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Exploring the Differential Impact of Sensory and Cognitive Feedback on Flow: An Experimental Study Based on Two Cars

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Abstract. The impact of feedback on flow has been extensively explored, yet limited attention has been given to sensory feedback and cognitive feedback. To address this gap, the present study investigates the distinct effects of sensory feedback and cognitive feedback on players' flow experiences. Employing a 2 (presence vs. absence of sensory feedback) × 2 (presence vs. absence of cognitive feedback) between-subjects factorial design, the experiment utilized a modified version of the "Two Cars" game as the experimental task. Forty-eight participants were randomly allocated to one of four experimental conditions utilizing a Latin square design. Flow experiences were assessed utilizing the Flow State Scale-2, and the results were analyzed via two-way ANOVA employing SPSS. The results revealed that, at the overall flow level, neither sensory nor cognitive feedback exhibited substantial main effects or interaction effects. However, a significant interaction effect between sensory and cognitive feedback was observed specifically within the dimension of action-awareness merging. Moreover, sensory feedback alone exhibited a significant main effect within the dimension of autotelic experience.

Keywords: Flow, Feedback, Sensory Feedback, Cognitive Feedback, Gaming Experience

1. Introduction

Flow is a psychological state in which individuals become fully immersed in the activity at hand [1]. When in a state of flow, individuals experience complete absorption, marked by heightened concentration, enjoyment, and a sense of control over their actions. During this state, they often lose awareness of both time and self [2]. According to Csikszentmihalyi, flow can be characterized by nine core dimensions [3]. Subsequent academic and empirical studies have classified flow features into three stages: antecedents of flow, flow experience, and flow consequences [4,5]. The antecedents of flow include explicit objectives, prompt and clear feedback, and a balance between challenge and skill level [2,3]. Immediate feedback not only assists individuals in adjusting their actions but also conveys symbolic information: the individual is in the process of achieving or has already achieved their goal. This feedback enhances the meaningfulness of the activity and fosters a sense of positive engagement, leading to greater satisfaction and enjoyment [6]. Clearly, feedback plays a pivotal role in the flow process.

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A significant amount of research has investigated the correlation between feedback and flow, analyzing diverse forms of feedback, such as auditory feedback and performance feedback, among others[7,8]. Moreover, several studies have compared different types of feedback, such as internal versus external feedback and positive versus negative feedback, highlighting the potential variance in how different feedback types influence flow experiences [9]. However, relatively few studies have distinguished between sensory feedback and cognitive feedback, which originate from sensory and cognitive aspects of the individual, respectively [10]. Consequently, the differential effects of these two feedback types on flow experience remain underexplored. In light of this gap, the present study aims to delve into this area, offering a nuanced perspective on the impact of feedback on flow. By conducting an in-depth investigation into this issue, the study aspires to contribute new insights to the broader research field concerning the role of feedback in flow. Furthermore, the findings could inform the enhancement of game design, ultimately enriching players' gaming experiences.

2. Literature review

2.1. Feedback and flow

Numerous studies have investigated the impact of feedback on the flow state. One intriguing finding reveals that during diabolo exercises accompanied by sound, elderlies experience significantly higher flow state scores compared to when the activity lacks auditory input. This finding underscores the facilitative role of auditory feedback in enhancing flow experiences [7]. Similarly, research conducted by Zhang et al. demonstrates that positive outcome feedback in competitive gaming environments can bolster players' flow states, highlighting the beneficial impact of feedback within gaming contexts [11].

In the realm of improvisational music creation, scholars have proposed a prevalent conceptual framework that categorizes feedback into two distinct types: internal feedback and external feedback. Internal feedback pertains to musicians' self-monitoring processes during performance, whereas external feedback arises from the interactive exchange of information between musicians and their audience during live presentations [9]. The study, albeit focused on improvised music, provides valuable insights about the presence of feedback from several sources. Furthermore, from the perspective of feedback perception, one can identify a distinction between positive and negative feedback. When recognized, positive feedback can foster confidence, so promoting the onset of flow. In contrast, negative feedback, when interpreted unfavorably, may trigger inappropriate attentional shifts, subsequently disrupting the continuity of flow experiences [12]. Notably, this nuanced dynamic between feedback perception and flow interruption has been corroborated by a plethora of empirical investigations.

