Research on the Interaction Design of AR Picture Books via Usability Test

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Abstract. In children's books, picture books account for seventy percent. With the development of information technology, picture book with Augmented Reality (AR) is an emerging application under the influences of digital technologies, which is a new kind of picture book with the auxiliary of games. The AR picture book bases on the children's cognitive level and the operation of the mobile devices, satisfying their needs of exploring and learning new things. Under the literature review and competitive analysis, we exploratively put forward the prototypes of interactive AR picture books, especially for the kids aged from 5 to 8. Furthermore, we designed the usability test on one of our prototypes, Rocket Dream, to better understand the process of interaction design. According to the results, we testify the feasibility of AR picture books as well as figure out some issues in the interaction processes, such as the weak guidance in the interactive operation, incomplete essential information in the interface, as well as the fact that children's preference of visible interaction and touch operations and they are more sensitive to large objects. Also, we propose potential solutions to these issues in the following parts, which could be useful for the future of AR picture books.

Keywords: AR picture books · Human-computer interaction · Interaction design · Child education · Usability test

1 Introduction

With the popularity of mobile intelligent terminal and the development of mobile communication network technology, the development of mobile applications start booming. More and more children are beginning to contact digital mobile platform. Digitalization is changing the children's reading, learning, education methods [1]. Gradually the standard of people's life is improving, and the investment to children's education also gradually increase. And the development of children-related applications become popular. And with the emergence of a growing number of mobile applications, the forms of human-computer interaction are becoming more and more diverse, from the initial simple clicks and drags, to today's more attractive interactions, like the multi-touch and the virtual space. People continue to pursue a more rich, three-dimensional and more vivid interactive experience.

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The picture book is an important medium for children to read and study, which is described as "the presentation of early childhood culture" and is also known as the golden key to unlocking the treasure house of life [2]. And the single reading model in the traditional kind already can't satisfy the needs of children exploring the world. Children in growth keep looking for more interesting and more operational models of learning. The diversity and technicality in children's publications directly impact on the experience gained by the children in reading [3]. Picture book combining with Augmented Reality (AR) emerges under this background, with the help of AR interactions, to combine the real space and virtual 3D models. Also, it could maximally give a virtual scene, containing complete and convenient experience, which can not only meet the paper reading experience, but offer a magical effect from plain text to 3D motions, to bring brand-new "more than one paper screen" reading experience.

According to the 2010 Children's User Scale and Internet Behavior Survey Report [4], by 2010, the number of children netizens in China had reached 89.582 million, and the penetration rate of children using the Internet had reached 51%, of which 67.7% of children think that the Internet is their favorite form of media. 5–8 years old child is in a critical period of the development of education. At this stage, children have strong curiosity and strong thirst for knowledge, thinking and consciousness. Although their consciousness fails to certainly fit the objective world, they already have preliminary abstract thinking. However, AR picture books could covert the obscure knowledge, into dynamic learning contents, to satisfy children's curiosity, attract their attentions, enhance the multi-dimensional knowledge transition, improve the experience of children's education, and also increase the communications between parents and children.

Interaction activity is the biggest difference between AR children picture books and traditional paper picture books. A good interaction design can attract children to read, enhance children's understanding of the content, and improve the immersive reading. It allows the transformation from the previously "fragmented" browsing reading mode into a state of in-depth reading in a visual, sensible space [5]. The AR children's picture books develop rapidly, while many products are not particularly mature. The main issues are listed following: the age positioning is not clear; the performance of the user experience is poor; the interactive design is not in conformity with the children's characteristics of operation and so on. This paper aims to focus on the improvement of interaction design in AR picture book, via the usability test on current prototype of it.

2 Background in AR Picture Books

Virtual Reality (VR) is a kind of computer simulation system, which can create and experience the virtual world. It utilizes computers to generate a simulation environment in both vision and physic, which combines multi-source information and interactive 3D, from the visual, auditory level to provide virtual scenarios for users.

Augmented Reality (AR) is a growing technology on basis of VR. Compared with VR, AR has real and simple scenario models. Augmented Reality technology provides the possibility to realize a variety of information presentation under the combination of virtual and real. No matter what kind of interface mode [6], it will rely on AR technology for visual presentation to achieve the purpose of natural interaction. The report

of Battelle Memorial Institute showed top 10 strategic technics in 2020, where AR ranked 10th place [7].

