Entertainment Computing 42 (2022) 100480

Contents lists available at ScienceDirect

Entertainment Computing

journal homepage: www.elsevier.com/locate/entcom

The mediating effect of fantasy on engagement in an AR game for learning

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ARTICLE INFO

Keywords:
Fantasy play
Presence
Autonomy
Intrinsic motivation
Augmented reality
Serious games

ABSTRACT

It is challenging to create an immersive and engaging remote education setting properly, especially for children who are less motivated and quickly distracted by virtual learning activities that fall short of leveraging the immersive design potential. To maximize the educational potential of AR game-based learning, designers need to align fantastical environments, learning content, and AR requirements. This task requires a thorough understanding of the impact of design choices on users' experiences. To gain insights into the motivational mechanics of fantasy elements in AR, we investigated the effect of two AR learning contexts—a fantasy setting and a daily setting—on children's experience and motivation. Our goal is to scrutinize the relationship between fantasy states, intrinsic motivation, and players' experience of autonomy and presence. Our results suggest that the relationship between imagination and enjoyment—stimulated by our two conditions—is fully mediated by experiences of autonomy and presence. Our research provides insights into the relationships between experience constructs and informs the design of fantasy learning experiences. We provide guidelines to support game designers and researchers to integrate the fantasy experience in AR learning games for children.

1. Introduction

Over the past years, there has been a trend towards virtual teaching because it mitigates temporal and geographical barriers [1]. Teachers and parents have recently raised concerns about remote learning: due to a lack of immersion, children are found to be less motivated and more easily distracted when engaging in remote learning [2]. To improve motivation, introducing playfulness into virtual learning has been another trend in recent decades [3]. Game-based learning, a form of serious games considered a plausible solution for "motivational inadequacies", has garnered research attention regarding its promising effect on cognitive learning outcomes [4]. However, how to design serious games to be motivating is still an open research question [5].

Games create a so-called "magic circle", an alternate bubble of reality where the player adopts a lusory mindset and engages with the game world by suspending disbelief [6]. Although game-based learning is generally more attractive to children than traditional textbooks, some serious games fail to live up to their motivational potential, for instance, because they are considered less sophisticated or immersive than entertainment games and have unimpressive storylines [7]. Consequently, the players of these serious games may not enter the "magic circle" and adopt a lusory mindset in the first place, therefore leading to lower motivation [8]. A critical catalyst for forming a pervasive and persuasive "magic circle" is the separation from ordinary life [6]. Malone describes elements that evoke mental images, physical objects, or social situations that are not actually there, as fantasy in games [9].

This separation from ordinary life is especially pertinent in Augmented Reality (AR), which blends the real and game world and thereby creates a liminal interface where the player has to shift between telic, paratelic, and paraludic domains [10]. The shift from a telic state to a paratelic state, i.e. from a task-oriented to a play-oriented mindset, is a transition from extrinsic towards intrinsic motivation [11]. Transgressing from the paratelic state through a paraludic interface into the game world comes through adopting the game rules or fiction and constructing meaning in this fictional reality [10]. In other words, to stop using an educational game as a tool for learning and to start actually playing requires stepping into the magic circle by adopting a playful (paratelic) mindset and immersing in the game world. AR has been shown to improve immersive experiences by expanding the magic circle's boundaries [12] and enhancing players' experience. In addition, or perhaps as a consequence of the enhanced experience, young generations, who grow up playing with digital technology, have a stronger preference for AR game-based learning than more conventional modes of education [13]. Since evidence for the positive effect of Augmented Reality on virtual learning has been found, how to maximize the educational affordance of technologies like AR has been one of the main

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https://doi.org/10.1016/j.entcom.2022.100480
Received 27 October 2021; Received in revised form 24 January 2022; Accepted 15 February 2022
Available online 17 February 2022
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focuses in recent research [14].

In this paper, we seek to gain a better understanding of the relationship between fantasy and enjoyment of serious AR games. Players' willingness to adopt and ascribe meaning to the rules of the game world (i.e., step into the magic circle) is, among others, contingent on the ability of the player to surrender themselves pleasurably to an imaginative world [15]. Consequently, both the game's fantasy, the player's abilities and preferences could interact with the enjoyment of the game. The challenge of adapting contemporary technologies and relating learning content to a fantasy narrative falls on designers' and researchers' shoulders. Developing compelling design strategies for game-based learning requires an understanding of how the fantasy environments shape users' mental state and how their mental activity affects the game experience, i.e. how their mental activities influence perceived enjoyable, immersive, and autonomous experience.

