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An AI-Assisted Adaptive Game Interface Framework based on Player Behavioral Data for Reducing Cognitive Load.

Zhou Zhuang[a]

School of Computing and Information Technology, Xiamen University Malaysia, 43900 Sepang, Selangor, Malaysia

[a]Email: SWE2409073@xmu.edu.my

Abstract

With the development of game systems, many are now complex; therefore, the older fixed user interfaces may not be suitable for all users and lead to difficulties in operation. This paper puts forward an AI-assisted adaptive game interface framework that integrates interface adaptation and user control. Based on Cognitive Load Theory and principles of Human-Computer Interaction (HCI), a web-based gaming platform was developed and evaluated in a user study by comparing static, automatic adaptive, and AI-assisted adaptive interfaces. A total of 15 questionnaires were distributed, and after excluding outliers, 11 were valid for analysis. Based on the above analysis, it can be seen that adaptive interfaces have achieved a better user experience than static interfaces; specifically, users feel more in control during the adaptation process, are more aware of how their interface operates, and thus have a higher level of satisfaction and acceptance of the changes. AI-assisted adaptive interfaces can thus improve the user experience of the game by providing adaptable interfaces that are convenient for users and still give users a sense of control.

Keywords

Adaptive User Interface; Game User Interface; Cognitive Load; Human–Computer Interaction; Artificial Intelligence.

1. Introduction

As the digital gaming industry has been developing rapidly in recent years, game systems have generally grown in scope and complexity of function and information. As a result, the Game User Interface (Game UI) is now a direct indication of how a player feels while playing and how conveniently they can use the game. Most commercial games are still based on an "average user" interface design and have not been updated. Thus, it does not consider that people are different in their cognitive strengths and gaming backgrounds, and also have different interaction preferences.

According to the global games market report by Newzoo, the age, experience and behaviour of the gaming population are all different [1]. This diversity indicates that one fixed interface design may not be suitable for all users. Nielsen Norman Group (NN/g) research has also shown that when the interface has a complicated information structure or is not in line with users' expectations, users need to exert more cognitive effort to learn about and operate it [2]. The mental stress will increase cognitive load, reduce operating efficiency, and be less user-friendly. Given the reasons mentioned above, the task-completion rate of these games may decrease, and a large number of operational errors may occur.

Recently, with the progress of Artificial Intelligence (AI) and Human-Computer Interaction (HCI) technology, the field of Adaptive User Interfaces (Adaptive UI) has developed. Previous studies have used automatic interface generation, models of user behaviour or optimisation of the

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interface via machine learning to develop adaptive interfaces [3-4]. The above studies have provided support for personalised interactive experiences. However, a few main problems have not been solved.

Firstly, most of the research has focused on how to improve the efficiency and optimise the performance of the system, and few studies have examined cognitive load, which is necessary for users' interaction with and use of the system in a task. Cognitive Load Theory (Sweller) suggests that people have limited processing capacity for information [5-6]. If the required tasks exceed the amount of these resources, performance and understanding will be greatly affected. For example, in a game interface, many pieces of information need to be processed by the user in a short period of time.

Secondly, many smart interface systems regard AI as an autonomous decision-making unit that directly decides how the interface should be adapted. Although the above automation can increase efficiency, it will also reduce the extent to which users participate in the change. If users are not involved, there will be an increase in the uncertainty of the interface changes, and a sense of control and predictability for users will decline. The pace of a game is relatively high; therefore, changes in the interface will affect both the operation and the sense of presence for players. Therefore, the problems of interface flexibility and user control need to be addressed in research at present.

Therefore, the purpose of this study is to solve the above problems by constructing an AI-assisted adaptive game interface framework based on Human-Computer Interaction (HCI) principles and Cognitive Load Theory [5-8]. The new system is not a fully autonomous adaptive system and, therefore, does not employ artificial intelligence for control; rather, it serves as a decision-support tool. The system will process the user's behaviour data and offer some interface adjustment suggestions; however, the user will be responsible for choosing whether or not to implement them. A new optional user confirmation and feedback module will be added to show users the modified interface before making the changes effective. It will help to maintain the autonomy and predictability of the adaptation process for users.