The picture book is not only a tool for children to read, but also a means for children to participate in interaction and exchange of ideas, hence the interaction of children's picture books is particularly important [8]. At present, in the entire AR book market, the proportion of books in early childhood education is as high as 90%, while the AR publications in the field of children's education and publishing mainly focus on children's knowledge learning publications, children's science publications and textbooks [9]. The common format of AR books is "books + mobile devices + app".

At the beginning, AR picture books allow users scanning 2D figures to display 3D models with pre-set gestures. After a period of time, the trend of AR picture books evolves from "look" to "play". "Paint & Fun" is a new interaction of AR game, which has white paper and wireframes for painting. After scanning with the mobile devices, users could see the 3D model of their paints, also they could make some interactions with the models, such as moving, zooming, rotating, etc. Today's AR picture books possess multimodal interaction patterns, and pay great attention to the optimal presentation mode of the combination of virtual and real interface and 3D model [10]. As shown in Fig. 1, taking The Adventure of Trilobite Pangpang AR book as an example, readers could download apps on their mobile phones or tablet. Then they could use the App scanning on the specified page in the book, to see dinosaurs. Through clicks and drags by single finger, and scaling by two fingers, they can interact with the dinosaurs, like rotation and scaling, accompanying with the sounds of roar.

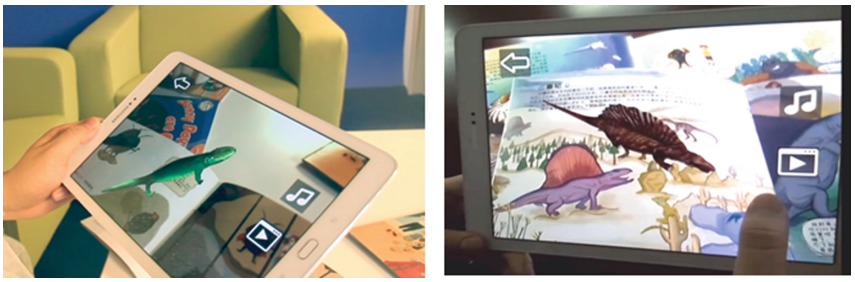


Fig. 1. The Adventure of Trilobite Pangpang Interaction diagram

3 Rocket Dream

Rocket Dream uses the combination of multiple comics and cross-page with a total of 19 large pages, of which 10 pages are storytellings and 9 pages are interactive games, where the interactive games are interspersed in the story. The story draws forth the knowledge point explanation of the interactive game, while the interactive game promotes the narrative process of the story. The screenshot of the picture book is shown in Fig. 2.

The application interface and functions are shown in Figs. 3, 4 and 5.

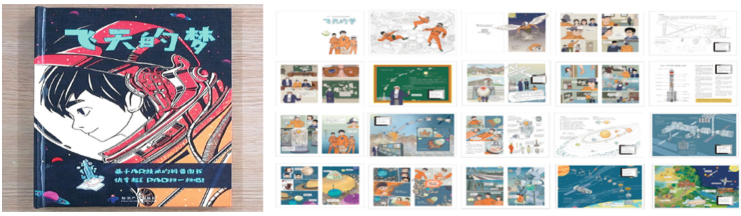


Fig. 2. The finished book and picture book of *Rocket Dream*

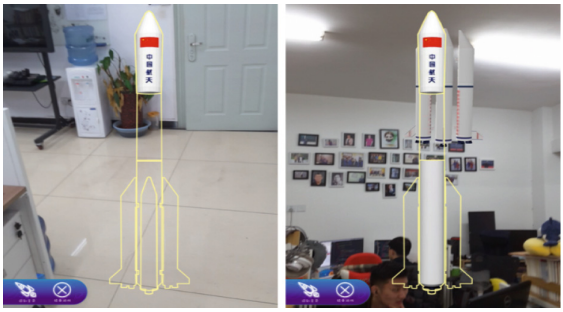


Fig. 3. Virtual and real interaction - space-aware rocket structure assembly game

