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Original Article

Research on the Design and Optimization of Human-Computer Interaction Experience Based on Augmented Reality

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Abstract: *With the development and application of information technologies such as artificial intelligence, big data, and cloud computing, research on augmented reality technology has become a major focus in the field of information technology. Augmented reality technology, which allows virtual scenes and real scenes to interact deeply with the assistance of computer graphics and sensing technologies, not only integrates virtual information into real scenes but also enhances the transmission of various types of information such as images, sounds, and sensations. This technology further enriches various social activities of human beings and finds wide applications in various fields, promoting social development. Human-computer interaction plays a crucial role in augmented reality technology. Excellent human-computer interaction design can effectively improve the application value of augmented reality technology, enhance user experience, and reduce the probability of device failures. Thus, the development of augmented reality systems that meet the practical needs of different users greatly relies on exploring human-computer interaction techniques and optimizing them within augmented reality systems. This research has significant importance and application value.*

Keywords: *Augmented Reality, Human-Computer Interaction, Design and Optimization.*

I. INTRODUCTION

There are various ways of human-computer interaction, among which the most intuitive is the interaction between humans and robots. In the process of societal development, in order to reduce labor costs, robots have been employed to replace human labor in production operations. In this production process, human involvement takes the form of controlling the behavior of the machines, thereby generating interactive behaviors between humans and robots. This has become one of the key focuses of current research on human-computer interaction design and optimization [1-3]. Based on augmented reality, the design and optimization of human-computer interaction mainly consider three aspects: the distance of human-computer interaction, the posture of human-computer interaction, and the feedback style of human-computer interaction. Therefore, this study on the design and optimization of human-computer interaction based on augmented reality focuses on the aforementioned three aspects and adopts experimental verification to analyze the design and optimization of human-computer interaction conducted on the foundation of augmented reality technology.

II. OVERVIEW OF AUGMENTED REALITY-BASED HUMAN-COMPUTER INTERACTION TECHNOLOGIES

AUGMENTED REALITY

Augmented Reality (AR) is a technology that utilizes computer technology to generate virtual objects, scenes, etc., and then integrates the generated content with real-world scenes, thereby enhancing control over real-world objects through the virtual overlay. This allows for a more natural interactive mode between the real and virtual scenes [4]. The process of implementing AR is illustrated in Figure 1, depicting the human-computer interaction workflow of augmented reality technology.

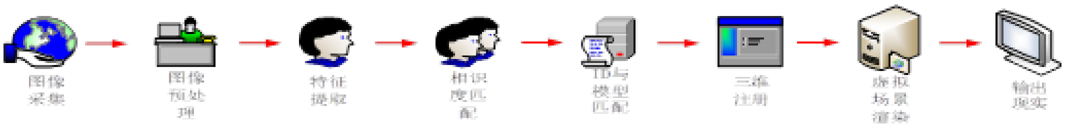

Figure 1: Human-Computer Interaction Process of Augmented Reality Technology

A. Implementation Process:

Step 1: Image acquisition; through the built-in API interface of the system, the connected camera captures and retains the scene image, which is then used as the basic framework content of the virtual world [5].

Step 2: Image preprocessing; enhance and extract the edges of the captured image to obtain details such as contours, specifications, objects, etc., in order to prepare for feature extraction. This step aims to obtain clear image boundary information, effectively reducing the computational complexity and difficulty of feature extraction.

Step 3: Feature extraction; in order to determine the similarity between the captured camera image frame and the target image, the discrete cosine algorithm is used for calculation. The formula is (1). Assuming the input image is M and the known image is N, the similarity between the camera image frame and the target image can be calculated using the distance formula DCT, which is represented by formula (2). If the similarity value obtained is greater than a certain threshold, it can be determined that the target image can appear in the real scene. The feature extraction has excellent performance and can be fully replicated in the virtual scene.

Step 4: Model matching; using pattern recognition matching algorithms, the ID of the real scene captured by the camera is obtained, and then the pre-defined mapping relationship with the 3D model is used to effectively enhance the augmented reality scene.

Step 5: 3D registration and rendering of virtual and real scenes; based on computer vision camera calibration, marker identification is performed. The four coordinate systems involved in the calibration process (world, imaging plane, camera, image display) are used as the basis for transforming 3D to 2D images. Then, using the transformation relationship, the position of the 2D coordinate points in the 3D real space is calculated. At the same time, using the camera's internal and external parameters and OpenGL, the generated 3D model is mapped to the real scene, achieving accurate alignment and fusion of virtual and real scenes.

