

Study on the Design of Intelligent AR Toys to Exercise Spatial Perception

Guanghong Xie

School of Media and Arts, Chongqing University of Posts and Telecommunications, Chongqing
400065, China;

qq490825705@163.com

Abstract

With the rapid development of science and technology, AR toys frequently appear in the side of the bit by bit, Rubik's cube, building blocks, robots and other puzzle toys continue to integrate with AR technology; With the concept of "Edutainment", children interact with each other through immersive digital games to develop spatial thinking ability. This paper studies and expounds the existing toys that cultivate spatial perception ability from the hardware section of building blocks and the game software side combined with augmented reality technology.

Keywords

Spatial perception; AR toys; Children's thinking.

1. Design concept of intelligent AR toys to exercise spatial perception

1.1. Background

According to the research, spatial thinking ability is one of the seven human intelligence, it includes spatial imagination, spatial reasoning, spatial sense and so on. The research shows that the spatial intelligence of preschool children in the natural condition is an important indicator of their future mathematical learning ability. Spatial thinking also plays an important role in everyday life, such as knowing where to go, reading a map, playing sports and even how to pack more items into a suitcase.

Among them, spatial perception ability can be divided into basic, intermediate and advanced. Basic abilities include spatial perception ability and spatial memory ability; Observed ability is reflected in the child's ability to discover spatial graphic features, such as the recognition of the lines and components of a figure in life, and memory ability is reflected in the process of recalling or reconstructing these features in the mind. The intermediate ability has the spatial imagination ability, which is embodied in the process of using the existing spatial graphics knowledge and features to associate with other graphics or features, such as the rotation of an existing triangle in the head; The advanced ability is the spatial thinking ability, that is, the ability to abstract and summarize spatial figures. For example, in the solid geometry course of high school mathematics, the statistical process of the number of lines of different planes of the existing cube tensor is carried out.

1.2. Importance analysis

Based on the analysis of the process of children's spatial cognition, the process is the theoretical stage, the perception stage and the operation stage. The theoretical stage contains the space tube erasing ability mainly is the observation (azimuthal), namely the horizontal (front and back left and right) and vertical (up and down) of the directivity and the inside and outside of the inside and outside. The perception stage includes spatial memory ability and spatial imagination ability, which mainly refers to perception (informality), namely the shape, size,

light and shade, color, material and orientation in the information: movement, padding, pushing down, and touch, comparison and direction in the informality. The operation stage includes spatial thinking ability mainly to create and use (variability), that is, to change the form of the assembly, spatial cohesion, spatial transition and ending function in the definition of the scene, the definition of functional modules, playing games, play house.

The importance of spatial imagination is crucial in life, study and future choice. The lack of spatial imagination in life will cause obstacles in life, such as easy to get lost, a weak sense of direction, no way to start board games, etc., affecting children's study and life. When students with poor spatial imagination learn mathematical geometry, physics and other knowledge, as long as they can not see the real object or can not see the image of the experimental demonstration, animation demonstration, they can not imagine the principle. In the long run, the level of spatial imagination directly determines a child's ability to solve math, physics, chemistry and other subjects, and basically determines the child's future academic performance and career choice.

1.3. Perfect timing

The famous psychologist Piaget divided children's psychological structure and children's psychological development into four stages: Sensorimotor stage (0-2 years old), pre-motor stage (2-7 years old), specific motor stage (7-11 years old), and formal motor stage (after 11 years old). According to the theory of children's cognitive development proposed by Piaget, the cognitive development stages and characteristics of children are sorted out, as shown in the table:

Stage of development	Sensorimotor stage	Premotor stage	Specific stage of movement	Stage of formal motion
Age	0-2 YEAR	2-7 YEAR	7-11 YEAR	11 YEAR AFTER
Abstract characteristics	Understanding the world through one's own actions in the environment, not internal thought processes	The symbolic thinking is no longer confined to the reality of the here and now	Reasoning systematically, solving problems in a logical way, and letting go of self-centeredness	Children reach an advanced stage of thought
Activities	Sucking, grasping, caressing, biting and other sensory movements	Think of an object as many different things	The concept of sorting, categorizing, and counting	Ability to reason abstractly, apply logic, and solve problems at a higher level

