

1 **Evaluating the intention of downloading augmented reality games**

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16
17 **Abstract**

18 Recently, augmented reality (AR) games have gained popularity as consumers'
19 acceptance for AR games as a new lifestyle is rising. In this study, we use the gray relational
20 analysis method to construct players to evaluate the factors and order of downloading AR
21 games. Finally, Pokémon GO, Pet City, and My Hero GO, three different AR games, were
22 evaluated for player download factors to provide game developers with reference indicators
23 for developing real-life games.

24 *Keywords: Augmented Reality, Grey Relational Analysis, Position Model*

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27 **1. Introduction**

28
29 The augmented reality (AR) market share has been dramatically
30 increasing since being viewed as an integral part of new technology
31 products by the general public, businessmen, and students. Therefore,
32 understanding the motivation for the intention of use by the public toward
33

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1 AR games has become a topic of interest. In July 2016, the Pokémon GO
2 online game market, the use of smartphones on AR virtual objects, and real
3 environment integration, all contributed to making AR games trendy. Unity
4 3D is a game development platform that allows virtual game characters
5 to interact with the real world, players can use their own smartphones
6 and embed photo images into Unity 3D and then use Qualcomm AR
7 development program technology to complete the build of a game. We
8 were able to overcome the problem of virtual and real environment
9 integration of software and hardware; however, the sustainability and the
10 willingness of players downloading remain a problem. Su[1] proposed the
11 “psychologist want to tell you” issue analysis, Pokémon GO can be difficult
12 for players to extricate themselves as the four major charms include (1)
13 classic reproduction: a lot of children have significant memories regarding
14 Pokémon, so the fact that this “unrealistic” content can live in real life
15 provides a unique attraction; (2) the virtual and real collision of new fun:
16 with virtual and real life staggered, people expect to encounter a surprise
17 as they turn a corner; thus, many players at every turn will take out their
18 phone to confirm this; (3) interpersonal links: another type of community
19 and interpersonal links are created as people meet and cohere; (4) exercise:
20 because this is an AR game, the actual situation is integrated; hence, many
21 people at home are willing to take to the streets, indirectly feeling the
22 benefits of exercise. Peng et al. [2] proposed a phone with AR and the
23 world map combined so that players subject to an indoor environment can
24 bring the virtual world into real life, making the video game suitable for
25 use at home. It also gives the wisdom machine a new role to become an
26 AR hand-wear device. Lin [3] applied social grooming and the signaling
27 theory to explain how we look at each other when facing concern about
28 a situation, or praise, among others, to represent the social interaction
29 between people, which will be created using Pokémon GO.

30 In this study, the gray relational questionnaire, presented by Lin et al.,
31 Chang et al., Huang et al., and Mahalik [4, 10, 11] was used to analyze the
32 same attributes of the questionnaire in the game market in 2016 and 2017.
33 The three AR games Pokémon GO, Pet City, and My Hero GO, participated
34 in the evaluation of players (1) to experience playing these three games
35 simultaneously, and (2) willing to accept an online assessment. Through
36 the player’s download and play, the intentions of the AR game are to assess
37 the player and provide game developers with the factors players consider
38 when downloading the game.

2. Determining the download AR game intention using GRA

The concept of grey relational space was proposed by Deng based on the combined concepts of system theory, space theory, and control theory [5, 6]. It can be used to capture the correlations between the reference factors and other compared factors of a system. One of the features of GRA is that both qualitative and quantitative relationships can be identified among complex factors with insufficient information (relative to conventional statistical methods). Under such conditions, the results generated by conventional statistical techniques may not be acceptable without sufficient data to achieve the desired confidence levels. In contrast, the grey system theory can be used to identify major correlations among system factors with a relatively small amount of data [12]. The procedure for calculating the GRA is as follows:

Step 1: Determine the analysis sequence

Let X_0 be the referential series with k entities (or criteria) of $X_1, X_2, \dots, X_i, \dots, X_N$ (or N measurement criteria). Then

$$\begin{aligned} X_0 &= \{x_0(1), x_0(2), \dots, x_0(j), \dots, x_0(k)\}, \\ X_1 &= \{x_1(1), x_1(2), \dots, x_1(j), \dots, x_1(k)\}, \\ &\quad \vdots \\ X_i &= \{x_i(1), x_i(2), \dots, x_i(j), \dots, x_i(k)\}, \\ &\quad \vdots \\ X_N &= \{x_N(1), x_N(2), \dots, x_N(j), \dots, x_N(k)\}. \end{aligned}$$