III. EXPERIMENTAL VERIFICATION OF HUMAN-MACHINE INTERACTION

Data Source A total of 20 participants were selected for this study, with no specific gender restrictions. However, in order to ensure the accuracy of the experiment, there were 10 male and 10 female participants, with an average age of 24±2 years and an average height of 165±5cm [6]. All participants were in good physical condition, without any sensory diseases, and had normal limb motor abilities.

Experimental Procedure Prior to the start of the experiment, the participants were introduced to the purpose of the experiment and the equipment was calibrated. After the participants became familiar with the experimental procedure, they were randomly assigned to two groups with opposite states. The participants in each group interacted with the robot in different postures and at various distances, resulting in a total of eight different experimental conditions. Before each individual experiment, the participants were asked to engage in a natural interaction with the robot, without overly restricting their line of sight and perspective. The robot then adjusted itself based on the participants' states to achieve the conditions for interaction. The duration of each individual experiment was controlled within 3-5 minutes, and the total experiment completion time was controlled within 60-80 minutes [7].

Data Analysis The analysis of the data focused on assessing the normality of the data. Firstly, the Shapiro-Wilk test was employed, and the corresponding validation was obtained ($p > 0.05$). Secondly, a repeated measures analysis of variance was used to analyze the effects of distance, posture, and feedback style of human-machine interaction on subjective and objective indicators. Additionally, a sphericity test was conducted to evaluate whether the data met the assumption of sphericity in the design. If the assumption was violated, the Greenhouse-Geisser correction was applied to ensure the scientific validity of the degrees of freedom and p-values. Finally, SPSS 22 software was used for data analysis, with a significance level set at 0.05.

IV. EXPERIMENTAL RESULTS ANALYSIS

A. Impact of Scenarios on Performance in Human-Robot Interaction

The results of the analysis of the impact of scenarios on the accuracy of robot action simulation instructions in the process of human-robot interaction are shown in Tables 1-1 and 1-2. Tables 1-1 and 1-2 indicate that there is no significant difference in the accuracy of instructions given by different human-robot interaction distances, postures, and feedback styles, nor is there any clear interaction effect. Table 1-1: Impact of Human-Robot Interaction Distance, Posture, and Feedback on Instruction Accuracy.

Table 1: Impact of Human-Robot Interaction Distance, Posture, and Feedback on Instruction Accuracy

Interactivity Scene Factors		Command Accuracy: %			
Factors	Level	Descriptive Analysis		Analysis of Variance	
		Mean	Standard Deviation	F	P
Distance	0.7	51.3	16.3	1.381	0.258

	1.6	51.2	16.8		
	2.4	53.2	17.2		
	3.6	56.0	14.5		
posture	Positive	51.1	15.1	0.403	0.534
	Negative	54.8	17.2		
Feedback Style	Positive	52.7	17.4	0.003	0.954
	Negative	53.2	15.1		
Posture and Feedback Style				0.570	0.697
Distance and Feedback Style				1.590	0.253
Posture and Distance				1.553	0.261
Posture, Distance, and Feedback Style				0.269	0.882

Table 2: Influence of Posture, Distance, and Feedback Style on Command Accuracy in Human-Machine Interaction Scenarios Variables

<table>
<tr><th>Item</th><th colspan="2">Command Accuracy (Positive): %</th><th colspan="2">Command Accuracy (Negative): %</th></tr>
<tr><td>Posture</td><td colspan="2">＞50</td><td colspan="2">55＜x＜60</td></tr>
<tr><td>Feedback Style</td><td colspan="2">＞50</td><td colspan="2">＞50</td></tr>
<tr><td colspan="5">Distance</td></tr>
<tr><td>Length: m</td><td>0.8</td><td>1.5</td><td>2.5</td><td>3.5</td></tr>
<tr><td>Command Accuracy: %</td><td>55</td><td>＞55</td><td>＞55</td><td>＞55</td></tr>
</table>