《Children's cognitive development stages and characteristics》

Summary: From the superscript, we can see that children of different ages have distinct cognitive characteristics, and the thinking ability of children after the age of 11 has gradually taken shape. However, the age of 7-11 years old, when thinking ability is not yet formed, but basic number and shape concepts have been developed, is the golden period of spatial intelligence development.

1.4. Influencing factors

Definition: spatial perception ability mainly includes spatial observation ability, spatial memory ability, spatial imagination ability and spatial thinking ability.

Cognitive process: The process of children's spatial cognition mainly includes observation, perception and creation and utilization stages.

Importance: Spatial imagination has an impact at all stages of a child's life.

Golden Age: There are significant cognitive differences among children of different age groups. The age of 7-9 is the golden age of spatial intelligence development.

2. Analysis of competitive products in intelligent AR toy design to exercise spatial perception

2.1. Existing training methods

According to scientific statistics, there are four training methods of Rubik's Cube training, APP training, building blocks training and classroom three views. The training points of Rubik's Cube training are multi-angle observation of objects, spatial conversion ability and spatial judgment ability. Advantage is interesting, suitable for a wide range of ages, can effectively exercise children's thinking, disadvantage is difficult to get started, and through the existing formula to spell, the effectiveness of exercise will be reduced; The training point of APP training is the ability to move and rotate the Angle of the module by observing the corresponding relationship between different objects. Its advantage lies in rich forms, entertainment and sociability at the same time. Its disadvantage is that it is easy to indulge in games and ignore training, and can not be observed in real scenes; Building block building training points stimulate children's imagination, hands-on ability and building ability; Advantage is good interaction, children can play together, exercise children's hands-on ability; The disadvantage is that the way is boring, easy to get bored, need to design a lot of modeling. The training point of three views in class is the ability to transform plane into stereo. Its advantage is strong pertinence, can quickly and effectively improve the spatial imagination; The disadvantage is boring, poor spatial sense of children easy to travel negative psychology, hit the child's self-esteem. To sum up, there are various ways to help children train their spatial imagination, but each has its advantages and disadvantages.

2.2. Overview and analysis of competing products

2.2.1 An overview of the

After systematic investigation, it is found that the competing products mainly come from two different products of the software end and the hardware end. Among the hardware splice building blocks, the direct competing products include magnetic building blocks, magnetic pieces, magnetic bars, gear building blocks and ball tracks. Indirect competition products are stacked blocks, gravity maze, laser maze, building blocks simulation house; Software related puzzle APP directly competing products include spatial imagination, building block puzzle, building block Mosaic battle, block recognition, building blocks; Indirect competitors include I Love to Build a House, Joy to Build a Building, and Lego Infinity.

2.2.2 Hardware side analysis

Starting from the analysis of the functions of competing products on the hardware side, the emphasis on manual operation, space and imagination exercise can be summarized from the basic functions of manual assembly, logical reasoning, spatial exercise and thinking exercise. From the intelligent combination of special functions, scenario simulation, soft and hard interaction, the emphasis on situation simulation can be summarized to increase the interest; From the interactive mode of operation tips and real-time feedback can be summarized intelligent products to increase the real-time feedback function; From the community center of social function, check in and punch in, and ask for help, it can be summarized that non-intelligent products lack social function. The lack of design for children's sense of achievement can be summarized from the leaderboard and online competition in achievement experience.

