論 文 内 容 の 要 旨

Game difficulty is a critical issue in video game design and is highly concerned by designers and players. It has been reported that game difficulty impacts gameplay, player experience, and engagement. Therefore, both entertainment and serious games should be designed based on adequate consideration of the difficulty factor.

Despite various empirical and design studies, current research on game difficulty faces three challenges. First, there is no broad consensus or clarification research on the concept of game difficulty. Therefore, different definitions and understandings are mixed in use, which compromises the clarity of research findings. Second, due to the first issue, there is no standard measuring method for the game difficulty measurement. Current quantifying or measuring of game difficulty is insufficient comprehensiveness and thus lacks effectiveness. Third, these two issues further restrict the design practice of game difficulty. Especially as a promising difficulty mechanism proposed in recent years, Dynamic Difficulty Adjustment (DDA) has not achieved the expected success in game design.

Therefore, this dissertation aims to provide solutions to these three challenges in concept, measurement, and design. To reframe game difficulty, a player-game interaction perspective was adopted, and theoretical (Chapters 3 and 7), exploratory (Chapter 4), quantifying (Chapters 5-6), and empirical (Chapter 8) studies were accordingly conducted. We proposed new definitions of objective game difficulty (OGD) and subjective game difficulty (SGD), and an interpretive interaction model. The partial matching relationship between SGD and OGD was determined, and the effective measuring methods of them were provided. We also proposed and validated a new DDA definition and the design methodology. Further insights and implications to game difficulty were finally discussed.

We summarize our studies in this dissertation by chapter as follows.

Chapter 2 first introduced how the concepts of game difficulty were divided into OGD and SGD. Currently, OGD refers to the level of demands the game imposes on players' skills, and SGD is about the player's general experience of difficulty from the game playing. According to research, game difficulty is dynamic and occurs in the interaction, but clear definitions of them from an interaction perspective were lacking. We also found that the relationship between OGD and SGD needs to be clarified, for studies indicated that they did not match exactly. The current

measuring methods for these two difficulties also need to be improved. For OGD, it was suggested to be measured by a probability function of player failure at a specific time. However, quantifying this function lacks a clear and universal method. SGD can be measured by self-report and psychological indicators. However, a comprehensive measuring method that involves the multi-dimension of SGD is lacking. We further introduced the multidimensional structure of SGD based on the three interaction components, which indicated this summary could be the basis for developing a new SGD measuring method. For game difficulty design, we introduced the current research on how game difficulty impacts players, but we found the separate impacts of OGD and SGD need to be clarified. Research on the DDA mechanism was also introduced, but we found rethinking the theoretical fundamentals of DDA is urgent for design.

Chapter 3 first introduced the three components of player-game interaction: game tasks, players and their characteristics, and the interaction between game tasks and players. Tasks can be defined as activities that should be conducted and can be designed in specific forms with four basic elements: goals, rules, states, and presentation. Players have different self-efficacy, motivation, skills, and game experience. These factors affect OGD and SGD by influencing the player-game interaction process. The interaction is how players get the information in visual and auditory forms from the game tasks and then process the information to input to meet the task demands. Players will have corresponding feelings of the game difficulty from the aspects of the task, the interaction process, and their own. Based on these findings, we built a model to illustrate how OGD and SGD occur in the game-playing process. We further redefined OGD and SGD based on this interaction perspective. We redefined OGD as "during the interaction process between players and game tasks, the dynamic meeting of the player's skill to the game task demand", and redefined SGD as "the player's subjective evaluation of game difficulty based on their perceptions of the game task, game-playing, and themselves." These contents supported our studies in the following chapters.

Chapter 4 explored the relationship between SGD and OGD, and their separate impacts on players. A research framework and seven hypotheses were proposed for studying whether SGD and OGD match and how they affect player experience, engagement, and self-efficacy. In addition, OGD was measured by the failure rate, and SGD was measured by the proposed six-dimensional measuring method. We designed a game to manipulate the failure and success of players and an experiment to test our hypotheses. We found that OGD and SGD only partially match each other,

and we argue that the reason is their structure differences. Our findings support that SGD mediates the OGD's effect on player experience, engagement, and self-efficacy and indicate that SGD has an indispensable role in influencing players. These findings provide empirical support to the partial matching relationship between OGD and SGD and valuable insights into game difficulty design.