2.2. The mechanisms by which feedback influences flow

Self-Determination Theory (SDT) provides an insightful paradigm for comprehending the impact of input on the flow state. SDT posits that humans have three essential psychological needs: autonomy, competence, and relatedness [13]. Autonomy denotes the belief that one's acts are voluntary, encapsulating a sense of freedom and control over decisions. Competence, on the other hand, reflects the belief in one's ability to successfully tackle challenges and master tasks. Relatedness involves feeling connected to others, experiencing meaningful relationships, and receiving social support and validation from the environment. When feedback effectively nurtures these core needs—autonomy, competence, and relatedness—it fosters intrinsic motivation,

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subsequently enhancing psychological well-being and overall happiness. Conversely, if these needs are suppressed or overlooked, individuals may experience diminished intrinsic motivation, manifesting as passivity, disengagement, or even psychological distress.

Flow can be conceptualized as a self-determined motivational state [13]. To experience flow, individuals must be capable of making autonomous decisions, accompanied by a perceived sense of control over the task at hand [6]. Given the inherent link between autonomy and flow, it follows that fostering autonomy significantly contributes to flow experiences. Consequently, feedback that bolsters autonomy is likely to enhance flow. In a notable study, Steele and Fullagar examined university students' flow experiences within academic contexts, exploring factors that facilitate flow. Regression analysis revealed that autonomy was a significant predictor of flow ($\beta = .41$), indicating that increased decision-making freedom directly enhances the likelihood of experiencing flow. Furthermore, feedback also emerged as a significant factor influencing flow ($\beta = .32$), indirectly fostering flow by strengthening students' sense of autonomy [14]. In parallel, research has underscored the significant impact of feedback on competence [15]. When individuals perceive themselves as capable of achieving goals and successfully interacting with their environment, they experience a heightened sense of competence [16]. This perceived competence, in turn, fortifies intrinsic motivation and amplifies the flow experience [17].

2.3. Distinction between sensory feedback and cognitive feedback

In the realm of gaming experiences, feedback can be classified into two primary categories: sensory feedback and cognitive feedback. Sensory feedback originates from sensory experiences linked to factors including screen dimensions, audio fidelity, visual realism, and three-dimensional display features [18,19]. Feedback obtained from sensory experiences falls under the category of sensory feedback. On the other hand, cognitive feedback arises from the intrinsic motivational aspects of the tasks within the gaming process. It is a type of feedback based on the task itself, providing information related to the progress, performance, or outcomes of the current task [20,21]. When both sensory and cognitive feedback coexist, the feedback received by the individual becomes more comprehensive. Nonetheless, while prior research has thoroughly examined the connection between feedback and flow, and a significant body of work has investigated different forms of feedback, there is a paucity of studies that explicitly differentiate and contrast sensory and cognitive input.

In fact, many studies tend to conflate the two, despite both types of feedback being significantly important to individuals. Therefore, this study aims to build on previous research by differentiating and comparing these two types of feedback. It seeks to address the following research questions: Do both types of feedback influence an individual's flow experience? Is there a difference between sensory feedback and cognitive feedback in terms of their impact on the flow experience of gamers? Based on these questions, the following hypotheses are proposed:

Hypothesis 1: Sensory feedback can enhance individuals' flow experiences.

Hypothesis 2: Cognitive feedback can enhance individuals' flow experiences.

Hypothesis 3: There is a difference between sensory feedback and cognitive feedback in their effectiveness in promoting flow experiences.

Hypothesis 4: Sensory feedback and cognitive feedback interact in influencing flow experiences. Specifically, when sensory feedback is present, cognitive feedback exerts a stronger positive impact on flow experiences.