The core function of magnetic building blocks is to build different shapes to exercise spatial imagination. The advantage is to build different shapes to increase interest, while the disadvantage is that the basic block is more fixed. The core function of the magnetic piece is to cultivate the ability of structural modeling and hands-on ability. The advantage is that the structure is stable and clear, while the disadvantage is that the disassembly is troublesome and the modeling is fixed and single. The core function of the magnetic bar is to cultivate the ability

of spatial logical reasoning. The advantage is the point-and-line connection, which is more intuitive. The disadvantage is the decrease of interest without situational simulation. The core function of gear building blocks is to cultivate hands-on ability and imagination. The advantage is more stable connection mode and interesting modeling. The disadvantage is that the latter stage is mostly repetitive entertainment. The core function of the ball track is to assemble the labyrinth track according to the imagination. The advantage is that the single module is easy to operate, and the disadvantage is that there is no shape design and situational design. The core function of piling blocks is to cultivate the ability to observe models from multiple perspectives. The advantage is that different puzzle methods can stimulate children's thinking. The disadvantage is that the difficulty level is set high and there is no feedback. The core function of gravity maze is to cultivate logical reasoning and planning ability. The advantage is interesting and beautiful, and the disadvantage is that the operation is completely prompted and the mystery is ignored. The core function of laser maze is to stimulate children's imagination and logical thinking. The advantage is fun and authenticity, while the disadvantage is that the shape is fixed and can not be created by themselves. The core function of building block simulation is to teach children how to use real products. The advantage is to teach children how to use real products through entertainment. The disadvantage is that they cannot create new scenes by themselves.

2.2.3 Software-side analysis

Based on the analysis of the functions of competing products on the software side, seven products can be summarized from the basic functions of manual assembly, logical reasoning, spatial exercise and thinking exercise, which focus on space and imagination exercise. From the intelligent combination of special functions, scenario simulation and soft-hard interaction, 7 products can be summarized, which pay attention to the situation simulation to increase the interest. From the operational tips and real-time feedback in the interactive mode, the advantages of APP terminal can be summarized as operation tips and real-time feedback. From the community center of social function, checking in and punching in, and asking for help, it can be summarized that the APP terminal still lacks online social function. It can be concluded from the leaderboard and online competition in achievement experience that the situational simulation APP pays more attention to the design of children's sense of achievement.

The core function of spatial imagination is to create side view and front view according to the stereogram. Its advantage is that it can generate entities quickly and rotate with gestures. Its disadvantage is that it has a single interactive mode and can not choose the mode of challenge. The core function of building block jigsaw puzzle is the principle of three-dimensional tangram. The advantage is to cultivate the ability of logic and imagination, the disadvantage is that there is no prompt operation, difficult to blow the confidence; The core function of building block splicing is to cultivate spatial logical reasoning ability. The advantage is that real-time rotation is interactive and natural, while the disadvantage is that the clearance is possible through unconscious operation. The core function of block routing battle is to cultivate the ability of programming and hands-on operation. The advantage is to cultivate the ability of logical thinking and strong interest. The disadvantage is that there is a large possibility of mistake through the game. The core function of building blocks is to cultivate programming ability. The advantage is reasonable difficulty setting, while the disadvantage is poor interface design and many advertisements. I love building a house core function to cultivate logical thinking ability, the advantage is interesting and beautiful, the disadvantage is that it may cause addictions to the game world did not achieve the training purpose; The core function of Happy Building is to cultivate spatial imagination. Its advantage is interest and interactivity, while its disadvantage is that it has a single form and no ladder difficulty setting. Lego is infinite.

The core function is to construct community interaction in the space world. Advantages are fun, authenticity and interactivity, while disadvantages are easy to indulge in the game world.

2.3. Summary of competing products

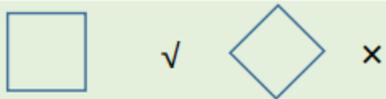
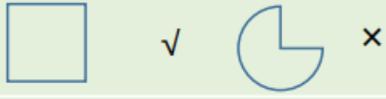
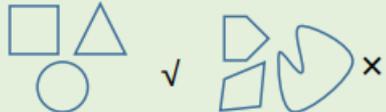
Through the analysis of competing goods analysis, we found that the hardware and software each have each advantages and disadvantages of the toy, but there is no one on the market for space imagination to develop hardware and software products, so we sure our product positioning for hardware and software interactive products, combining software and hardware, better training effect.