B. The Influence of Scene on Eye Movement Metrics in Human-Computer Interaction Process

The distance, posture, and feedback style in human-computer interaction have no significant impact on the average visual diameter of the experimenters, as shown in Tables 2-1 and 2-2. However, distance and posture have a significant impact on the visual diameter, demonstrating a significant interaction effect (F=8.082, P<0.01). In negative human-computer interaction, the average visual diameter varies inversely with the interaction distance, as shown in Figure 2. Similarly, in positive interaction, it varies directly with the interaction distance. Furthermore, the duration ratio of the experimenters' and robots' gaze time does not show a significant impact from the distance, posture, and feedback style in the human-computer interaction process, as shown in Table 2-3. However, for the ratio of the experimenters' gaze frequency to the robot, the interaction distance (F=32.501, P<0.001) and feedback style (F=7.167, P<0.05) have a significant impact, as shown in Table 2-4. Additionally, there is a significant interaction effect between the distance, posture, feedback style, and the ratio of the robot's gaze frequency. This is represented by F=4.397, P<0.01.

Therefore, in the context of negative feedback, the ratio of the experimenters' gaze frequency towards the robot is greater than in positive feedback scenarios. The gaze frequency ratio varies with the interaction distance, displaying a directional pattern. Moreover, the variation is more pronounced under positive feedback conditions, as shown in Figure 3.

Table 3: The Impact of Human-Computer Interaction Distance, Posture, and Feedback on Eye Movement Metrics

Interaction Scene Factors Visual		**Diameter: mm**				**Proportion of Gaze Duration: %**			
Reason	**Horizontal**	**Descriptive Analysis**		**Analysis of Variance**		**Descriptive Analysis**		**Analysis of Variance**	
		Mean (%)	**Standard Deviation**	**F**	**P**	**Mean (%)**	**Standard Deviation**	**F**	**P**
Distance	0.7	4.4	0.5	0.289	0.872	73.3	12.8	1.139	0.321
	1.6	4.4	0.5			73.4	13.5		
	2.4	4.4	0.5			73.6	15.2		
	3.6	4.4	0.5			76.2	12.4		
Posture	Positive	4.4	0.5	4.102	0.085	74.6	13.5	1.257	0.247
	Negative	4.4	0.5			73.4	13.5		
Feedback Style	Positive	4.4	0.4	0	0.0989	71.7	14.9	0.143	0.791
	Negative	4.4	0.6			76.3	11.5		
Posture and Feedback Style				0.004	0.984			0.147	0.704
Distance and Feedback Style				1.644	0.191			1.665	0.186
Posture and Distance				8.082	0.002*			2.205	0.099
Posture, Distance, and Feedback Style				0.765	0.518			0.187	0.905

<table>
<tr><th colspan="4">Ratio of Gaze Count: %</th></tr>
<tr><th colspan="2">Descriptive Analysis</th><th colspan="2">Descriptive Analysis</th></tr>
<tr><th>Mean (%)</th><th>Standard Deviation</th><th>F</th><th>P</th></tr>
<tr><td>91.3</td><td>10.1</td><td>32.501</td><td><0.001***</td></tr>
<tr><td>89.3</td><td>8.5</td><td></td><td></td></tr>
<tr><td>81.4</td><td>11.7</td><td></td><td></td></tr>
<tr><td>72.8</td><td>15.0</td><td></td><td></td></tr>
<tr><td>84.8</td><td>12.7</td><td>3.92</td><td>0.068</td></tr>
<tr><td>82.6</td><td>14.5</td><td></td><td></td></tr>
<tr><td>78.7</td><td>15.3</td><td>7.167</td><td>0.014*</td></tr>
<tr><td>88.6</td><td>9.2</td><td></td><td></td></tr>
<tr><td></td><td></td><td>0.014</td><td>0.902</td></tr>
<tr><td></td><td></td><td>4.397</td><td>0.008**</td></tr>
<tr><td></td><td></td><td>2.725</td><td>0.054</td></tr>
<tr><td></td><td></td><td>0.368</td><td>0.775</td></tr>
</table>

Table 4: The Influence of Posture, Distance, and Feedback Style on Average Visual Diameter in Human-Computer Interaction Scenarios

<table>
<tr><th>item</th><th colspan="3">Average visual diameter (positive) : mm</th><th>Average visual diameter (negative) : mm</th></tr>
<tr><td>Posture</td><td colspan="3">4.5</td><td>4.6</td></tr>
<tr><td>Feedback Style</td><td colspan="3">4.5</td><td>4.6</td></tr>
<tr><th colspan="5">Distance</th></tr>
<tr><td>Length: m</td><td>0.8</td><td>1.5</td><td>2.5</td><td>3.5</td></tr>
<tr><td>Instruction accuracy rate: %</td><td>4.51</td><td>4.57</td><td>4.61</td><td>4.61</td></tr>
</table>