Chapter 5 provided a new OGD measuring method. Measuring OGD requires a deep understanding of game tasks. Therefore, to identify classical forms of game tasks, we first conducted an investigation of commercial video games. We found that based on the input forms, seven basic game task types can be identified to represent all game tasks, which also means that we can quantify OGD by players' input. We further proposed a new OGD measuring method, including an operational definition and calculation formulas of OGD. We suggested that OGD could be operationally defined as: "an integral ratio of the player's input incorrectness to the game task's required input correctness within a given time frame". Subsequently, we quantified OGD to produce several formulas by combining variables of input correctness and time in the interaction. We tested our method through a case study. We first designed a game that includes the seven basic game tasks with different complexity, then conducted an experiment to compare our method and the failure rate method in measuring OGD. The results showed that our method had a closer correlation with SGD, which indicated its measuring efficacy was better. This method also provided a better interpretability of OGD in the interaction process.

Chapter 6 developed and validated an SGD scale with six dimensions of game complexity, game completion difficulty, game-playing difficulty, player competence, player pressure, and player effort. The complete development process of this instrument contained the three stages of item generation, scale development, and scale testing. We first generated 60 items in the item generation stage based on the literature review in Chapter 2. In the second stage, we conducted an investigation to verify the construct validity and exclude the ambiguous items. Twenty-seven items that confused participants were removed and in the third stage, the 33-item version scale was tested. The results showed that our final version of the SGD scale with 33 items had good reliability and validity and was thus promising for future measurement of SGD.

Chapter 7 rethinked the fundamentals of DDA mechanisms to improve its design theory and provide effective design methodology. We have addressed the four crucial questions regarding DDA's issues, definition, scope, value, and design through a comprehensive literature review and discussion. This rethinking offers new insights

into DDA and its design: DDA should not depend on Flow theory but should be defined based on game difficulty concepts, and it should be designed toward specific design goals. We proposed a new DDA definition, “a game difficulty control mechanism that aims to control the difficulty automatically in game interaction by evaluating objective and subjective game difficulty data and modifying game tasks”. DDA was also re-identified as an adaptive game difficulty mechanism that only takes effect in game interaction. We also suggested the value of DDA was that it could be a game difficulty control tool that guides game difficulty progress more precisely to support the difficulty design for various goals. We further proposed a new DDA design methodology, including a design framework and a 6-step design process. This methodology advocates a design goal-oriented DDA design. This work is promising to improve DDA through theoretical exploration.

Chapter 8 validated the proposed DDA design methodology in Chapter 7 by a design case. We designed a cognitive training VR exergame to enhance the cognitive abilities of the elderly and tested the basic gameplay and game difficulty design with a game pretest. The DDA mechanism was then designed based on the proposed design methodology. There were two goals of game difficulty design: one was the serious goal of improving the elderly players' cognitive abilities, and the other was the entertainment goal of providing a satisfying player experience to support this training. Toward these goals, the DDA mechanism in this game was accordingly designed. In addition, the manual difficulty adjustment (MDA) mechanism was also designed for effect comparison. Subsequently, we conducted an experiment to train two groups of elderly participants for two months through the game with DDA and MDA separately. The results showed that the designed DDA had a similar effect in improving the elderly's cognitive abilities with MDA but better improved the player experience. This case study validated the effectiveness of our DDA design methodology and provided valuable insights into game difficulty design.

In chapter 9, based on all our findings in the previous chapters, we discuss the concepts, measurement, and design of game difficulty in video games. For the concepts, we first summarized our definitions of OGD and SGD and then explained the meaning of dynamic in more detail. We also discussed the ideal relationship and suggested that it is necessary to respect their nature and acknowledge that there will be a partial match between OGD and SGD in the interaction of players and games. For the measurement, we summarized the three main situations that need measuring game difficulty, i.e., difficulty design validation, difficulty research, and real-time difficulty adjustment, and discussed how to conduct corresponding

measurement. For the game difficulty design, valuable design implications were proposed. More specifically, we suggested designers design OGD and SGD separately towards specific design goals. OGD should be designed to combine mature design tools (e.g., difficulty curve) and SGD could be designed by referring to the proposed six dimensions. In addition, DDA design could utilize the partial matching relationship between OGD and SGD to create richer and healthier experiences of game playing. We also provide this dissertation's limitations and the future directions for research.

The contributions of this dissertation are three-fold: (1) enhancing the theoretical fundamentals of game difficulty by clarifying the concepts' connotations and relationships; (2) clarifying the relationship between concept to measurement and proposing effective measuring methods for game difficulty; (3) exploring the game difficulty's impacts on players and rethinking the DDA mechanism to provide practical design methodology and implications for game difficulty. The other specific contributions of this dissertation include: (i) Proposing new definitions of SGD and OGD and an interaction model to interpret these two difficulties. (ii) Determining the partial matching relationship between SGD and OGD. (iii) Proposing a new DDA definition and design methodology and validate them with a case study.