Step 2: Data normalization

Before calculating the grey relation coefficients, the data series can be treated based on the following three situations, and the linearity of data normalization, to avoid distorting the normalized data [7]. They are

(a) Upper-bound effectiveness measuring (i.e., larger-the-better)

$$x_i^*(j) = \frac{x_i(j) - \min_j x_i(j)}{\max_j x_i(j) - \min_j x_i(j)} \quad (1)$$

(b) Lower-bound effectiveness measuring (i.e., smaller the better)

$$x_i^*(j) = \frac{\max_j x_i(j) - x_i(j)}{\max_j x_i(j) - \min_j x_i(j)}. \quad (2)$$

1 (c) Moderate effectiveness measuring (i.e., nominal-the-best)

2 If $\min_j x_i(j) \leq x_{ob}(j) \leq \max_j x_i(j)$, then

$$3 \quad x_i^*(j) = \frac{|x_i(j) - x_{ob}(j)|}{4 \quad \max_j x_i(j) - \min_j x_i(j)} \quad (3)$$

6 If $\max_j x_i(j) \leq x_{ob}(j)$, then

$$8 \quad x_i^*(j) = \frac{x_i(j) - \min_j x_i(j)}{9 \quad x_{ob}(j) - \min_j x_i(j)} \quad (4)$$

11 If $x_{ob}(j) \leq \min_j x_i(j)$, then

$$12 \quad x_i^*(j) = \frac{\max_j x_i(j) - x_i(j)}{13 \quad \max_j x_i(j) - x_{ob}(j)} \quad (5)$$

15 where $x_{ob}(j)$ is the objective value of entity j .

17 **Step 3:** Calculate the correlation coefficient

18 The grey relational coefficient between the compared series X_i and
19 the referential series of X_0 at the j -th entity is defined as

$$21 \quad \gamma_{0i}(j) = \frac{\Delta \min + \Delta \max}{22 \quad \Delta_{0j}(j) + \Delta \max} \quad (6)$$

23 where $\Delta_{0j}(j)$ is the absolute value of the difference between X_0 and X_i at
24 the j -th entity, that is: $\Delta_{0j}(j) = |x_0(j) - x_i(j)|$ and $\Delta \max = \max_i \max_j \Delta_{0j}(j)$,
25 $\Delta \min = \min_i \min_j \Delta_{0j}(j)$.

27 **Step 4:** Calculate the grey relational grade

28 The grey relational grade (GRG) for a series of X_i is given as

$$29 \quad \Gamma_{0i} = \sum_{j=1}^K w_j \gamma_{0i}(j) \quad (7)$$

31 where w_j is the weight of j -th entity. If it is not necessary to apply the
32 weight, take $w_j = \frac{1}{K}$ for averaging.

34 **Step 5:** Sort the GRG

35 After calculating the GRG of the $X_i(k)$ sequence, the average value
36 of the correlation coefficients is calculated, and the average value Γ_{0i} is
37 called the GRG of $X_i(k)$.

1 **3. AR Game Description and Player Download Evaluation Process**

2 3.1 *AR game introduction*

3 (A) Pokémon GO

4 In 2016, Nintendo published the Pokémon GO AR game in the
5 Android and iOS platforms. The total number of downloads is more than
6 500 million. The number of people who have played Pokémon GO has
7 reached 4.6 billion kilometers, equivalent to the distance between Earth
8 and Pluto [8]. The game is based on the use of AR technology combined
9 with Google Maps, portable smart mobile devices, and installed AR virtual
10 objects. The virtual object can be integrated with the real environment, the
11 player can walk along a street, find the right position where a wizard can
12 be caught and treasure can be grasped. According to Li [9], statistics show
13 Pokémon GO has five world records, provided below.