Finally, the product is targeted at 7-11 years old children to design interactive products of hardware and software related to building blocks. The function of the product is to cultivate the spatial imagination ability and hands-on operation ability at the hardware end of the building blocks. The App end combines the existing technology to carry out gamification and situational design. The design goal is to interact with the software in real time in the process of building, so that children can train their spatial thinking in the process of playing. Technical reference: Neuron module building block toys developed by Makeblock and existing AR and VR toys.

3. Study on User Design of Intelligent AR Toys to Exercise Spatial Perception

3.1. The literature research

In order to determine the design strategy, a literature search was conducted. Psychologist Kurt Kofka applied Gestalt Gestalt psychology to explain the physical and mental development of children. He accumulated data and obtained a common cognitive pattern in most people's perceptual activities. One of the most important theories is a phenomenon called closure in the field of vision, as shown in the figure below:

Tendency to type	Performance	Graphic
Tendency 1	Tends to reduce the figure to horizontal and vertical rather than slanting symmetry	
Tendency 2	Symmetry tending towards symmetry rather than slanting	
Tendency 3	Prefer aggregation of fundamental geometry rather than arbitrary and ambiguous aggregation	

Graph: General cognitive patterns summarized by Kofka

Summary: From the pattern summarized by Kofka, we can learn that the simpler and more regular the shape is, the easier it is to be perceived and understood by us. However, how to grasp the cognitive law of children and specific spatial graphics and use it to guide the design requires us to study and discuss the spatial cognitive process of children and find the guiding law from the three aspects of children's cognitive psychology, ability expression and behavior mode. Following this, we will conduct a user survey for manufacturers, parents and children.

3.2. User Research Framework

Firstly, relevant preparations were made for the survey. The target users were primary school children aged 7-13 / their parents/building block manufacturers. The research methods were table top research, observation method and interview method. Understand the characteristics and preferences of target users, understand the status of users when using related products, understand the importance parents attach to the development of children's spatial thinking

ability, and understand the process of research and development and production of such toys from the manufacturer.

The second aspect is the implementation of research. First, the characteristics and preferences of target users are understood: 1. Basic information about the child; 2. The child's character and characteristics; 3. Hobbies, what games do you like to play? 4. Children's learning. The second is about the understanding of the connection between users and products, which aspects of the relevant products users are concerned about: 1. Like the type of game, features; 2. The types and functions of the existing toys and the frequency of playing games; 3. The habit of playing games, alone or in groups; 4. The state of the game, the time invested. The third is about the content of spatial thinking development to understand the current status of the user's spatial thinking development: 1. Whether parents pay attention to the development of spatial thinking ability; 2. The ability to perceive space in current life; 3. Pain points and solutions; The fourth is about the content of the product to understand the user's needs and expectations for the product: 1. 2. Attitude, Suggestions, Opinions; 3. User evaluation.

3.3. Interview outline and analysis summary

3.3.1 The interview outline

Stakeholder classification is used to conduct research here. From the perspective of the manufacturer to think about three levels: product market, product function, product design; Product Market: What are the best sales of space stereo toys? How are toys divided into different age groups? What is the gender difference in the toy market between 7 and 13 years old? Parents buy toys when what to consult more questions? Product Features: What functions do these toys have? What is the main function? What are the effects of these features? How do you judge this function can exercise children's imagination? Product Design: Do you think it is feasible if smart building blocks are matched with APP? What should we pay attention to in the design process? What suggestions do you have for smart blocks and apps? From the perspective of parents, consider three aspects: feature preferences, spatial thinking, product design; Features like: the basic situation of the child, how old, what grade? What is the child's character? Do you have any hobbies? What toys do children like to play with? Do you have building blocks? How do you like to play with blocks? What do you prefer about building blocks? Spatial thinking: do you pay special attention to the development of children's spatial imagination?