Table 5: Influences of Posture, Distance and Feedback Style on Gaze Duration Ratio in Human-Computer Interaction Scenarios

<table>
<tr><th>item</th><th colspan="3">Fixation duration ratio (positive) : %</th><th>Gaze duration ratio (negative) : %</th></tr>
<tr><td>Length: m</td><td colspan="3">77</td><td>74</td></tr>
<tr><td>Command Accuracy: %</td><td colspan="3">71</td><td>78</td></tr>
<tr><th colspan="5">Distance</th></tr>
<tr><td>Length: m</td><td>0.8</td><td>1.5</td><td>2.5</td><td>3.5</td></tr>
<tr><td>Fixation duration ratio: %</td><td>72</td><td>74</td><td>75</td><td>76</td></tr>
</table>

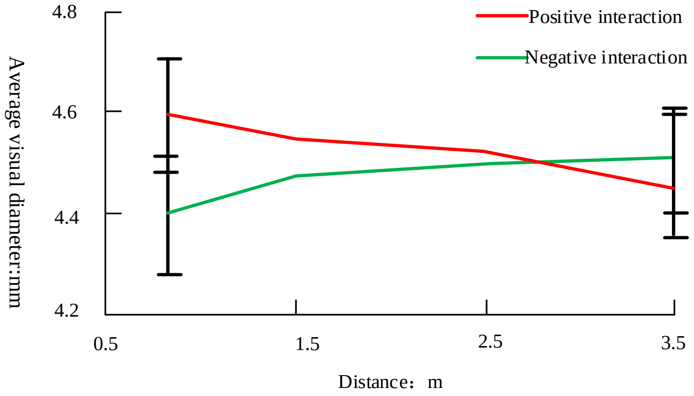

Figure 2: Interaction of Distance and Posture on Mean Visual Diameter

Table 6: Influences of posture, distance and feedback style on gaze ratio in human-computer interaction scenarios

<table>
<tr><th>item</th><th colspan="2">Fixation Ratio (Positive): %</th><th colspan="2">Fixation Ratio (Negative): %</th></tr>
<tr><td>Posture</td><td colspan="2">78</td><td colspan="2">77</td></tr>
<tr><td>Feedback Style</td><td colspan="2">70</td><td colspan="2">75</td></tr>
<tr><th colspan="5">Distance</th></tr>
<tr><td>Length: m</td><td>0.8</td><td>1.5</td><td>2.5</td><td>3.5</td></tr>
<tr><td>Gaze ratio: %</td><td>71</td><td>72</td><td>74</td><td>75</td></tr>
</table>

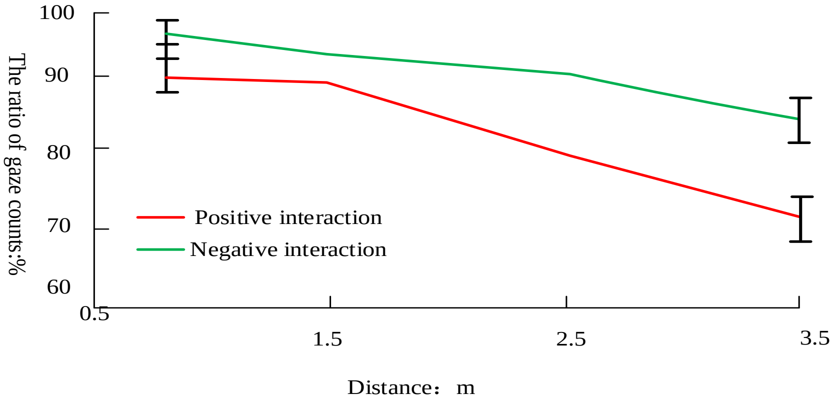

Figure 3: Interaction of Distance and Feedback Style on Gaze Ratio

C. The Influence of Scenarios on Subjective Perception in Human-Computer Interaction Process

The distance, posture, and feedback style of interaction in the human-computer interaction process have an impact on subjective perception. The main scenario factors are involvement and acceptance, as shown in Table 3-1. Among them, involvement has no significant impact on the interaction of distance, posture, and feedback style. However, acceptance does have an impact on interaction. The statistical value is F=5.347, with a significance level of P<0.003.