The adaptation mechanism in this paper only addresses interface structure and information display. It will not change the rules and system of the game or its difficulty. This design helps ensure that the differences in user experience are mainly caused by interface adaptation rather than changes in gameplay.

There are theoretical and practical contributions of this study. Theoretically, it is an expansion of the work on adaptive interfaces based on the concepts of cognitive load and user control for intelligent interfaces. Research on the Human-Computer Interaction (HCI) problem in intelligent systems and how user cognition is affected by interaction has also been conducted. In practice, the above framework can help build an adaptive game interface that is both personalised and offers the user a degree of freedom. The objective of the framework is to support interface adaptation and a good user experience without increasing the user's cognitive load, and users should be able to perform these adaptation decisions.

In short, this paper proposes a user-centered strategy for interface adaptation assisted by AI that reduces cognitive load and enhances user control. We hope that the results will help design the interface of an intelligent game and provide a foundation for further research on human-AI collaboration.

The whole research path of this study is shown in Figure 1.

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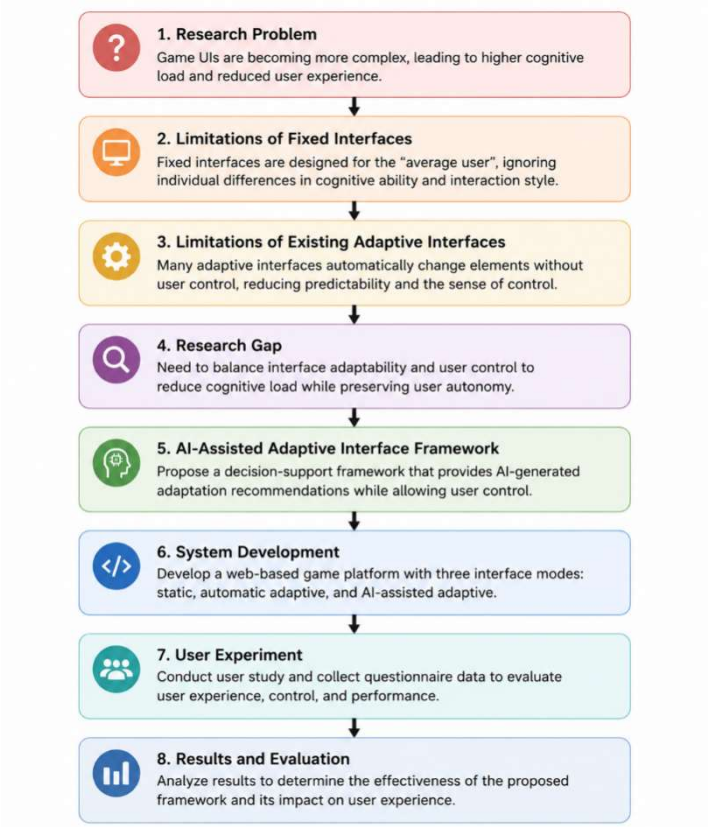


Figure 1. General Research Framework of the Study

2. Theoretical Model / Framework

2.1. Theoretical Foundation

Many theories and ideas of Human-Computer Interaction (HCI) are used as the foundation for this study.

In short, the above framework meets the requirements of usability and user control [7-9], and it should be possible for users to understand how the system functions and keep the right to choose during use [7-10]. They are particularly suitable for adaptive systems, and thus any changes in the interface may have an adverse impact on user experience and trust.

Second, the theoretical basis of this paper is mainly the Cognitive Load Theory (CLT). CLT is based on the limited cognitive resources of users for information processing [5-6]. If the interface is too complicated and places a large burden on users' cognition, then their task-completion rate will decrease, they will be unable to decide in time, and thus have a poor user experience. Therefore, one of the main purposes of interface design is to lower the amount of thought users need to perform.