To investigate player experience in AR, we created one condition situated in a fantasy setting and the other condition in a daily setting within the custom build AR game MathMythos AR V2.0. However, designing fantasy game elements does not guarantee that the fantasy engages every user in the same way. Therefore, we incorporated the Fantasy State Scale (FSS) [16] to gauge players' mental fantasy states. We conducted a study with primary school students and collected their self-reported fantasy state, player experience, and motivation. We measured enjoyment using the enjoyment subscale of the Intrinsic Motivation Inventory (IMI) [17] and measured presence and autonomy using the corresponding subscales of the Player Experience of Need Satisfaction (PENS) [18] questionnaire. By comparing two narrative conditions, we intended to investigate the influence of different in-game fantasy settings on users' fantasy states, player experience of need satisfaction, and intrinsic motivation.

We performed analyses of variance and mediated regression analyses to answer three main research questions: (1) How do two AR fantasy settings (fantasy/daily) in games influence the general experience? (2) What are the mediation effects of fantasy states on the relationship between fantasy settings and enjoyment? (3) What are the mediation effects of need satisfaction on the relationship between players' fantasy states and motivation?

Contextualizing our findings from a quasi-experimental investigation of player experience, we discuss three major findings and their respective design implications. Our research contributes insight into the effects of fantasy in game design. We conclude a theoretical model for serious game designers who aim to implement fantastical settings in AR-based learning games.

2. Related work

Game-based learning is a method that applies games to learning content [19]. As a form of serious games, game-based learning aims for educational purposes rather than just for entertainment [20]. Research shows game-based learning is promising for acquiring cognitive, motor, affective, and communicative learning outcomes. Yet, not every game-mechanic is adequate for game-based learning [4]. To evaluate the influence of specific game features on play experiences in learning contexts, we examine relevant work on fantasy elements and states in gaming, as well as player-perceived experiences such as autonomy and presence.

2.1. Fantasy elements in games

Fantasy elements in AR game-based learning can make learning emotionally appealing to its users [21]. Fantasy experiences can be described as the experience of the unreal or as being fueled by imagination. When imaginary or unrealistic experiences are implemented in games, users can experience narratives, visuals, and actions, that they would never experience in real life [22]. The concept of employing fantasy elements in educational game design can be traced back to Malone et al. [9], who define fantasy settings as contexts that evoke mental images that are not present. Malone et al. [21] introduced the term "endogenous fantasy", meaning a fantasy that is aligned with the instructional content and can subsequently lead to intrinsic motivation for learning, and "exogenous fantasy", meaning a fantasy that is extrinsic to the learning content and subsequently more of an extrinsic motivator for learning [21]. Schwartz compares fantasy with realism in terms of foreign and familiar representations in games [22]. Recent research has focused on ways to integrate fantasy with learning content [23,24], while little research has been conducted on the effect of different fantasy components on the game-based learning player experience.

2.2. The players' state of fantasy in games

Choi et al. [16] developed the fantasy state scale to investigate mental states when interacting with digital games from aspects of imagination, analogy, identification, and satisfaction. They define identification as "mental states of players identifying themselves with games". Questions like "I feel it is the real me in this game, while playing" [16] are used to measure players' identification in terms of embodied presence. These are essential nuances of identification between the fantasy state questionnaire and the more widely used identification questionnaire developed by Van Looy et al. [25]. The fantasy state of imagination is defined as mental activities imagining and experiencing fictional events that unlikely happen in real life. In contrast to the imagination, the analogy of the fantasy state represents players' extent of feeling evoked by real-life related experiences. The satisfaction part represents the feeling of satisfaction about game elements. Significant correlations between all the four factors mentioned above were found during their validation process [16], which is worth noting when we process our own collected data.