If so, in what way? If not, why not? What do you think of children's spatial imagination? Has your child ever been exposed to APP puzzle games? How is it being used? Product Design: What is your attitude towards children's building blocks/mobile APP puzzle games? What features are you looking forward to? What aspects of building blocks and apps do you care about? From the perspective of children, think about the aspects of play and learning; What toys do you like? Have you ever played with blocks? Do you like building blocks with your classmates? What do you like about building blocks? Do you prefer to create your own designs or just look at the references? Do you like to use AR games? Do you have any other favorite games or toys? Study Situation: What kind of projects to exercise spatial imagination will you come into contact with during your study? Have you learned anything about solid shapes? Did the teacher teach it? Are there many courses now? Are there any classes that are difficult to take? How much time do you spend studying and playing games every day? Have you ever played a mini-game on your smartphone? What are the?

3.3.2 Summary of interview analysis

Based on the above problems, a series of studies were carried out and a detailed conclusion was finally drawn in terms of basic information, characteristics of consumer groups, characteristics of target groups, preferences, expectations and suggestions of target groups.

Basic information: 1. In terms of age, 6-10 years old like to play with building blocks. 2. In terms of gender, boys like cars and LEGO toys, while girls like kitchen toys. 3. In terms of sales volume, LEGO toys sell well, with good market feedback effect and a wide range of production series.

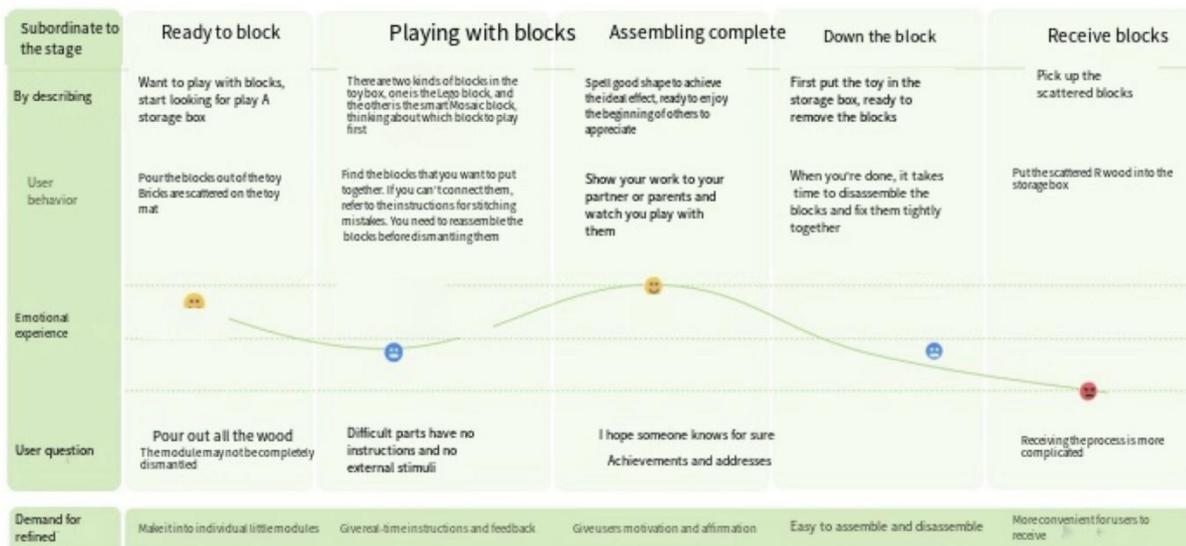
Characteristics of consumer groups: 1. For Lego toys, the user groups are concentrated in medium and high consumers, with an income of around 10,000, and users with low and medium consumption power also account for a certain proportion; 2. Parents with young children spend more on toys, spend more generously and pay more attention to the quality of toys; 3. Parents with older children will start to pay attention to educational toys and pay more attention to product functions;