Finally, the basis of this framework is Adaptive User Interfaces (Adaptive UI) [3,4]. Adaptive interfaces adjust the components of the interface according to the behaviour of a user and other environment information. However, unlike many traditional adaptive systems that make adaptations automatically and do not involve users, this framework emphasizes user participation in order to form a more balanced model of human-AI cooperation.

2.2. Model Introduction

From the theoretical bases presented above, the aim of this study is to propose a framework for adaptive game interface that seeks to decrease the cognitive load of players while maintaining their autonomy with the assistance of AI. The framework has four key modules, as shown in Figure 2.

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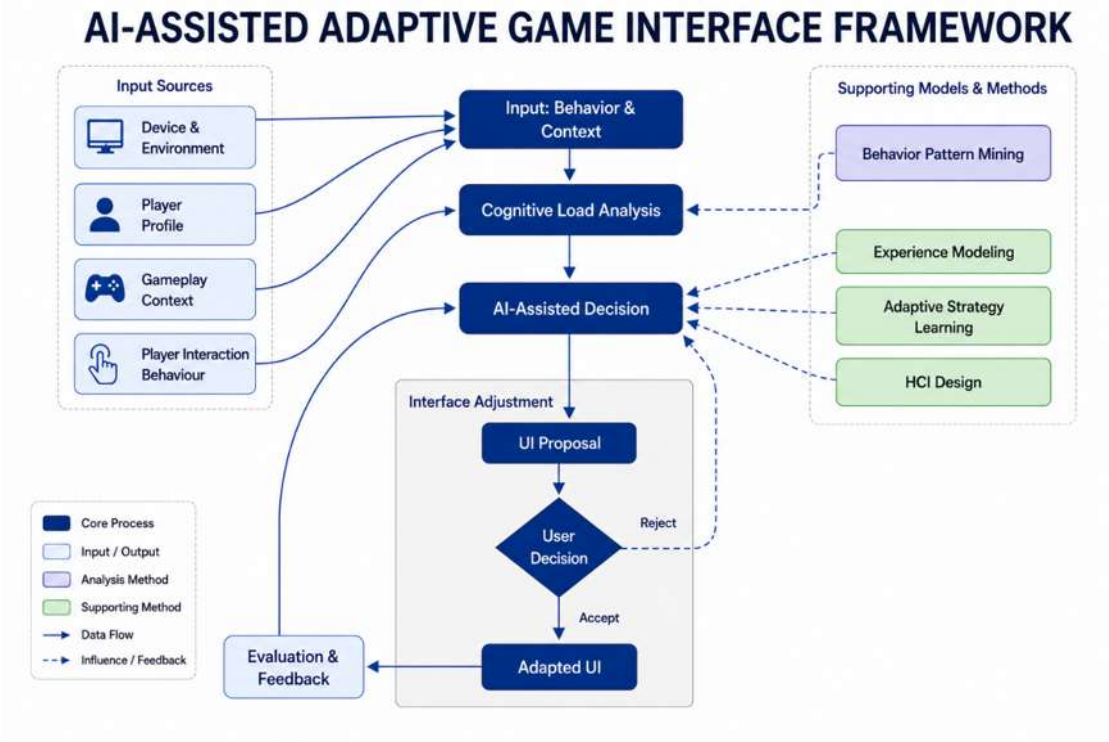


Figure 2. AI-Assisted Adaptive Game Interface Framework

(1) Behavior Sensing

A Behaviour Sensing module will collect data on the user and its environment. The collected data include click patterns, navigation paths, frequency of menu switching, task completion rate, page dwell time, etc. The above data will be used in the following analysis and decisions.

(2) Cognitive Load Analysis

The Cognitive Load Analysis module identifies the user's cognitive state through behaviour. For example, if the menu changes too frequently, there is a long pause, or multiple operating errors occur repeatedly, it may show that users are having difficulty using the interface correctly. They can show that the cognitive load is relatively high and need to be studied further.

(3) AI-Assisted Decision-Making

Based on the results of cognitive load analysis, the interface adaptation recommendations of the AI-Assisted Decision-Making module are provided. Some of the recommendations are to change the arrangement of the interface, reduce the quantity of information, organise the menu logically, and make frequently used functions stand out. AI is a decision-support system that does not operate independently. It generates interface adaptation recommendations but does not carry out interface modification directly.