2.3. Autonomy

Autonomy, meaning our willingness to engage under our own volition, is a crucial concept from self-determination theory [26]. A highly autonomous state occurs when individuals determine to interact based on their interests and values [27]. Autonomous motivation in an educational context is beneficial to students and educators [28]. It triggers higher academic achievement [29], positive emotional experiences like enjoyment [30], and acts of creation [31]. Since games have an evident appeal to their target groups, the motivational effect of game-based learning has been widely researched. In gameplay experiences, higher autonomy can be indicative of more engagement in the magic circle [6]. The magic circle is hypothesized to only work if people enter volitionally. In research by Deterding [32], users remarked that if they felt low autonomy while playing games, it no longer felt like playing the game but performing goal-directed work activities. This indicates that the player did not move from the telic to the paratelic mindset. Therefore, perceived autonomy during gameplay can be an important indicator of whether the game is actually approached like a game and not a learning tool. Ryan et al. [33] showed that intuitive game-control and immersive gameplay could bring stronger autonomy, and autonomous states can foster enjoyment in gameplay. As a part of players' needs satisfaction, users' autonomy is measured by a 5-item scale including a sample question such as "I did things in the game because they interested me" in the Player Experience of Need Satisfaction (PENS) questionnaire [18,34].

2.4. Presence

Presence representing the users' perception of themselves is sometimes also described as immersion in a game world [18]. It is a concept that denotes the experience of "being there" in a mediated environment [35]. A higher experience of presence would indicate relinquishing doubts toward the context, called suspension of disbelief [36]. Suspension of disbelief and immersing in the game world could be seen as indicators of crossing through the paraludic interface and being fully engrossed in a play activity. The experience of presence is greatly influenced by the context in which the user personally interacts. Ryan et al. [33] find compelling narratives, the visual setting, and in-game control can impact degrees of presence in games. They developed an assessment of presence in the PENS questionnaire [33] associated with intrinsic motivation. In line with Ryan et al.'s definition of presence, Augmented Reality can increase users' presence and immersive experiences [13,37]. Additionally, McCall et al. [37] found that an AR environment that is only somewhat interactive could cause a lower sense of presence.

3. Game design of MathMythos AR V2.0

3.1. Design strategies

MathMythos AR is a series of AR games designed with Unity and Vuforia to encourage children to learn and practice mathematical calculations outside the traditional classroom context. The 3D models and particle effects used in the design of the game were purchased through the Unity asset store or third party websites. We generated most 2D image targets using Adobe Photoshop. We created MathMythos AR V1.0 in the form of an AR card game to investigate the influence of fantasy on avatar identification [24]. In MathMythos AR V1.0, the background story of each character was only presented by plain words on cards, while in V2.0, we extended the narratives into books with pictures that can be scanned by AR devices for a more interactive experience. Using MathMythos AR V2.0, we explore the relationship between the game's fantasy settings, players' fantasy state, player experience, and motivation. Using Schwartz's definition of fantasy and realism [22], we designed two versions of the diegetic world: a fantasy setting that involves magic and monsters (Fig. 1) and a daily setting (Fig. 2) that involves school activities and shopping. Users play a gender-neutral role of Rubin, the magician, in the fantasy setting, or Robin, a gender-neutral student, in the daily setting. The fantasy version is designed to take players to a monster-fighting fictitious world where they may escape the boredom of repeated mathematics practice. The daily version is then intended to bring individuals to delightful times of festival celebration and preparation in their regular life.

3.2. The gameplay of MathMythos AR V2.0

In the fantasy setting, children are introduced to math magic, a magic power inside magic stones with different power values. The magic power is triggered by summing up the power of two stones. Playing the role of Rubin, children are first introduced to math magic by their magic teacher Steven and subsequently join in defeating monsters that destroy the local town's peacefulness. In this version, calculating the total sum of gems with different power levels will trigger a magic effect called math magic.

In the daily setting, playing as Robin, players acquire math knowledge from their math teacher Steven, calculating the total price of fruits. In this version, students calculate the sum of the grocery costs using math knowledge. Then Steven will guide players to go shopping for festival supplies, where children practice their calculation abilities, summing up the shopping expenses to receive festival items.

Both versions retain the same mechanics and apply the same interactions in their respective storylines. The player's journey was designed to incrementally increase the complexity, implementing flow theory [38]. Children will first be guided to scan the pattern to open the main character's eyes (Fig. 1.1), then navigated to respond to the teacher (Fig. 1.2), Steven, using a virtual button. In the fantasy setting, Steven will ask players to add up magic power using mathematical calculations and then hit the virtual button (Fig. 1.3). In the daily setting, the teacher, Steven, will ask players to summate the groceries' total price (Fig. 2.3). After that, players will engage in the game's main tasks, i.e., beat up monsters in the fantasy condition (Fig. 1.4–1.5) or prepare for the class party in the daily condition (Fig. 2.4–2.5) using cards they have received and knowledge they have learned on the previous pages.