Characteristics of target population: 1. Features of perception, attention and memory: attention is unstable and not lasting, and it is often closely related to interest, and mainly consists of unintentional memory, concrete image memory and mechanical memory; 2. Features of imagination and thinking: imagination has the characteristics of imitation, simple reproduction, intuitionism and concrete; 3. Psychological characteristics: poor psychological internal stability curiosity, sensitivity, competitive ability, lack of self-control, interpersonal relationship simplification or overwhelmed;

Preferences of target groups: 1. Among the surveyed groups, their favorite toys mainly include building blocks, car toys and plush toys; 2. Nowadays, children are very sensitive to APP games. They can learn without teaching and have strong learning ability. 3. Children's speed of building blocks is not fast, which is influenced by the structure of building blocks; 4. When playing with toys, most children want to share and play with other children, and like games with competition.

Expectations and Suggestions: 1. I hope that the number of toys is not too large, which is difficult to store and easy to lose. 2. It is hoped that the game can be set at different levels with strong interactivity, otherwise the children will not want to play after a while; 3. Difficulty should be targeted, to fully understand the child's preferences; 4. The building blocks should be put together in an interesting and aesthetic way; 5. The combination of software and hardware is feasible, but the APP should be attractive enough, but not too addictive for children. I hope to add a preventive reminder function.

Hardware side of block



Gamification software



4. Intelligent AR toy demand function extraction to exercise spatial perception ability

4.1. User Experience Journey Map

Here, the user journey diagram is divided into two parts, one is the hardware side of building blocks, the other is the gamification software side; As shown in the figure below:

4.2. Design strategy

The design strategy starts from three design points, corresponding to the definition and classification of cognitive space, design purpose, requirements and corresponding functions:

Design points	Spatial observation and understanding	Measurement of spatial perception	Change of spatial construction
Definition and classification of cognitive space	<ul style="list-style-type: none"> Azimuth space Gallery space Elevation difference space Nested space 	<ul style="list-style-type: none"> The perceptual space The type of space Unicom space Measure the space Sensory space 	<ul style="list-style-type: none"> Variability space Belonging to the space Partition space Combination of space Change the space
Design goal	Improve spatial orientation (front and back, left and right, up and down, inside and out)	Improve spatial perception (size, shape, connection, distance)	Construct the spatial concept of self
Requirements	Guidance and observation	Imagination elicitation and perceptual scheduling	Attributed to interest activation
Corresponding function	The ability to see from multiple angles	<ul style="list-style-type: none"> Number and shape combining ability Logical reasoning ability 	<ul style="list-style-type: none"> Spatial perception Plane stereo conversion ability

5. Design of intelligent AR toys to exercise spatial perception

5.1. Research framework

1. Insight into user needs: there are significant cognitive differences among children of different ages, and 7-9 years old is the golden period of spatial intelligence development. 2. Clear product positioning: AR interactive toys that exercise spatial perception. The combination of hardware and software, using AR real-time interactive means to assist children to train the spatial logic of building blocks. 3. Comb the plot: With the traditional Chinese story Journey to the West as the background, the story is adapted into 81 difficulty levels, enlighten and educate children through the moral behind the traditional story, and carry forward the traditional Chinese culture. 4. Seeking technical realization: Realize AR interaction effect based on Unity platform. 5. Hardware support design: building block gameplay design and prototyping. 6. APP mobile terminal design: information architecture and UI design. 7. Construction of business model: Based on the mature IP image of Journey to the West and the Ministry of Education's call for promoting traditional Chinese culture in primary and secondary school teaching, AR technology is adopted as the means to strengthen online publicity and broaden publicity channels to form a stable business model.

5.2. Stage summary

Through the above research framework, research background, user research (stakeholder classification), user portrait, competitive products research (offline and online research), we can find many problems, so as to make corresponding summaries.