(4) Interface Adjustment

The Interface Adjustment module is used for human-AI collaboration and handles the adaptation process. First, it will generate a candidate interface adaptation (UI Proposal) and then present it to the user. According to the user's choice, the above modifications will either be accepted or not. If approved, the adapted UI will be created and applied to the system.

The four modules listed above are also used to build an Evaluation and Feedback system. Based on the performance data and feedback of users, determine how effective the adaptations have been, and then inform the system of this information for continuous improvement and adjustment.

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2.3. Model Workflow

In short, the entire process of the above framework is a loop.

Continuously collect data on how the user interacts with the system and surrounding circumstances through the Behavior Sensing module. Then, according to what the Cognitive Load Analysis module shows, we can know how the user is thinking.

Then, the AI-Assisted Decision-Making module will be applied to the results and present the corresponding interface adaptation suggestions. The above are recommendations that will be presented to the user as a UI proposal.

Then the user will view the recommended adaptation and select one to keep or discard it. The Interface Adjustment module adjusts the interface according to the user's selection and builds the Adapted UI. If the recommended items are not liked by users, keep the existing interface settings and continue to collect behaviour data.

Finally, according to the performance of the users and the results of their use, determine whether the modifications have taken effect in the evaluation and feedback section. The evaluation results will be used for the next round of adaptation, and the cycle of optimisation will be repeated continuously.

2.4. Key Features and Contributions

The proposed framework differs from traditional adaptive-interface systems in three main aspects:

(1) Using AI to assist with decision-making

The proposed framework will not have AI autonomously adapt; it is only intended to be a decision-support system. Based on analysis of user behaviour, AI provides adjustment recommendations, but the final decision remains with the user. Therefore, this design will reduce the risk of unforeseen interface modifications and damage to user trust.

(2)UI-Only Adaptation

The framework only deals with the adaptation of the structure and display of the interface information. The essential elements, mechanics and difficulty of the game will not change in the adaptation. It is assumed that the difference in the experimental results is due to an effect of interface adaptation and not to differences in gameplay.

(3)User-Controlled Adaptation

One of the main contributions of this paper is that it adds user control to the adaptation process of the interface. The system will be more open, predictable and user-friendly; at the same time, the user can choose not to accept the interface adjustment suggestions. This philosophy of man-in-the-loop can achieve a more harmonious cooperation between the intelligent system and human judgment.

In short, the proposed system is based on a combination of Cognitive Load Theory, adaptive user interface concepts, and Human-Computer Interaction principles to achieve the goal of adaptive game interface design. Add AI and user controls to improve the convenience of the interface and reduce users' mental stress, but maintain a sense of control.

3. System and Experimental Design

3.1. Design of Game System

To verify whether the adaptive interface strategy is feasible, a web-based game platform has been built based on the AI-assisted adaptive interface framework introduced in the previous part. The first objective of this system is not to alter the rules of the game or increase the difficulty of play; rather, it aims to strengthen the user interface for learning about and using

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the game more conveniently, thus promoting the general enjoyment of the game through a dynamic interface adaptation.

Three versions of the game platform were designed and realised to study the impact of different adaptation methods.

3.1.1. Standard Static Game Interface

The first is a typical static interface design. This edition is not adjustable, and it does not have AI assistance. Menu structure, button location and the path for game navigation are all the same in the interaction process.

The current situation is a typical case (control case) in the experiment, and it is a traditional type of interface design for many digital games. Although the static interface is fixed and stable, it cannot respond to changes in user behaviour or other circumstances. Therefore, when operating the function selection part of the system, users will need to focus their attention more.

3.1.2. Auto-Adapting Game Interface

The second edition is now self-adjusting in the interface. Collect all the data about how the user interacts with the system, such as how many times they switch windows, how long they stay on a page, which game they choose to play and how quickly they can operate the function. The above observations are used to switch among the different modes of interface automatically, namely Flow UI, Exploration UI and Overload UI.