4. Experiment design

4.1. Measurement

The Player Experience of Need Satisfaction Questionnaire (PENS)

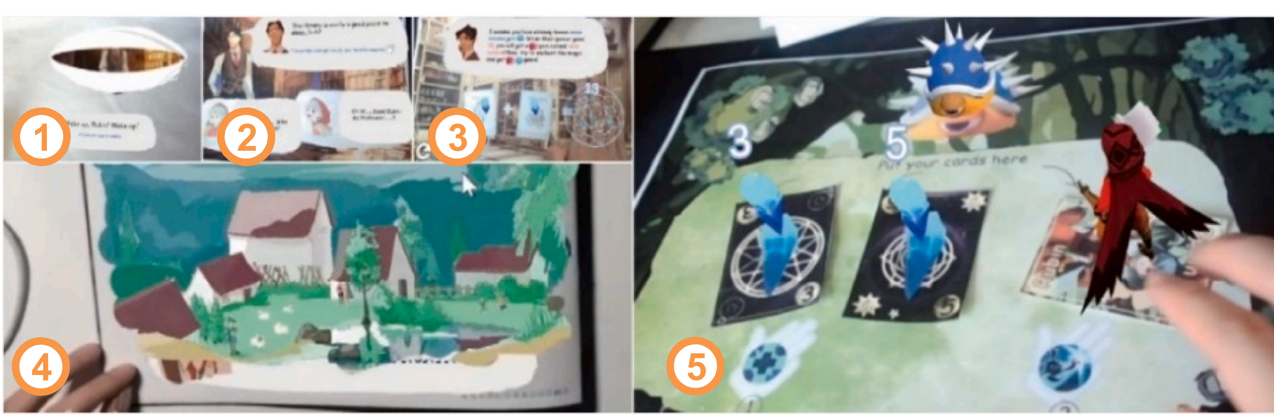

Fig. 1. The fantasy version of MathMythos AR V2.0; the orange numbers mark the scene's sequence. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fig. 2. The daily version of MathMythos AR V2.0; the orange numbers mark the scene's sequence. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Fig. 3. The 4-points animated smiley scale questionnaire was based on PENS and IMI. Participants received the Chinese version; English text was added in red for English readers. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

scale [18] and the Intrinsic Motivation Inventory (IMI) [17] were employed in this research. Due to the fact that the IMI and PENS include various dimensions with numerous questions, and children generally lose patience while answering too many questions [39], we excluded competence, relatedness, and intuitive control, from the PENS scale and effort, tension, and competence, from the IMI. We selected the autonomy and presence subscales from the Player Experience of Need Satisfaction (PENS) scale [18], because these scales would provide the strongest indication of the player being engrossed by fantasy. All questions from the Fantasy State Scale [16] were included to measure childrens' mental states of fantasy expressed in identification, imagination, analogy, and satisfaction.

However, the PENS and IMI are not explicitly targeted at children. Previous work suggests that some children have difficulties understanding abstract concepts, depending on their cognitive development and language ability [39]. Li et al. [40] found that children often give overly positive or negative answers because of the difficulties to express their feelings or understand emotions through written words. Some children also found the "neutral" option hard to understand. Therefore, Li et al. [40] developed a 4-point animated smiley scale for the PENS and IMI questionnaires. In our work, we adapted their animated scale and simplified sentences that we deemed to be too complicated for children to understand (Fig. 3). To ensure the accuracy and readability of the translated questionnaire for children, five design researchers and two primary school language teachers reviewed our version of the questionnaire.

4.2. Participants and procedure

The study was conducted in a classroom in an after-school tutoring institution in Qingdao, Shandong Province, China (Fig. 4). 31 Children were invited to participate in the study (of whom 18 self-identified as male and 13 as female), with an average age of 9 (seven years old = 1, eight years old = 9, nine years old = 8, ten years old = 9, eleven years old = 4).

