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Practicing drum on VR to promote rhythm performance: Exploring the learning progress related to incremental belief of rhythm, gameplay anxiety, flow experience, and perceived learning value

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A R T I C L E I N F O

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A B S T R A C T

Virtual technology in teaching can enrich the content and bring more possibilities. The present study used a virtual reality system named "Jazz-Drum-VR" which embedded a function to analyze learners' performance of simulating jazz drumming. The system enabled learners to know their mistakes and correct them based on its spontaneous feedback to promote the effectiveness of their rhythm learning. To understand whether this game could effectively enhance students' rhythm performance, this study adopted the cognitive-affective theory of multimedia to explore the relationship between students' gameplay anxiety, flow experience, and learning effectiveness when playing "Jazz-Drum-VR." Using purposive sampling, students in a high school were invited to take part in a quasi-experimental single-group time serial study involving five sessions over a period of 4 weeks. A total of 67 useful data were collected after Jazz-Drum-VR practices, and confirmatory factor analysis and structural equation modeling analysis were performed. Results revealed that rhythm incremental beliefs can negatively predict gameplay anxiety and positively predict flow experience; flow experience can positively predict perceived learning value and learning effectiveness; and perceived learning value can positively predict learning progress. The results implied that practicing Jazz-Drum-VR could significantly promote rhythm accuracy.

1. Introduction

Virtual reality (VR) can be used for learning from observation, for example, visiting zoos virtually to hear lions roaring; however, it can also be applied to skill learning. Some studies have examined the usage of VR for skill learning or motor learning, such as in neurosurgery and anatomy training [31,52]. In music learning, a previous study indicated that the piano takes the melody, the bass plays harmony, and the drums are suitable for practicing rhythm [33,49]. However, the relationship between cognitive and emotional problems and the use of VR to facilitate rhythm learning has not been thoroughly examined [76]; therefore, the present study designed a virtual jazz drums system named "Jazz-Drum-VR" for players to practice rhythm, and examined the learning effectiveness relevant to players' cognition and affection aroused by practicing drum rhythm with the VR system.

The phenomenon of cognitive-motor dual-tasking (tasks processed and executed simultaneously) has been studied in the past decades in the context of various cognitive tasks [72]. The dual-process theory predicts reduction in performance in dual-task situations. Performance in concurrent cognitive-motor tasks was found to have reduced accuracy and stability under cognitive challenge while involving a high attention task which limited cognitive execution [1]. According to Wickens [86], in cognitive-motor dual-tasking, a visual search task will interfere much more with a motor task than an auditory attention task, because the motor performance needs to be accompanied with the visual search task, which requires individuals to perceive and process spatial information while performing the auditory attention task. Moreover, according to the attention-to-affect theory, affect can be raised through current attention, which may contribute to the performance (Schaefer & Scornaienchi, 2020), [77]. The present study drew on the cognitive-affective

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theory of learning with multimedia (CATLM), which provides a rational framework for investigating instruction in interactive, multimodal contexts, which may contain text, story, visuals, music, and/or sound effects [58]. As a new medium for practicing rhythm, VR has an impact on our emotional and cognitive systems through modulation and enhancement [7,63]. Drawing on CATLM-VR, this study conceptualized a research model and used an experimental research method to explore how players' incremental beliefs about rhythm affected their affective factor (i.e., gameplay anxiety) and cognitive factor (i.e., flow experience) as reflected in their perceived value of practicing and their learning progress.