The displayed contents of the various modes are different. For example, if the system detects that the user switches between menus frequently or shows that they are having trouble operating the system, it can reduce the complexity of the interface and disable some non-essential information to focus only on necessary game information and operation instructions. Therefore, to reduce the cognitive load of users and help them find the functions they need more easily, modifications have been made.

This version is a traditional adaptive interface mode in which the system decides and applies interface changes automatically. Automation can improve efficiency, but the way in which it is adapted is not controlled by users. Therefore, the system may change the interface unexpectedly and reduce the sense of predictability and control for users.

3.1.3. AI-Assisted Adaptive Game Interface

The third version is based on an automatic adaptive interface and adds a control mechanism for the user to create an AI-assisted adaptive interface.

The system does not directly modify the interface at first; it observes users' operations and offers optimisation recommendations. The above suggestions are displayed to the user, and then the user can choose to accept or decline them. For example, if the system determines that the efficiency of use has declined or indicates mental fatigue, it can suggest reducing the number of functions on display. However, it will only be used after the user explicitly agrees to the recommendation.

Therefore, the AI will only function as a decision-support system and not as an independent controller. Respect for the user's freedom is shown by giving them the choice of whether or not to keep the changes made by intelligence. Combine AI-generated recommendations with user decision-making to meet the requirements of Human-Centered AI and Human-in-the-Loop interaction design.

3.2. Experimental Design

Based on the four-layer AI-assisted adaptive interface framework shown in Section 2, an experimental design was developed. The purpose of the experiments above is to study how various interface adaptation strategies affect the users' experience and cognitive load.

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The operating logic of the experimental system is in line with the above theoretical model. User behaviour data, such as the number of clicks, frequency of switching between different menus, length of time spent on a specific page, whether the game has been completed, and changes in score over time, are all continuously recorded during the experiment. The above behavioural indices are used to determine a user's state and, possibly, their required cognition.

For example, if users switch from menu to menu, they will probably have navigation problems; and if they stay in an activity for a long time, they will likely have trouble finding the target function they are looking for. According to how a user uses this system, it can decide whether to modify the displayed window.

When the indicator shows a decrease in interaction efficiency, an increase in operational errors or too many menu levels, then, to reduce cognitive load, one can reduce the number of interface structures, decrease information density, and highlight frequently used functions.

The main experimental factor is the type of interface adaptation. The second version of the platform is an autonomous-adaptable one. The third version, on the other hand, adds a user-involved element and asks whether the user will accept or reject the adaptation suggestion before making any changes to the user interface. This allows a comparison between a fully automatic version and a semi-automated version with human intervention.

A within-subject design was selected for the study of this difference. All the participants used the three versions of the platform. The order of the three interfaces was randomised for the subjects to avoid order bias and learning effects.

The whole experiment lasted about 15 minutes. Each interface version was used for about 5 minutes, and participants were asked to achieve as high a score as possible in the limited time. After finishing the three sessions, all participants filled out a questionnaire on how easy to use they found the system, their preferences for different interface designs, their focus levels, sense of control, general satisfaction, etc.

The three interface conditions were selected to study how humans responded and performed; it was determined whether AI-assisted adaptive interfaces had any advantages over both the traditional static interface and the fully automated adaptive interface. To some extent, we want to know if a user-selectable adaptive interface can improve the user experience without lowering the quality of the adaptable interface.

4. Results and Analysis

A total of 15 questionnaires were collected in the course of the study. The four responses that had extremely high or low scores and were significantly outside the distribution of the whole set were considered outliers, so they were excluded from the final data to enhance the reliability of the analysis. Therefore, the 11 valid answers were retained for analysis.

According to the above data, most of the participants are relatively young and play games frequently. It can be seen from this that the participants are familiar with game interactions and can provide feedback on the interface Design. Some participants have also pointed out that they have already made errors in using the interface due to poor design, and some believe that a sudden change in the interface will cause a period of adjustment difficulty. Based on the above observations, the interface design directly influences the mental load users experience when using it.