Two Huawei Mate 30 cellphones running Android, two Lenovo Thinkbook computers with Windows 10, and two storybooks were set up on the gameplay table. Additionally, we set up a GoPro Hero 9 to record behavioural data. Informed consent was obtained before the experiment from both parents and children. Demographic data was collected via a questionnaire—participants were encouraged to use nicknames to keep their demographic information anonymous. Ethical approval was obtained from the Eindhoven University of Technology's Ethical Review Board with the approval number ERB2020ID165.

The procedure of the study started with a tutorial to explain the interactions. We prepared the tutorial with only text and a blank sphere to allow children to get used to interactions such as image target tracking and virtual button holding in AR. After finishing the tutorial, they were invited to play either the fantasy or the daily version of MathMythos AR V2.0. After playing one version, they were asked to fill in the questionnaire and repeat the procedure with the other version. The versions were offered in a counterbalanced manner to mitigate sequence effects. All questions in the questionnaire showed up in a random sequence.

4.3. Reliability

Cronbach's alpha of most questionnaires is within an acceptable range (0.6–0.8), except fantasy satisfaction = 0.5, daily satisfaction = 0.6 and daily enjoyment = 0.5. Removing reversed items, Cronbach's alpha increases: fantasy enjoyment = 0.8, daily enjoyment = 0.7; fantasy presence = 0.8, and daily presence = 0.8. The interpretation of reversed items was likely challenging for our participants, considering their age (8–12) [40]. Therefore, we exclude fantasy satisfaction in all further analyses and remove reversed items when calculating mean values.

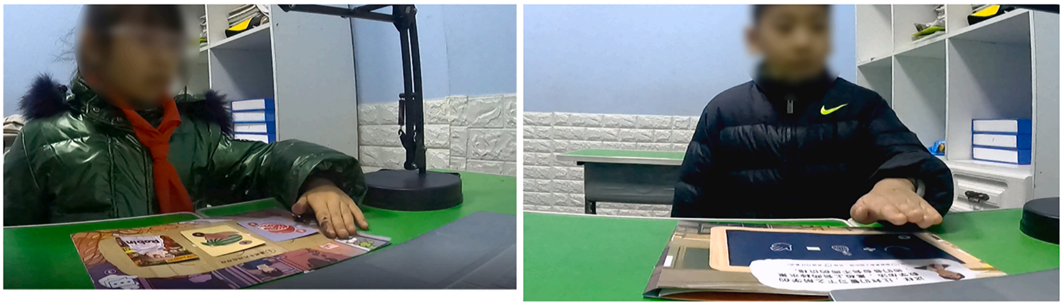

Fig. 4. Children interacting with the storybook using virtual buttons and target tracking.

5. Results

5.1. Normality

Since our sample size (N = 31) is near to the boundary of where data tends toward a normal distribution in accordance with the central limit theorem, which demands sample sizes greater than 30 or 40 [41], we run a normality test.

The results indicate non-normality for all the data collected ($p < 0.05$). Therefore, non-parametric statistics have been applied in the analysis of comparisons and correlations. For the within-group comparison, the Wilcoxon S-R test was conducted. For between-group tests like gender differences, the Mann-Whitney *U* test was applied.

5.2. Fantasy narrative vs daily narrative

To answer RQ1—"How do two AR fantasy settings (fantasy /daily) in games influence the general experience?"—we conducted a comparison between fantasy and daily conditions. A Wilcoxon Signed-Ranks test indicated that the imagination brought on by the fantasy version (mean rank = 11.06) of MathMythos AR V2.0 is significantly higher than in the daily version (mean rank = 7.33), Z = −3.12, p = 0.002. The experience of presence in the fantasy version (mean rank = 9.15) is significantly stronger than in the daily version (mean rank = 8.50), Z = −2.00, p = 0.042. The identification score in the fantasy version (mean rank = 9.08) is higher than in the daily version (mean rank = 8.75), Z = −2.00, p = 0.046. No significant difference is found in the two versions' autonomy, enjoyment, analogy, and satisfaction scores. In general, players perceive higher presence, fantasy states of imagination, and identification when playing the fantasy version of the game.