1.1. Incremental belief of rhythm intelligence

Based on the implicit belief of intelligence [19], entity theorists believe that although individuals are able to learn new skills and knowledge, their underlying intelligence level does not tend to change. In comparison, incremental theorists believe that with hard work and continued learning, it is possible to improve and cultivate intelligence over an individual's lifetime [18]. Of the multiple intelligence types, Gardner [29] defined the "object-related" intelligences as logical-mathematical, spatial, and bodily-kinesthetic, while the "object-free" forms of intelligence are verbal and musical. It has been hypothesized that musical intelligence is less open to change, compared with verbal and bodily-kinesthetic intelligences which are considered to be more open to development [28,29]. As most rhythm practice incorporates executive-control motor processes [67], bodily-kinesthetic intelligence can be taken as incremental intelligence [75]. Since applying VR to jazz drum playing is related to bodily-kinesthetic intelligence [26], incremental belief of rhythm was adopted in this study. If some people are able to maintain rhythmic performance without frequent errors, they may be considered as having an incremental belief of rhythm intelligence. In line with this, how this incremental belief affects participants' learning when playing Jazz-Drum-VR was explored in this study.

1.2. Gameplay anxiety

Due to advances in technology, virtual environments have been able to be designed for relaxation, and a review study found that such environments can reduce anxiety [14]. On the other hand, as VR-based studies depend on motion capture equipment, VR is an effective means of eliciting mobility-related anxiety [66]. Johnston et al. [44] highlighted two types of interactivities in virtual surroundings: functional and cognitive interactivity. Accordingly, when using Head Mounted Displays (HMD), many people potentially experience frustration and anxiety related to how to manipulate the system (i.e., functional anxiety). Moreover, if participants have less of the necessary knowledge to interact with the content, they will have another type of anxiety (i.e., cognitive anxiety). Combining these two types of anxiety, the present study used the term gameplay anxiety in VR (hereafter gameplay anxiety).

1.3. Flow experience

Csikszentmihalyi [13] proposed flow experience as a state in which people are fully engaged in an activity situation and are able to focus their attention and filter out all irrelevant perceptions; this is also called flow state. If an individual can achieve a flow state during the learning process, it not only enhances their cognitive absorption, but also increases their intention to continue learning [24]. VR can be used for emotion-induction to promote the user's sense of presence [3]. For example, designing digital didactics can promote players' natural interaction and immersion in virtual environments to learn music (e.g., classical, country, jazz, and swing) [43] and flow experience in training [88,89]. As a bodily-kinesthetic practice system presents a potential immersive tool which includes gestural control for music learning, user's flow experience evaluation of the system should be of interest [26]. In line with bodily-kinesthetic practice, this study used Jazz-Drum-VR to investigate the flow experience of learners during the practice process.

1.4. Perceived learning value

The expectancy-value theory [87] states that the choices individuals make tend to reflect both the outcomes they expect to achieve as a result of engaging in activities and the value they place on those activities. Perceived value can be measured as it is specifically related to the perceived usefulness of a choice [80]. For example, students' learning environment selection might be influenced by their perceived value of a course based on their satisfaction with e-learning [11]. Another study showed that in blended learning with a MOOC (Massive Open Online Course) in an introductory course of "Fundamentals of Administration," the functional value was perceived by the students [15]. This study extends previous research by demonstrating how the design of Jazz-Drum-VR contributed to the pedagogical process of rhythm learning and increased the value perception of learners at the high school level. Moreover, attention to emotion, a facet of emotional awareness, is defined as the extent to which people attend to and value their feelings [70], and the higher-order cognitive challenge of effortful control, which includes both attentional and affective control, is associated with the performance of some types of tasks [83]. However, to explore the challenge of playing Jazz-Drum-VR, the present study implemented a supporting system for players to be aware of their errors and to reduce their mental effort by displaying their errors. Thus, the learners' value perception of this design was examined in this study.

1.5. Learning progress

Music education involves practical activities such as learning to play musical instruments as well as theory. It has been found to be beneficial for learners' spatio-temporal cognitive skills [12]. VR fosters educational experiences that draw on "learning-by-doing" and "situated learning" [43] and affords learning that takes place as a result of frequent practice, in the same context in which it is applied [78]. Trained participants who used an embodied VR environment gained significant accuracy of bodily movements with mental imagery [79]. However, there is a gap in the use of VR for learning assessment in jazz drumming skills training. Therefore, Jazz-Drum-VR, the research tool of this study, provides an analysis and scoring model for users to automatically and objectively assess their learning progress. Thus, this study aimed to investigate the learning progress of learners using Jazz-Drum-VR after several practices with the same melody.