Furthermore, in the positive feedback style, when the interaction distance is closer, the difference in acceptance between positive and negative interactions is smaller. On the other hand, when the interaction distance is farther, the acceptance of positive and negative interactions shows an inverse relationship, with a higher acceptance for positive interactions than for negative interactions, as shown in Table 3-2. Additionally, under the negative feedback style, the impact of interaction distance and posture is opposite to that of the positive feedback style, as shown in Figure 4.

Table 7: Effects of Human-Computer Interaction Distance, Posture, and Feedback on Scene's Subjective Feelings

Interactivity Scene Factors		**Degree of Participation**				**Acceptability**			
Factors	**Level**	**Descriptive Analysis**		**Analysis of Variance**		**Descriptive Analysis**		**Analysis of Variance**	
		Mean	**Standard Deviation**	**F**	**P**	**Mean**	**Standard Deviation**	**F**	**P**
Distance	0.7	3.380	0.817	0.248	0.863	3.251	0.880	1.143	0.936
	1.6	3.456	0.817			3.114	0.934		
	2.4	3.456	0.761			3.110	1.007		
	3.6	3.451	0.678			3.051	0.934		
posture	Positive	3.496	0.156	1.455	0.244	3.157	0.958	3.750	0.070
	Negative	3.372	0.154			3.082	0.929		
Feedback Style	Positive	3.252	0.754	0.133	0.718	3.104	0.266	0.006	0.943
	Negative	3.617	0.732			3.084	0.266		
Posture and Feedback Style				0.232	0.653			0.036	0.848
Distance and Feedback Style				2.273	0.083			0.865	0.470
Posture and Distance				1.185	0.343			1.275	0.289
Posture, Distance, and Feedback Style				1.329	0.254			5.347	0.003

Table 8: Influences of Posture, Distance, and Feedback Style on the Introduction Degree of Interaction in Human-Computer Interaction Scenarios

	Distance: m			
Interactive Acceptance	0.7	1.6	2.4	3.6
Front Faces	3.0	3.2	3.6	3.6
Positive and Negative	3.2	3.4	3.0	3.0
Negative Positive Side	3.5	3.3	3.0	3.2

Negative and Negative	3.1	3.1	3.2	3.1

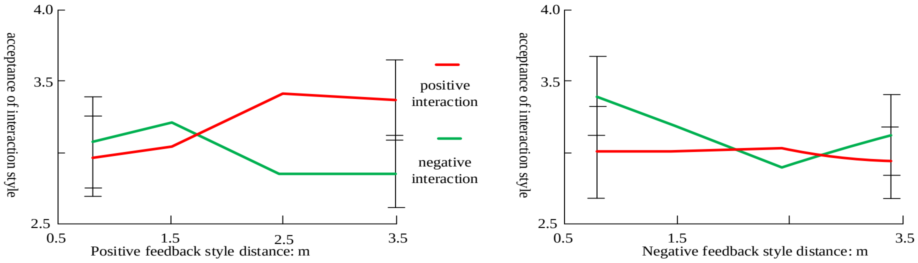

Figure 4: The Interaction of Distance, Posture, and Feedback Style on the Acceptance of Interaction Mode

V. EXPERIMENTAL DISCUSSION

Experimental Discussion Through the above experiments, it was found that there is a significant interaction effect of interaction distance and posture on visual diameter in human-machine interaction. Moreover, the distance and feedback style have a significant impact and interaction effect on the ratio of the experimenter's gaze to the robot, indicating a significant interaction effect of distance, posture, and feedback style in the acceptance of interaction methods. Therefore, the following discussions are conducted:

A. Discussion 1:

Distance and posture have a significant interaction effect on the visual diameter index of the experimenter. With the increase of distance, the visual diameter of the experimenter shows a reverse change under two different interaction postures. When the distance is 0.7m, there is a significant difference in visual diameter. The main reason for this may be that the interaction distance and posture undergo changes that affect the experimenter's level of emotional stimulation, resulting in a nonlinear relationship between visual diameter and emotional influence, while showing a linear relationship with the level of stimulation. In addition, the results of this study also indicate that when the experimenter is at a distance of 0.7m, negative interaction states stimulate emotions to the greatest extent, but the reasons for the stimulation cannot be identified. This is because the level of stimulation is just one aspect of the emotional model, and highly stimulated emotions contain more content.