5.3. Mediation

To investigate RQ2—"What are the mediation effects of fantasy states on the relationship between fantasy settings and enjoyment?"—we performed a mediation analysis. Mediation is a complex regression procedure. A simple mediation model explains how the independent variable X influences the dependent variable Y by the mediating variable M [42,43]. The path from X to Y (c') is called the direct effect. The pathway from X to Y through M (ab) is called the indirect effect. The total effect is the sum of the direct and the indirect effect. In this research, we use the bootstrap method with 5000 samples. As bootstrap is a distribution-free method, it applies to non-normally distributed data [44]. If the bootstrapped confidence interval does not straddle 0, the statistically significant indirect effect is validated, and the mediation model is significant [42,43]. The result is presented in the diagram indicating the mediational relationship and the beta weight on each path. The total effect's R square is reported below the diagram. Tables of Bootstrap [45] results are provided below diagrams.

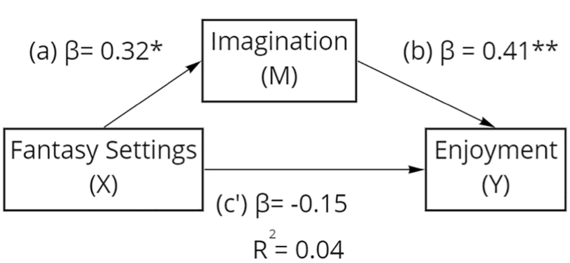

Fig. 5. The Mediation model uses imagination as the mediator (M), and **enjoyment** as the outcome **(Y)**, controlling gender.

Fig. 5 and Table 2 show the Mediated regression with setting as the predictor (X), imagination as the mediator (M), and enjoyment as the Outcomes (Y). Imagination as the mediator brings significant indirect effects to enjoyment (their bootstrapped confidence intervals exclude zero). There is no significant direct effect between X and Y in the model (their bootstrapped confidence intervals include zero). This mediation is valid because current mediation practice no longer requires a precondition of the relationship between X and Y [42]. When the relationship between X and Y entirely accounts for M, it is often interpreted as a full (complete) mediation.

The direct effect value of the enjoyment model indicates there is a negative but not statistically significant direct effect of the game's narrative setting. Mediated by imagination, the indirect effect leading to enjoyment becomes significantly positive. The opposite signs before the value of the model's direct and indirect effects make these three models inconsistent mediations [46,47]. The resulting total effect is insignificant because the total effect is the sum of direct and indirect effects. In this case, the mediation model still can be accepted [48].

After identifying imagination as the key in the relation between conditions and enjoyment, we were curious to see if player experience plays a role in the relationship between imagination and enjoyment. Therefore, we present a mediation analysis (Fig. 6, Table 3) to answer RQ3—"What are the mediation effects of the player experience of need

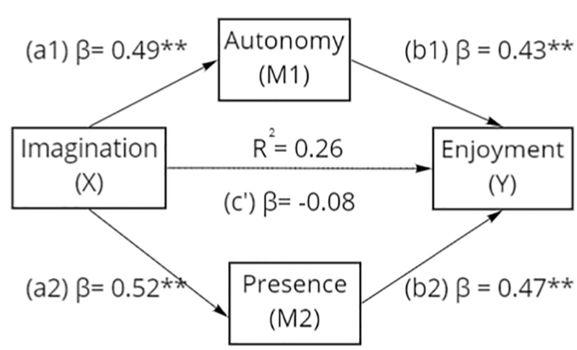

Fig. 6. The Mediation model uses **imagination** as the Predictor (X), **autonomy** (M1), and **presence** (M2) as the mediators, and **enjoyment** as the outcome (Y), controlling for gender.

satisfaction on the relationship between fantasy states and motivation?".

Fig. 6 and Table 3 indicate a significant mediation effect while setting autonomy and presence aspects of players' need satisfaction as mediators between the relationship of imagination and enjoyment.

6. Discussion

We present two mediation models to investigate the relationships between fantasy states (analogy, imagination, identification), player experience (autonomy, presence), intrinsic motivation (enjoyment), and the two conditions (daily and fantasy). The models demonstrated that imagination acts as a mediator between fantasy settings and enjoyment; autonomy and presence act as mediators between imagination and enjoyment. This section interprets the findings and explores answers to the research questions, laying the groundwork for synthesizing design strategies of employing AR fantasy in game-based learning.