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3. Experimental design

3.1. Participants

This experiment was conducted offline, recruiting a total of 48 participants from Tsinghua University. Among them, 22 were male (45.8%) and 26 were female (54.2%). To mitigate potential background differences among participants, a Latin square design was employed to allocate subjects into four distinct groups. This methodological approach ensured balanced group composition, rendering factors such as academic major and prior gaming experience inconsequential during recruitment. Each group consisted of 12 participants, categorized as follows: the control group, the sensory feedback group, the cognitive feedback group, and the full feedback group. This organized classification enabled systematic comparisons, aiding in the understanding of the varying impacts of sensory and cognitive feedback on flow experiences.

3.2. Experimental paradigm

To investigate the proposed research questions, this study employed a modified gaming experimental paradigm known as the Two Cars game. In this game, players are tasked with simultaneously controlling two cars, each traveling on its own designated track. The primary objective is to collect specific items (coins) while deftly avoiding obstacles (barriers). The experimental design follows a 2 (sensory feedback: present/absent) × 2 (cognitive feedback: present/absent) between-subjects factorial structure. Sensory feedback included auditory feedback and haptic feedback. Auditory feedback was characterized by the presence or absence of key sounds, while haptic feedback was differentiated by the keyboard type: the sensory feedback group used a mechanical keyboard, and the no sensory feedback group used a regular keyboard. Cognitive feedback consisted of immediate feedback, score feedback, and post-game feedback. Immediate feedback was reflected by a score indicator, score feedback showed the current score, and post-game feedback provided final speed and score information.

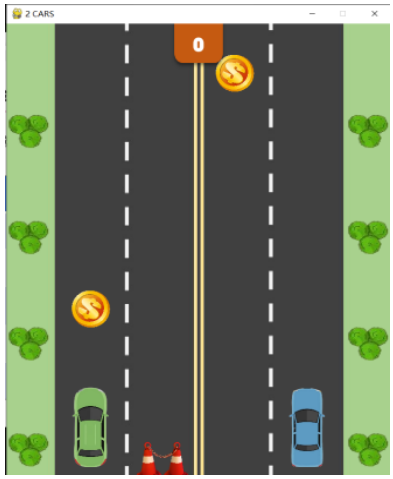

Figure 1: The interface of the Two Cars Game used in the experiment

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3.3. Experimental process

Each participant underwent both a practice phase and an experimental phase. The practice phase lasted 5 minutes, during which the experimenter recorded the participant's game speed. During the game, the game speed was adjusted automatically and adaptively to ensure a balance between skill and challenge for each participant. The formal experimental phase lasted 10 minutes and consisted of one session. Participants played the game according to their assigned group conditions.

3.4. Measurement

In this experiment, flow experience will be measured using the Flow State Scale-2 (FSS-2) [22]. The FSS-2 consists of 36 items similar to a 5-point Likert scale, where participants respond to questions related to their thoughts and feelings during gameplay (e.g., "Do I feel a sense of control over what I am doing?"). A score of 1 indicates "strongly disagree," while a score of 5 indicates "strongly agree." The 36 items of the scale are divided into nine dimensions: Challenge-skill balance, Merging of action and awareness, Clear goals, Unambiguous feedback, Concentration on the task at hand, Sense of control, Loss of self-consciousness, Transformation of time, Autotelic experience. Each dimension contains four items. The Cronbach's α coefficient for the scale is 0.936, indicating high reliability. The FSS-2 is extensively utilized to evaluate flow experiences. To guarantee measurement validity, this study will additionally utilize this scale to examine participants' flow experiences in video games.

3.5. Data analysis

The data gathered in this study will be evaluated utilizing SPSS (Mac version 27.0). A two-way analysis of variance will be performed to investigate differences in flow experience among the four participant groups. The initial step will involve assessing the general disparities in flow experience among the groups. The variations in flow experience will thereafter be analyzed according to the nine dimensions of the FSS-2 scale.