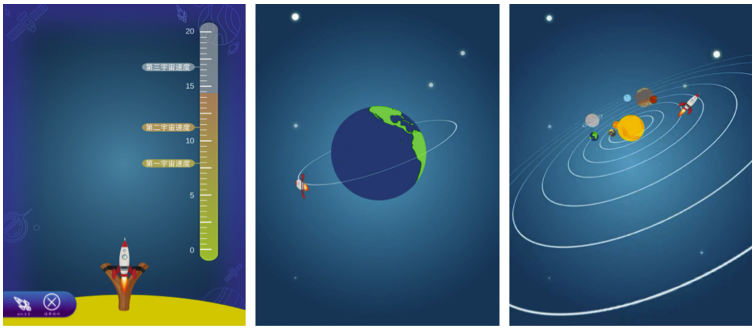


Fig. 4. Virtual and real interaction - rocket launch game

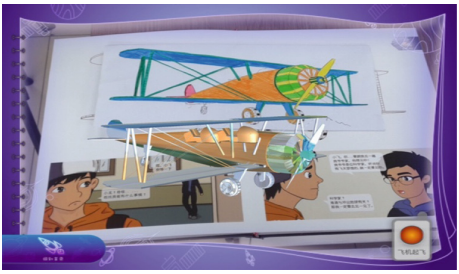
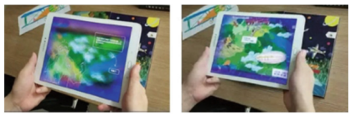
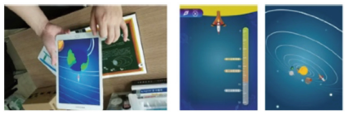
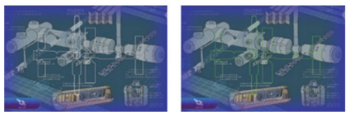


Fig. 5. Virtual and real interaction - AR coloring interactive gameplay

The interactive games are divided into the following 9 categories. The specific types and screenshots are shown in Table 1:

Table 1. *Rocket Dream* interactive game classification

Content	Interactivity Type	Screenshot
History Introduction	2D Interactive Animation	
Aircraft	Paper Painting	
Cosmic velocity	Entertainment Game	
Spacecraft	Paper Painting	
Rocket parts	Virtual Assemble	
Launch process	Video Display	
Solar system	Virtual 3D Model	
Space station	2D Plane Assemble	
Rocket return cabin	Video Display	

4 Usability Test Design

This experiment aims to evaluate the usability of the AR interactions in *Rocket Dream* AR. According to the interview, we collect the data of their feedbacks. Then, we suggest potential improvements based on the analysis of the data.

4.1 Sample Space

Details of the sample space are shown in the Table 2.

Table 2. Sample space of the volunteers

Volunteer	Gender	Age	Grade	School	Parents' occupation	Ever tried AR products?	Ever read AR picture books?
A	M	5	Preschool	Houxiaohe Primary School	Staff	No	No
B	M	6	1st	Houxiaohe Primary School	Middle school teacher	No	No
C	F	6	1st	Beijing World Youth Academy	Staff	No	No
D	F	7	1st	Beijing World Youth Academy	Freelancer	No	No
E	F	7	1st	Beijing World Youth Academy	Freelancer	No	No
F	F	8	2nd	Beijing World Youth Academy	College teacher	Yes	Yes
G	M	8	2nd	Houxiaohe Primary School	Middle school teacher	No	No
H	F	8	2nd	Houxiaohe Primary School	Doctor	Yes	Yes

4.2 Tasks

Task1: read the instruction, open the app and use the scan function to scan one page
Task2: turn to page 10, launch a rocket with the second cosmic velocity

Task3: turn to page 17, find the suspending fairing, complete assembling and launch the rocket

Task4: turn to page 24, find the orbit period of Venus

4.3 Process

Test is performed in the usability laboratory, with independent test room and observe room. There are two video cameras in the testing room: one is for facial expressions and the other is for the interactions between volunteer and mobile device. And tester takes the responsibility of observing and note taking. Detailed process is shown in the Fig. 6.