6.1. How do different AR fantasy settings in games influence the general experience?

The Wilcoxon Signed-Ranks test shows players perceived significantly stronger imagination, presence, and identification in the fantasy narratives. The result of higher imagination scores under a fantasy narrative meets our expectations. This result suggests that designing a fantasy game world with events that deviate from real-world settings can trigger players' imagination in serious gameplay. Participants' presence and identification scores are significantly higher in the fantasy context and could be attributed to both the effect of fantasy [21] and AR [14]. In alignment with previous research, fantasy avatars and stories provide imaginary characters that allow players to identify themselves with, fulfilling their emotional needs [16]. This result suggests an integration of AR and fantasy can maximize both affordances and enhance players' immersive experience more than a daily setting in game-based learning.

6.2. What are the mediation effects of imagination and identification on the relationship between fantasy settings and enjoyment?

We found differences in scores of imagination and identification but no difference in enjoyment between conditions, which leads us to explore any mediated effect between the game's fantasy settings and the player's enjoyment. The results show that only imagination mediated the relationship between game conditions and enjoyment. Although previous research suggests that identification is central for motivation [49], our result indicates that the richness of the imaginative fantasy scenario plays an even more central role. This result suggests that designers should focus on designing for worlds that foster imagination over analogy and identification. It is more important that fantasy games create imaginary realms than that they enable identification with a representation, at least as it appears for our current demographic and learning context. Similar examples are often found in commercial games: even if players do not identify with fictional characters like Geralt of Rivia from "The Witcher", or Link from "The Legend of Zelda," these games can still provide joyful and immersive environments that stimulate their fantasy.

6.3. What are the mediation effects of need satisfaction on the relationship between fantasy states and motivation?

Autonomy's mediating role in the model emphasizes imagination with fantasy enables players to approach AR game-based learning more as gameplay rather than a learning tool. Our findings imply that even though the game interaction remains unchanged, game storylines that elicit greater imagination can help players feel more autonomous, allowing them to enjoy AR game-based learning more. Related back to Ryan et al.'s finding that intuitive control increases users' autonomy, users' autonomy, in turn, predicts their enjoyment in games. We recommend designing fantasy environments with open-thinking, choice, options, opportunities that stimulate imagination in game-based learning.

Additionally, the experience of feeling present in the fantasy in game-based learning is also a fundamental bridge to motivational learning. AR technology combines an imaginary world with the real world, creating a feeling of presence and being placed within mixed reality [46]. Employing fantasy that stimulates players' imagination in AR creates an immersive experience that makes learning more enjoyable and motivating to players. Stapleton [50] defines the immersive effect of fantasy and AR as a Mixed Fantasy Continuum. Following Stapleton, our findings support that imagination is the key to motivational gameplay. We assume that because fantasy enables players to experience more presence, fantasy enhanced game-based learning will be experienced as more enjoyable.

6.4. Individual preference for fantasy

We noticed gender differences in our study: participants identifying as male scored significantly higher in autonomy, presence identification, and analogy, but only in the fantasy condition. While we aimed to eliminate gender effects by designing two gender-neutral character conditions in our design, children might still have perceived the role of Rubin in the fantasy setting as more boyish than Robin in the daily setting. Another explanation could be that boys are more frequently exposed to fantasy game contexts than girls [51]. They perceive such types of fantasy as familiar stories, which makes it easier for them to enter into a paratelic (playful) mindset and subsequently rate their perceived autonomy higher. Children's preference for fantasy settings in games is often regarded as a choice predicated by their fantasy proneness [52] and fantasy orientation [53]. The application of avatar and narrative customization [49] can be a solution to accommodate individual preferences.

6.5. General descriptive data

The general descriptive data (Table 1) shows children enjoy playing both settings of MathMythos AR V2.0. Their high level of presence shows that Augmented Reality can foster enjoyment. Their elevated autonomy and enjoyment scores across both conditions suggest that the AR game is being regarded as a play activity capable of successfully engaging children in math learning. Although a pretest version without AR is not applied as a comparison group in our research, we find in previous work that virtual environments like AR can increase users' presence [55]. Since AR's novelty can be a vital factor here, for those who had never experienced AR, comparing fantasy and daily settings in

Table 1
Descriptive Statistics of identification, analogy, imagination (FSS), and autonomy, presence (PENS), enjoyment (IMI) in fantasy narrative and daily narrative conditions.