From Figure 4, it can be observed that when the interaction distance is maintained at 0.7m, the negative interaction posture is not preferred by the experimenter. The combination of negative interaction posture and negative feedback style weakens the acceptance of the interaction method by the experimenter. Therefore, negative interaction can be considered as a low acceptance but highly stimulating interaction method, which can be classified as negative stimulation. Conversely, if the acceptance of positive interaction methods continues to increase, the experimenter's acceptance can promote the interaction method, especially in close proximity. Therefore, when designing human-machine interaction and adopting a close interaction mode, it is necessary to ensure that the robot and the person engage in positive interaction. If the designed interaction posture is negative, the robot needs to adjust its posture and prevent the context of the interaction scene from becoming negative, ensuring that the user's emotions are not negatively stimulated. This will help maintain a close interaction mode in human-machine interaction, making it more consistent with the standards and norms of interpersonal communication and further improving the user's experience of human-machine interaction.

B. Discussion 2:

The interaction distance and feedback style in human-machine interaction show a significant interaction effect on the ratio of the robot's gaze. With the increase of interaction distance, the ratio of gaze significantly increases. This may be due to the ecological effect of distance, which gradually expands the experimenter's field of vision, attracting their attention to other external stimuli and reducing their intention to interact with the robot. Negative feedback style of the robot can attract the experimenter's attention. Therefore, in this study, it can be determined that if the robot can clearly perceive that the user's attention is not focused, it can use negative feedback style to remind the user to concentrate. Although negative feedback style can attract more attention from users, it is necessary to consider whether users can accept negative contextual reminders from the machine during usage. The results show that positive feedback in long-distance and positive interaction can increase the user's acceptance of the robot, while negative feedback in close proximity can counteract the negative interaction. Therefore, in the design and optimization of augmented reality-based human-machine interaction, the ideal range of interaction distance is 1.6-2.4m. In this range, a robot with a positive feedback style can maintain a positive interaction state, providing users with better service and a more interesting human-machine interaction experience.

C. Discussion 3:

In the negative interaction mode, which involves multiple users and a single robot, although this type of human-machine interaction will create an interactive scene, it is difficult for users to accept the one-on-one negative interaction mode. The reason for this may be that in negative interaction, the user's field of vision narrows, making it difficult for the user to accurately perceive the interactive actions, and thus unable to experience a relaxed interaction state. Therefore, in the one-on-one human-machine interaction scenario, the negative interaction mode can stimulate the user's negative emotions and reduce the overall experience of human-machine interaction. Hence, in the design and optimization of augmented reality-based human-machine interaction, it is advisable to minimize the occurrence of negative interaction modes.

D. Discussion 4:

There is a significant interaction effect between interaction feedback style and distance/posture on the acceptance of interaction methods and the ratio of gaze. This study found that the interaction mode with a positive feedback style is more favored by users. However, the interaction mode with a negative feedback style, to some extent, can attract the user's attention, as users pay more attention to the negative feedback information from the robot and hope to receive constructive feedback from the robot about themselves. Therefore, in the design and optimization of augmented reality-based human-machine interaction, it is recommended to appropriately increase the design of negative feedback style interaction to remind or alert users of their own negative interactive habits, further correcting their words and actions.

VI. CONCLUSION

In conclusion, the research on design and optimization of human-computer interaction based on augmented reality (AR) is summarized. Firstly, the theoretical support for this research is provided by outlining the technology of AR-based human-computer interaction. Secondly, experimental verification is conducted to highlight the content of this research. Finally, recommendations for design and optimization of human-computer interaction based on augmented reality are proposed through discussions, thus completing this research. Additionally, there are some limitations in this study, mainly reflected in the lack of comprehensive human-computer interaction scenarios and a significant bias. Therefore, in future research, various scenarios and applications of human-computer interaction will be fully considered to comprehensively analyze how to design more intelligent human-computer interaction models based on augmented reality technology, further contributing to the research of human-computer interaction.

Conflict of Interest:

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Data Availability Statement:

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Author Contributions:

The author confirmed the contributions of the five authors and agreed to publish them.

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Research on the Influencing Factors and Model Construction of Mobile Short Video

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Compliance with Ethical Standards

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