4. Results

4.1. Data analysis result

The results of the two-way ANOVA conducted using SPSS indicate that, with respect to the overall flow state, neither the main effect of sensory feedback nor the main effect of cognitive feedback is significant (sensory feedback: $F=0.285$, $p=0.596$; cognitive feedback: $F=0.322$, $p=0.573$). Additionally, the interaction effect between sensory and cognitive feedback is also not significant ($F=0.627$, $p=0.433$). Therefore, hypotheses 1, 2, 3, and 4 are all rejected. Subsequently, the study performed separate data analyses on the nine dimensions of flow experience. The significant findings are as follows: In the dimension of Merging of Action and Awareness, a significant interaction effect between sensory feedback and cognitive feedback was found ($F=6.321$, $p=0.016$). In the dimension of Autotelic Experience, a significant main effect of sensory feedback was observed ($F=5.705$, $p=0.021$), indicating that the mean flow experience in groups with sensory feedback was significantly higher than in groups without sensory feedback. All other results were not statistically significant.

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4.2. Result discussion

Overall, neither sensory feedback nor cognitive feedback significantly promoted the flow state of individuals, which contradicts the findings of previous studies. This discrepancy may indicate potential issues within the experimental design of this study. Firstly, regarding the sample, the sample size may need to be expanded to obtain meaningful results. Moreover, since all participants recruited in this study were undergraduate students from Tsinghua University, it is possible that the university student population (around 20 years old) possesses superior cognitive abilities, reaction speed, and information processing skills [23,24]. This advantage may make them more adept at playing games, thereby weakening the potential impact of timely feedback on their flow experience. For instance, they may perceive the game as relatively simple, resulting in a persistent state of boredom. Secondly, concerning the manipulation of independent variables, the operations designed in this experiment may not have been sufficient to create a clear distinction between the experimental and control groups in terms of the two types of feedback. Future studies could consider conducting a preliminary experiment to confirm the validity of variable manipulation before proceeding with the formal experiment. Furthermore, as the game in this experiment had both coins (positive feedback) and obstacles (negative feedback), the negative feedback may have detrimentally influenced the flow experience, so confusing the impact of the independent factors on flow. Thirdly, regarding measuring instruments, while numerous studies have employed the FSS-2 scale to yield reliable experimental outcomes, it continues to be difficult to encapsulate the essence of flow through questionnaire scoring, experience sampling, or comprehensive interviews [25]. This issue might be reflected in the present study, as some participants reported after the experiment that they were “unsure what the questions were asking.” Lastly, in terms of the experimental procedure, the practice session lasted for five minutes. While the original intent was to better match the game’s difficulty with the player’s skill level, this setting may have led to over-familiarity with the game or induced boredom. Even though the game featured adaptive adjustments (such as increasing the car’s speed when collecting coins and decreasing it after hitting obstacles), participants still struggled to achieve a state of flow. Furthermore, the duration of the formal game session may also need adjustment based on practical considerations, as excessively long game sessions might cause boredom.

The significant interaction effect observed in the Merging of Action and Awareness dimension and the main effect of sensory feedback on Autotelic Experience are consistent with previous findings that feedback can influence flow. This result may suggest that different dimensions of flow vary in sensitivity to different types of feedback, highlighting the complexity of this area of study. Future research should more precisely investigate the mechanisms of different flow dimensions. However, since the majority of data analysis results in this study are not significant, it remains challenging to derive a systematic conclusion regarding the effects of sensory and cognitive feedback on flow experience.

5. Conclusion

This study sought to examine the influence of sensory feedback and cognitive feedback on the flow experience inside a gaming scenario. While the overall results demonstrated that neither sort of input exerted a significant main effect or interaction effect on the flow state, notable findings were identified in particular dimensions of flow. Notably, there was a significant interaction effect between sensory feedback and cognitive feedback on the Merging of Action and Awareness dimension, and sensory feedback demonstrated a significant main effect on the Autotelic Experience

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dimension. These findings suggest that different types of feedback may influence distinct dimensions of flow, highlighting the complexity of feedback mechanisms within the flow experience. However, the lack of significance in most analysis results indicates that future research should further optimize the experimental design, including increasing the sample size, improving the operationalization of feedback conditions, and adopting more refined tools to capture the subjective experience of flow.

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