- 14 (1) During the first month after launch, of the game reached a revenue
15 of up to \$ 250 million, the highest for a mobile phone game.
- 16 (2) In the first month after launch, the number of downloads of mobile
17 phone games was up to 130 million downloads. With the number
18 of Pokémon GO players being more than the population of the
19 Philippines of 30 million people.
- 20 (3) During the first month after launch, the game topped the list of 70
21 countries and regions.
- 22 (4) The game reached the top of the national revenue list of mobile
23 games in 55 countries and regions.
- 24 (5) 20 days after release, the game was the fastest to break revenue of
25 100 million dollars in mobile games.

26 (B) Pet City

27 Pet City is a pet-oriented AR mobile game in which the player acts as
28 a pet farm operator. Through mobile phone positioning in the real world,
29 and through the collection of Gold coins and more, a variety of pets can be
30 captured, pets can be individual or exclusive farm pets. The game features
31 are as follows:

- 32 (1) players can arrange farm and community interaction and other
33 functions.
- 34 (2) AR technology and the player's real-life situation are combined to
35 capture more than 30 varieties of pet animals.

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- 1 (3) players can experience farm-rearing animals, the longer a player
- 2 watches their pet, the bigger they grow.
- 3 (4) a variety of decorative buildings, allowing the player to lay out an
- 4 exclusive farm shape.
- 5 (5) hundreds of puzzle hurdles, players can take a pet with a challenge.
- 6 (6) players can take pictures of their own farm and share with friends.
- 7

8 (C) My Hero GO

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10 My Hero GO is a game that combines AR with mobile positioning
11 technology to go outdoors in urban and rural areas, and with ancient
12 and modern heroes, the role of the game is the fusion of Chinese culture
13 legend so players are able to collect and exchange distinctive heroes in any
14 country, city, street or alley. The hero exchange function provides players
15 with a more exciting gaming experience as they have the opportunity to
16 collect rare heroes, through time and space, composed of the strongest
17 hero clan. The game's collection of heroes, and the creative role, allows
18 players to have an educational experience as they become intimate with
19 their characters' backgrounds and stories.

20 21 3.2 *Player download evaluation factor*

22 The common features of the three AR games mentioned are (1)
23 outdoors, as they combine with the real external environment, (2) the
24 script content is attractive to players to download and play these games.
25 This study proposes four major charm factors: classic reproduction, virtual
26 and real collision of new fun, interpersonal, and sports. This study uses
27 the GRA questionnaire [4, 10, 11] to evaluate the combined value of these
28 three AR games, providing game developers with important reference
29 factors for designing AR games. The evaluation process is as follows:

30
31 **Step 1:** Completion of the online questionnaire and the selection of an
32 assessor.

33 A total of 47 players in the community network accepted the GRA
34 questionnaire for the three AR games Pokémon GO, Pet City, and My
35 Hero GO. The GRA questionnaire answers involve a scale from 0 to 1,
36 the more full the scale the better the characteristics, the less full the scale,
37 the better the features; the questions are of a moderate nature. The GRA
38 questionnaire has four topics, defined as follows:

- 1 (1) Education: memories throughout the course of life, a common
2 knowledge or historical stories, can cause players to talk about the
3 topic.
- 4 (2) New fun: the combination of virtual and real scenes allows players
5 to play a role in the virtual world, creating new fun.
- 6 (3) Interpersonal links: in the virtual world, a player is linked to the
7 common organization of a virtual team, historical or fictional stories
8 are imitated to complete a task.
- 9 (4) Exercise: Participants are able to walk outdoors and work together.
10

11 **Step 2:** Guide the player to complete the online questionnaire

12 There are four assessment questions, including educational, virtual
13 and real collision of new fun, interpersonal links, and sports. According to
14 the characteristics of these four questions, the bigger the better. Therefore,
15 to guide the player to fill the direction of 1, on behalf of the bigger and
16 better features, close to 0 is the smaller the better features. In this case,
17 the four characteristics are the bigger the better, and after filling, the 47
18 questionnaires were averaged. The calculated average is shown in Table 1.

19 **Step 3:** Data normalization and calculating the difference sequence
20

21 The four questions, with the bigger the better features, were evaluated
22 using the information in Table 1, the reference sequence can also be found.
23 $x_0 = (0.82, 0.94, 0.83, 0.92)$. Eq. (1) was used to normalize the data, then eq.
24 (6) was used to calculate the comparison sequence. The results from the
25 calculation are shown in Table 2.