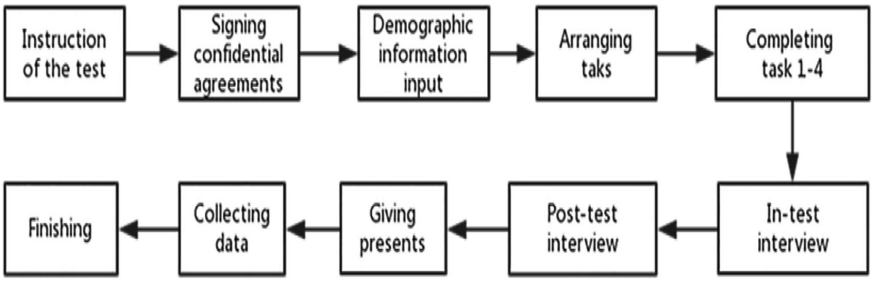


Fig. 6. The flowchart of testing process

5 Results

The metrics of this test are error rate, efficiency and user satisfaction.

Error is divided into two categories: technical error (system collapse, power off, etc.) and non-technical error.

Success: finish the test with/without hint

Hint: finish the test after hint

Help: finish the test after help

Independent Success (Ind. Success): finish the test without hint

Error rate is shown in the Table 3.

Efficiency was counted based on the time spent on each task, which is timed between the start word “start” and end word “finish” by the facilitator. Detailed data is shown in the Table 4.

User satisfaction was collected by the in-test interview. Volunteers were asked to grade each task from four perspectives, difficulty, expectation, fault tolerance, and learnability. The grade was scaled from 1 to 5. And volunteers were asked to explain their grades if the grade was below 2.

Table 3. Error rate

Success		Volunteer									
		A	B	C	D	E	F	G	H	Success rate	Error rate
Success	Task1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%	0%
	Task2	Yes	No	Yes	Yes	No	Yes	Yes	Yes	75%	25%
	Task3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%	0%
	Task4	No	Yes	No	No	No	Yes	Yes	Yes	50%	50%
Hint	Task1	Yes	Yes	No	No	No	No	No	No	75%	25%
	Task2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%	0%
	Task3	Yes	Yes	Yes	yes	Yes	Yes	Yes	Yes	100%	0%
	Task4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	87.5%	12.5%
Help	Task1	No	No	No	No	No	No	Yes	No	12.5%	87.5%
	Task2	Yes	Yes	Yes	Yes	No	Yes	No	Yes	75%	25%
	Task3	Yes	Yes	Yes	No	No	No	Yes	No	50%	50%
	Task4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100%	0%
Ind. Success	Task1	No	No	No	No	Yes	No	No	Yes	25%	75%
	Task2	No	No	No	No	No	No	Yes	No	12.5%	87.5%
	Task3	No	No	No	No	No	No	No	Yes	12.5%	87.5%
	Task4	No	No	No	No	No	No	No	No	0%	100%

Table 4. Time spent on each task per volunteer

Task	Volunteer								
	A	B	C	D	E	F	G	H	Avg.
Task1	45 s	58 s	65 s	48 s	39 s	37 s	51 s	42 s	48 s
Task2	106 s	81 s	72 s	60 s	54 s	45 s	26 s	27 s	59 s
Task3	90 s	71 s	152 s	93 s	72 s	55 s	56 s	64 s	82 s
Task4	170 s	111 s	80 s	53 s	34 s	25 s	56 s	47 s	72 s

Q1: What is the difficulty of this task? 1 refers to hard, and 5 refers to easy.
Q2: Does the task result meet your expectation? 1 refers to no, and 5 refers to yes.
Q3: Do you think this task is fault tolerable? 1 refers to no, and 5 refers to yes.
Q4: How do you grade the learnability of this task? 1 refers to hard, and 5 refers to easy.

The grades of user satisfaction are shown in the Table 5.

Table 5. Results of user satisfaction

Task		Volunteer								
		A	B	C	D	E	F	G	H	Avg.
Task1	Q1	4	4	5	5	3	3	5	5	4.3
	Q2	2	4	2	4	1	1	1	2	2.1
	Q3	2	1	1	2	1	3	2	1	1.6
	Q4	4	5	4	5	4	4	5	5	4.5
Task2	Q1	4	3	2	2	3	3	3	3	2.9
	Q2	2	3	2	5	2	3	3	2	2.8
	Q3	3	4	2	4	3	4	4	3	3.4
	Q4	3	4	3	3	2	3	5	5	3.5
Task3	Q1	4	4	3	4	3	3	5	5	3.9
	Q2	2	4	5	5	5	2	5	4	4.0
	Q3	3	4	4	4	5	3	5	5	4.1
	Q4	3	4	3	3	2	4	5	4	3.5
Task4	Q1	2	1	4	4	1	3	2	1	2.3
	Q2	4	4	5	4	4	4	2	5	4.0
	Q3	1	1	2	5	5	5	2	2	2.9
	Q4	4	4	1	3	1	4	5	5	3.4