	Identification M (SD)	Analogy M (SD)	Imagination M (SD)	Autonomy M (SD)	Presence M (SD)	Enjoyment M (SD)
Fantasy	3.65(0.45)	3.43(0.6)	3.48(0.58)	3.66 (0.44)	3.50 (0.35)	3.63 (0.49)
Daily	3.44(0.63)	3.46 (0.59)	3.16(0.60)	3.52 (0.58)	3.42 (0.45)	3.63 (0.44)

Table 2
The effect, Standard Error, upper and lower limits of 95% confidence intervals of Bootstrapping (5000 samples) results for **enjoyment**, mediated by imagination.

	Effect	SE	BootLLCI	BootULCI
Indirect Effect	0.13	0.075	0.24	0.33
Direct Effect	−0.15	0.11	−0.36	0.07
Total Effect	−0.02	0.12	−0.25	0.22

[1] *$p < 0.05$; **$p < 0.01$.

Table 3
The effect, Standard Error, upper and lower limits of 95% confidence intervals of Bootstrapping (5000 samples) results for **enjoyment**, mediated by imagination.

	Effect	SE	BootLLCI	BootULCI
Indirect Effect (Total)	0.45	0.12	0.23	0.69
Indirect Effect (Presence)	0.24	0.10	0.07	0.48
Indirect Effect (Autonomy)	0.21	0.07	0.09	0.36
Direct Effect	−0.08	0.11	−0.28	0.12
Total Effect	0. 37	0.12	0.20	0.55

[1] *$p < 0.05$; **$p < 0.01$.

our game may be less impactful than the technology itself.

7. Limitation and future work

There are a few limitations to the experimental setup. Children, in general, give overly optimistic results, potentially because children find understanding neutral emotion challenging and tend to give extreme answers [40]. Additionally, some children may respond to meet what they think is the experimenter's expectation to achieve recognition from adults [54]. Although we apply an animated scale to reduce children's burden on understanding the questionnaire, they still appear to have difficulty understanding reversed posed questions. A pre-instruction of the Likert scale and reversed questions for child participants might be needed for young participants in future research. We provide a magic school life and a daily school life of narrative contexts in our designed game. More types of fantasy remain to be explored.

The purpose of our study was to investigate the interplay of autonomy and presence and their relationship with fantasy states and enjoyment. Therefore, exploring other associations, such as the influence of competence on fantasy experience and enjoyment, would require a different focus in the study design and data collection, e.g., through investigating a competitive game.

There are more profound and complex implications to be explored in future work. The learning outcomes were not our prime focus in this research, but the effect of mixed fantasy on learning, e.g., cognitive skills, working memory, is worthy of exploration. There are three promising directions for our future research: (1) the after-play effect of mixed fantasy in game-based learning; (2) the application of narrative choice and fantasy customization in AR serious games; and (3) the educational benefits of fantasy and imagination.

8. Conclusion

Our work aims to understand the influence of fantasy elements on children's serious gameplay experience through MathMythos AR V2.0. We found that fantasy contexts stimulate a significantly higher imagination, presence, and identification in children. Their imagination plays an essential role in bridging the fantasy context to enjoyable AR game-based learning experiences. An AR fantasy context creates a mixed fantasy, where imagination is a crucial bridge to transgress the liminal interface between the real world and the game world, between playing and learning. It is also notable that children's autonomy and presence are critical mediators between their imagination and enjoyment. Based on these findings, the following suggestions are concluded from the previous discussion for serious game designers to consider when designing for children in a classroom setting: 1) The design of fantasy elements in an AR game should stimulate players' abilities to imagine 2) The design integration of fantasy should stimulate creating imaginary realms over how players identify with the game 3) providing a fantasy context with openness and creativity, immersion, and mixed fantasy can enable players to enjoy game-based learning through imagination towards fantasy; and finally, 4) according to various individual preference, fantasy characters and storylines can be tailored to specific gender groupings or personal tastes.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

We would like to express our deep and sincere gratitude to colleagues and friends who helped contact the local school and conduct the experiment in Qingdao. We are grateful to friends who gave technical support in game development, friends who gave support on experiment measures.

Funding

This work was supported by the Chinese Scholarship Council [grant numbers 201806790091].

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.entcom.2022.100480.

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