26 **Step 4:** Calculate the degree of gray correlation
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28 Eq. (6) was used to calculate the degree of gray correlation, the
29 results of which are shown in Table 3. The correlation value represents the
30 importance of the three AR games in the four evaluation questions. Then,
31 eq. (7) was used to calculate the GRG, the results are shown in Table 4. In
32 the 47 players comprehensive evaluation of the value found to download
33 play sort for Pokémon GO, My Hero GO and Pet City.

34 **Step 5:** Draw the association graph
35

36 According to step 4, to calculate the degree of grey correlation of the
37 three AR games, an association diagram was drawn, as shown in Figure
38 1. From Figure 1, the importance of the four GRA evaluation questions is
39 clear.
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Table 1
Questionnaire assessment values

Criteria AR Gmae	Education	New Fun	Interpersonal links	Exercise
Pokémon GO	0.62	0.94	0.78	0.92
Pet City	0.46	0.66	0.58	0.63
My Hero GO	0.82	0.76	0.83	0.78

Table 2
Resultant of Δ_{oi} (j)

Criteria AR Game	Education	New Fun	Interpersonal links	Exercise
Pokémon GO	0.56	0	0.2	0
Pet City	1	1	1	1
My Hero GO	0	0.64	0	0.48

Table 3
Summary of the Resultants Relational Coefficients

Criteria AR Game	Education	New Fun	Interpersonal links	Exercise
Pokémon GO	0.64	1	0.83	1
Pet City	0.5	0.5	0.5	0.5
My Hero GO	1	0.61	1	0.67

Table 4
Summary of the GRG Γ_{oi}

AR Game	Γ_{oi}	Rank
Pokémon GO	0.87	1
Pet City	0.5	3
My Hero GO	0.82	2

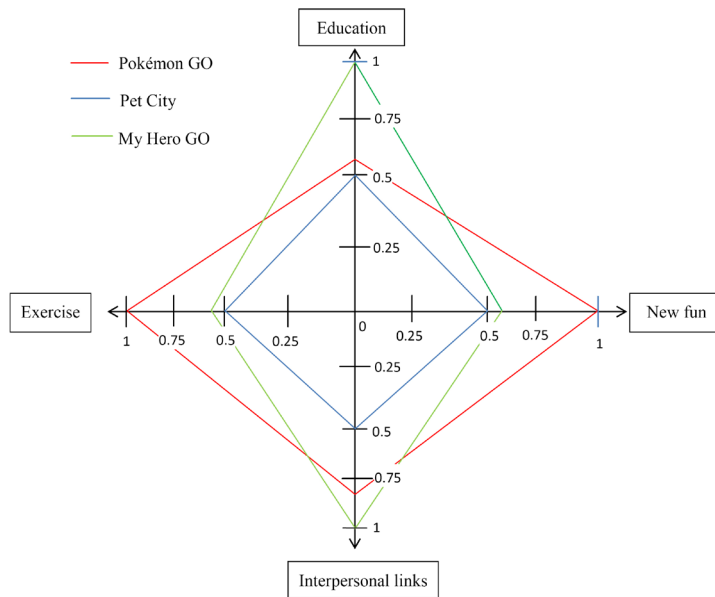


Figure 1
AR Games Association Graph

4. Conclusion

AR is a popular topic, virtual reality technology has been widely used in industrial, medical, logistics, and other various fields. Through the social function of the game platform, game operators can expand to advertising, direct marketing, and even mobile e-commerce. AR allows the game industry and AR industry people to explore a new business model or new game product development model. This study constructs the GRA evaluation framework to evaluate the psychological factors that players utilize in AR games to improve the willingness of players to download and continue to play AR games. This provides game developers with an important reference for the design of virtual reality games. The contribution of this study is as follows:

- (1) This study used the internet to download the most popular three AR games, and to understand players' motivation to download and to continue to play the games.
- (2) Through this study, it is clear to understand why the mentality of the three AR games can help game developers to develop new games or

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1 improve the function of existing games, shortening the gap with the
2 player's awareness.

- 3 (3) This study used a GRA questionnaire to provide players with the
4 choice of a comprehensive evaluation of the weight of the three
5 AR games and provided players with a reference to download AR
6 games.
7
8 (4) The player can make an objective measurement and description of
9 the weight of the player's experience through the evaluation decision
10 model of this study.

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