Among the three experimental groups, the AI-assisted adaptive interface had the highest positive evaluation. As shown in Figure 3, 72.7 per cent of the participants thought that Website 3 had a good overall user experience. Among all the interfaces listed, 72.7% of the people chose Website 3 instead of Website 1 and Website 2. 72.7 per cent of the participants also found that Website 3 had an easier-to-focus interface for gameplay.

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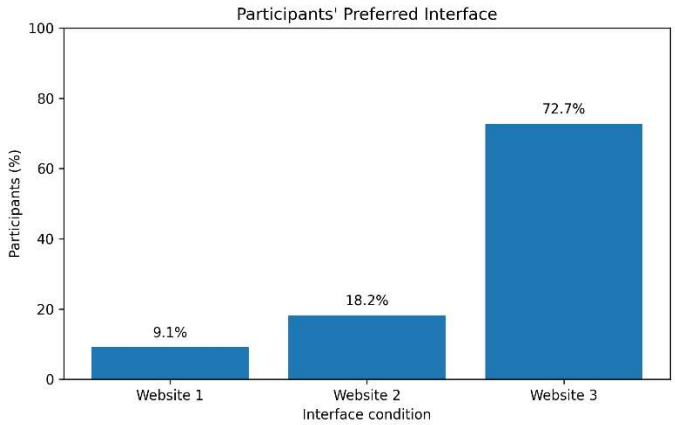


Figure 3. Participants' Preferred Interfaces in the Three Experimental Conditions.

Based on the feedback from the participants, the modified adaptive interface is now more convenient for them to find the desired functions and has reduced annoying extra information. Therefore, based on the above results, behaviour-based interface adaptation can guide users to focus on the interaction process more and improve interaction efficiency; thus, it will help reduce the cognitive load aimed for in this study.

Figure 4 is the mean score of the three interface conditions. As shown in the above tables, the three sites have had different effects on users. The mean scores for Website 1, Website 2 and Website 3 were 2147.6, 2186.0 and 2716.0, respectively. Among the three conditions, Website 3 had the highest average score. Compared with the old fixed-layout screen, the one using AI assistance for adaptation is about 26.5% better on average.

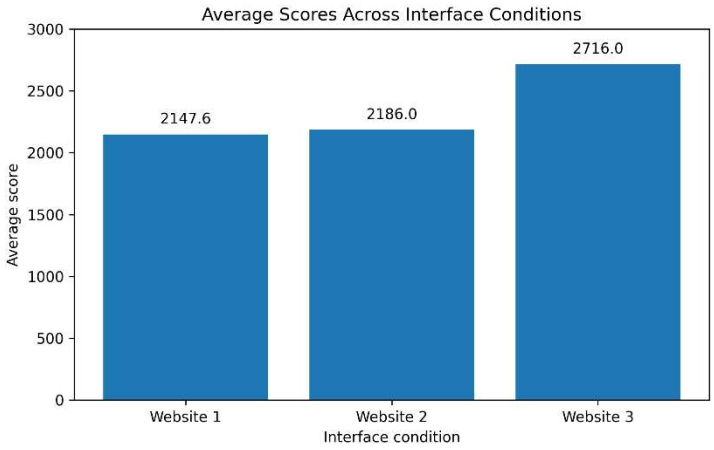


Figure 4. Comparison of Average Scores Under the Three Experimental Conditions.

In addition, many of the participants thought that the recommendation-and-confirmation mode in Website 3 made them feel more in control of the change in the website. The user did not encounter unexpected changes in the interface and was able to select whether or not to apply the adaptation recommendation. It appears that the added controls have improved the degree to which users are willing to accept the modified interface, and at the same time, adaptive functions have been added.

Based on the results of the questionnaire and performance data, it was generally found that the AI-assisted adaptive interface provided benefits in terms of user experience, concentration and task performance compared with a traditional static interface and a fully automatic adaptive

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interface. Although a traditional index of cognitive load was not employed in this paper, it was found that, after using adaptive interface technology and user control, the users' cognitive load decreased and their experience improved.

