movement through the input mechanic of having to point the mobile phone at the AR markers that we placed in a wide variety of locations and positions (F11: 'Physical comfort'). This way, we hoped we promoted bodily movement that provided a welcoming change to mostly standing still.



(a) Poster, showing the theme

(b) Queuing area

Fig. 13. The figures show the Wild Wild West ride in which the experiments were conducted.

8 LIMITATIONS AND FUTURE WORK

Studies in the wild dramatically differ from controlled studies in that several parameters cannot be fully controlled by the research team. This study was no exception and indeed the current limitations of our work primarily stem from this. Due to operational constraints of the theme park (i.e., peak season), we were not able to carry out the study where we had originally planned (the 'Justice League' area) and we had to switch to a new area (the 'Wild Wild West' ride area). This led to some thematic disconnection in the game content, which could however be easily fixed: game location(s) could be made more 'alive' as opposed to the static (albeit beautiful) venues they are now. An example would be using existing posters in the location (see Figure 13(a)) to create characters (e.g., cowboys in classic western movies) that 'pop out' of the wall and interact with players in mixed reality.

Moreover, control props and objects in the environment (see below) via simple and inexpensive off-the-shelf mobile robotic kits (e.g., Arduinos and Raspberry PIs), could be used to control doors, gates, lights, ropes and so on. This leads to a stronger sense of immersion and presence in the game world. Also, we did not deploy any of the content we had originally planned to include in-between levels, e.g., a 'shop' to purchase new weapons and power-ups, which could have had a positive impact on longevity as well as on perceived waiting times. We were hesitant about adding this new feature as it could have impacted the stability of our game prototype: we leave this future work, as well.

Furthermore, we did not compare time perception in participants playing their favourite mobile game in the queue as this would have meant a supplementary layer of complexity in tracking each individual user behaviour on the provided mobiles (which, in fact, were sand-boxed for security reasons). We feel this could be an interesting experiment to run, which, however, would not weaken the strength of our results but rather it could put them in a broader perspective. Moreover, it could be argued that time perception was an essential element in our experience and that other games could fare well in this respect. However, it would not be easy to reproduce the kind of social experiences our AR game prototype delivered without extensive deliberate design, ruling out the vast majority of existing mobile games.

Finally, due to the in-the-wild nature of this study, it was not possible to properly isolate players from non-players. This allows for one group to be influenced by the other. In particular, it is possible that the awareness of the game in non-players may have caused an unintentional bias, a form of jealousy toward players. If this effect caused a higher perceived time, this would mean the results we calculated should be interpreted as upper bounds. We do not believe this is the case, as we observed non-players to be actually entertained by their fellows pointing the smartphone toward markers, while their friends were energetically tapping on the screen. The data itself does not contain elements that can help answer whether this effect was real and how large it was. For this reason, the conclusion should be interpreted as an upper bound on the effect of playing our game on time perception.

9 FUTURE WORK AND CONCLUSIONS

Developing an AR game as a novel experience for customers in theme park queue was a very exciting albeit challenging endeavour. To the best of our knowledge, our in-the-wild study using log data and interviews is a unique kind of collaboration. Our main result demonstrated that every minute playing in the queue was perceived to the same extent as about 5 minutes of abstinence from play: we feel this result is encouraging. We hope our work provides a significant example of how games could be used in everyday life to make our lives more playful and in fact enjoyable.

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