6 Discussion

Through the analysis of the behavior of children's using mobile devices, we find that compared with adults, children's acceptance to complex gestures is low. Children tend to click on the simple gestures. Their curiosity is strong. They may click on any elements on the screen to discovery the new contents, and carries on the repetitive operations. In addition, children aged from 5 to 8 are in the developing stage of their listening, speaking, reading and writing abilities. Comparing with the abilities of speaking, reading and writing, their abilities of voice recognition are relatively high. The voice interaction not only decreases the difficulty of the use of applications for children but also attracts their attentions [11]. There are three main practical issues in our test as following.

6.1 The Lack of Guidance

This issue appears in two occasions. Firstly, there is no feedback when the users give inputs or interactions, thus users will get confused. Secondly, there is no correct guidance or feedback when the users give wrong actions.

For our users, low-age kids, real-time feedback is required. Especially, AR is a brand-new interaction for them. It is necessary to let them know clearly where they are and what the next is. We could have a hint, like animation, for the next step if users do not give correct inputs in 5 s.

6.2 The Lack of Essential Information

Young-age users have uncertainties about the location of clickable areas. There are always invalid clicks. The design of icons directly effects the identification and efficiency of children while using, and simple icons with the necessary text can directly convey the operation instruction [12]. We would better distinct where clickable areas are by using special icons, shades, animations, etc. These areas should be good-looking and easy to understand. The size of the buttons and icons should also be appropriate, and the convenience of child operation should be satisfied. Moreover, interface feedback and tips should be in a way that children can easily understand and remember. In addition, the interaction design should be more visual, and should minimize the use of text as much as possible; the interactive interface should show the current state, so that children do not be confused and misunderstood [13].

6.3 Preference of Children for Visible Interaction and Touch Operations

Compared to clickable interactions, children are more sensitive to large objects and colorful interfaces. Children prefer to interactive operation by their hands. They love to walk around in the room or outsides best. The designers should bring the sensory experience into the design, where they could implement the improvements of visual, auditory, tactile and other sensory experience functions [14]. According to the facts, the design of AR interactions needs to meet the child's psychological and physiological cognition. Thus, we may have long-term games or tasks for kids. For example, kids need to find parts and pieces by walking around to assemble the rocket. At the same time, the interface will refresh per 10 min and those parts and pieces will appear, which could be set in the system backend. Also, the refreshing time may be reduced by giving correct answers to the pre-set questions.

7 Conclusion

The popularity of mobile Internet and smart phones promotes the development of AR picture books. And new technology gradually infiltrates into the field of younger users. The study by Saidin (2015) confirms that in learning and education, if new techniques cannot promote critical thinking, meaning generation, or metacognition, technology will create a process of passive learning [15]. Therefore, in order to impress consumers, designers need to focus on not only the contents, but also the interactive operation, like AR. And the user-centric design for kids is a key to the success of AR products [16]. Many AR children picture books on the current market does not match the cognitive ability of school-age children. They do not conduct comprehensive analysis and researches on the operation abilities and the characteristics of mobile devices for children. Also, the interactions are very simple, mostly in the form of 3D model and animations after scanning, which are poorly made. While now published AR educational picture books based on mobile devices, to some extent hinder the communication between parents and children. Parent-child reading can cultivate children's reading

interest and ability, also can help with meeting the attachment psychology of children, and promote the social development of them [17].

Research work of this article mainly divides into four parts, introduction of product background, product status analysis, user research, and summary of user demand analysis. We prototyped an AR picture book, Rocket Dream, for kids aged 5 to 8, and conducted usability test. Then, we concluded the feasibility of improving parent-child communication and increasing child learning interest with the platform of AR picture book, by providing excellent interaction experience.

The deficiency and subsequent recommendations of this article: this article belongs to the exploratory research. The research on 5 to 8-year-old children's cognitive characteristics, behavior and psychological characteristics still needs further study. And the practice research of AR picture books is unrepresentative. Due to restrictions of time and resources, research results of this article still need further improvement and demonstration. In general, we believe there will be promising future of the AR applications, especially in children education and entertainment.

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