5. Discussion

Based on the above results, it can be seen that the overall design of adaptive interface intelligence and user autonomy is reasonable. Compared with a traditional adaptive system that automatically modifies the interface, our method can also be used as a decision-support tool for artificial intelligence. We have added a function in our framework to verify changes to the interface for users. It will allow users to take part in the modification and retain some of the original layout changes.

Theoretically, our work adds to the current studies in intelligent user interfaces by showing the advantages of using AI tools in conjunction with human decision-making. In other words, AI will be an assistant for people to do in adaptation, not a substitute. Improve the interface and, at the same time, let the user maintain control over the modified content. The results of our work are also in line with Cognitive Load Theory; that is to say, the adaptive interfaces supporting user control can reduce extraneous cognitive load and improve user experience.

Most other studies on adaptive user interfaces do not consider how users take part in the adaptation process. Most of the current adaptive systems focus on automatic adjustment and system efficiency; our study also found that user control, predictability and acceptance of the game interface design are necessary. A sudden change in the game's display will disturb the players' concentration and sense of being immersed; as a result, they may not understand the goals of the game and lose the enthusiasm to play. Therefore, we can allow users to decide whether to accept the adaptation suggestions in the system and make it more user-friendly.

There are some defects in our study as well. First, the scale of our experiment was relatively small, so the results may not be generalisable to other cases. Second, our adaptive mechanism was a set of behavioural rules and did not use advanced machine learning. Thirdly, since we did not measure cognitive load directly, we derived it from behaviour and a questionnaire.

In the future, the above deficiencies will be addressed by increasing both the quantity and diversity of participants, using machine-learning-based adaptation models, and applying standardised instruments for measuring cognitive load, such as NASA-TLX. In the future, other interactive systems such as learning management systems, productivity tools and virtual reality applications may also be applied to explore AI-assisted adaptive interfaces.

6. Conclusion

This paper investigates the application of adaptive interfaces based on artificial intelligence in enhancing the user experience of online games under the condition that users can choose whether or not to use them. According to the principles of Human-Computer Interaction and Cognitive Load Theory, an AI-assisted adaptive game interface framework has been developed to correct the deficiencies of the old-style static interface and fully automated adaptive interfaces.

A web-based game platform was built with three interface modes: a fixed-position normal interface, an automatically adjusting interface, and an AI-assisted automatic-adjusting interface, and their performance was assessed in a user study. According to the above experiment, the AI-assisted adaptive interface had the highest user preference, concentration level and task performance among the three conditions. Generally speaking, most of the participants were happy with the intelligent recommendation and personal control functions of the adaptive system; therefore, it can be used to increase people's acceptance and usability of such systems.

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Finally, it was found that a new and interesting way to construct adaptive interfaces can be achieved by combining AI-assisted adaptation and user control. The proposed framework offers a direction for the future research and development of intelligent interactive systems with a user-centred approach, and the intelligent system will provide support while allowing users to decide how they want to use the system independently.

References

[1] Newzoo. (2024). *Global games market report*. https://newzoo.com

[2] Nielsen Norman Group. (2024). *User experience research and usability guidelines*. https://www.nngroup.com

[3] Brusilovsky, P. (2001). Adaptive hypermedia. *User Modeling and User-Adapted Interaction*, *11*, 87–110.

[4] Jameson, A. (2009). Adaptive interfaces and agents. In A. Sears & J. A. Jacko (Eds.), *The human-computer interaction handbook* (pp. 433–458). CRC Press.

[5] Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*, 257–285.

[6] Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. Springer.

[7] Norman, D. A. (2013). *The design of everyday things*. Basic Books.

[8] Rogers, Y., Sharp, H., & Preece, J. (2019). *Interaction design: Beyond human-computer interaction*. Wiley.

[9] Shneiderman, B., Plaisant, C., Cohen, M., et al. (2016). *Designing the user interface: Strategies for effective human-computer interaction*. Pearson.

[10] Benyon, D. (2019). *Designing user experience: A guide to HCI, UX and interaction design*. Pearson.