The following conclusions can be drawn from the research on competing products: 1. At present, there is a lack of toy products of building blocks that specifically exercise the spatial perception. New technology toys are taking over the market, so toys need to be updated urgently. 3. The interactive products of hardware and software are relatively independent and weak in combination.

According to the above favorable analysis, it can be concluded that the target users are 7-9 years old children who need to exercise their spatial imagination; The product is positioned as a soft and hard interactive toy with spatial perception ability to observe, perceive, create and utilize; Product functions are divided into two parts: the main function: to cultivate spatial perception ability, logical reasoning ability, multi-angle observation ability, secondary function: plane and three-dimensional conversion ability, digital and graphic combination ability.

5.3. Designed in this paper

5.3.1 Product introduction

BlockWorld is a smart toy designed to exercise spatial awareness and is aimed at children aged 5-9.

Based on the theory of children's cognitive psychology, the training method of spatial logic of building blocks is integrated and carried out around interactivity.

Combined with AR interactive means and taking the traditional Chinese story Journey to the West as the background, gamification is adopted to train and strengthen the spatial perception logic power.

5.3.2 Story Level Design

For children aged 7-9, the theme of the story of Journey to the West was adopted. The design of cartoon characters and level setting based on traditional culture stories can not only teach and play, but also allow children to get in touch with excellent traditional Chinese culture from an early age.

Design 81 checkpoints, according to the story background of the Journey to the West adaptation of the path of ninety-eight difficult, children will encounter obstacles and monsters, so it is

necessary to open the brain, building blocks. Levels from easy to difficult, step by step, gradually exercise children's spatial perception ability. Four different modules are set: 1. Connecting module is used for spatial measurement ability, projection image imagination ability and spatial connection ability; 2. The ability to observe the mobile module from multiple angles, the thinking ability to flip the module, and the spatial conversion ability; 3. The staircase module is used for flexible thinking ability, spatial position conversion thinking ability and selective observation ability; 4. Rotation module is used for stereo perception ability and space construction ability.

The positioning base plate in the game rules: the coordinate positioning base plate is designed as the building carrier of splicing blocks, and the accuracy of children's game process is improved, thus enhancing the user experience. The six sides can be spliced blocks in the rules of the game: the six-side splicing structure is adopted, and the six sides can be spliced freely, which can maximize the ability of children's hands-on operation. Rule 1: use a given number of blocks to connect the starting point and the end point into a path to cultivate children's logical reasoning ability. Rule 2: Connect all the marked yellow sites with props to cultivate children's ability to think globally. Game metrics give feedback on the success and failure of the game and visualize the ability to improve in the form of stars.

5.3.3 Product value

The value level is divided into three levels: basic, experience and emotion. From the basic level, its core functions, AR technology effectively improves game experience, and immersive games effectively exercise the spatial imagination ability. The product value is based on AR interactive technology to give real-time feedback to children, exercise their spatial perception ability and stimulate their imagination. From the perspective of experience level, its core function is to stimulate children's spatial awareness and exercise their spatial thinking, and encourage children to observe their daily life carefully. Its product value lies in the more intelligent, efficient and interesting interactive experience, and the construction of virtual scenes to make up for the defects of traditional building blocks. From the emotional level, the core function is to carry forward Chinese traditional culture with fun and efficiency. The multi-dimensional stimulation of children's understanding of traditional culture, the value of its products in the background of Chinese traditional culture stories, to fill the market vacancy of toys in this field. In the future, more IP resources will be integrated into the development model of the product, and IP resources will be charged accordingly. More traditional Chinese culture will be integrated into education, so that children can exercise their spatial thinking in the process of games, and deepen their understanding of traditional Chinese culture in an imperceptible way. Multiplayer game mode is designed to increase the difficulty and interactivity of the game, so that children can exercise their spatial thinking and team cooperation ability while improving their social skills in the process of game.

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