1.6. Hypotheses

1.6.1. Incremental belief and gameplay anxiety

Marsh and Hattie [54] mentioned that students' beliefs about their learning abilities are also known as self-concept, which is formed through the interrelationship between the person and the learning environment. For example, learners' language self-concept is strongly associated with their language learning progress, and the same is true for mathematics, where learning progress increases when learners' mathematics self-concept is high [32,55]. When learners have adaptive beliefs, they can perform problem solving accurately; on the other hand, fixed beliefs may prevail when solving highly complex problems [50]. In educational psychology, a link has been made between beliefs as self-attributes such as intelligence and a wide range of outcomes. Fixed belief is predictive of future anxiety or distress [74]. Taken together, this study translates self-concept into an incremental belief of rhythm, and hypothesized that students' own incremental belief of rhythm would affect their anxiety. The following hypothesis was therefore proposed:

H1: Incremental belief about rhythm is negatively related to gameplay anxiety.

1.6.2. Incremental belief and flow experience

It is known that gamification experience can create a number of desired states including flow [6] and engagement [51]. Flow is considered to be important because it provides a framework which allows us to understand game experiences [85]. Moreover, an individual's set of beliefs about their ability to perform across domains is called their self-concept [20]. White et al. [84] suggested that flow experience can be guided by an individual's beliefs. Many studies have suggested that ability belief in using digital game-based learning can enhance learners' flow experience and further improve their learning progress (e.g., [46,85]). However, few studies have focused on exploring the correlates between incremental belief of rhythm and flow experience when playing Jazz-Drum-VR. Thus, the following hypothesis was proposed:

H2: Incremental belief about rhythm is positively related to flow experience.

1.6.3. Gameplay anxiety and perceived learning value

Research suggests that anxiety can lead to negative attitudes and outcomes in individuals' interactions with the learning progress [8]. When individuals are faced with challenging tasks, they may experience feelings of uncertainty about the task outcome and their performance, and have doubts about their self-achievement [2], which can cause them to become anxious [59]. In particular, in a situational game when the cognitive complexity increases for learners, participants' anxiety also increases, but it significantly improves their learning value [71] if they outperform others [74]. Thus, participants' perceptions of how the complexity of playing Jazz-Drum-VR affected their gameplay anxiety and was reflected in their perception of the learning value was hypothesized as follows:

H3: Gameplay anxiety is negatively related to perceived learning value.

1.6.4. Flow experience and perceived learning value

Dede's [16] study mentioned that the immersive learning environment brought by virtual reality can enhance learning through contextualization, that students are able to do reflective practice, and that learning value is created by practicing. VR provides a better sense of presence and immersion than traditional PC environments, further enhancing the perceived learning value of the individual [65]. VR enhances the individual's flow experience through a vivid and interactive experiential process [47]. However, when using technology-driven devices to perform tasks, overly complex features can result in complexity perceptions that may reduce the users' interaction and their perceived value [38]. As flow experience is a key factor in students' personal and academic performance [4], how participants' perceptions of the complexity of playing Jazz-Drum-VR affected their flow experience and was reflected in their perception of learning value was hypothesized as follows:

H4: Flow experience is positively related to perceived learning value.

1.6.5. Perceived learning value and learning progress

Expectancy-value theory [22] suggests that a value refers to an individual's perception that learning content and tasks are valuable [21]. The control-value theory implies that the effects of value appraisals can control individual engagement and affect their performance [61]. Moreover, driving factors of a value perception can influence individuals' performance and may result in higher or lower rates of performance; thus, it is of vital importance to explore how value perception as a driving factor influences system performance [69], and yet there appear to have been no studies on the influence of perceived value on rhythm performance. Based on this, this research put forward the following research hypothesis:

H5: Perceived learning value is positively related to learning progress.

1.6.6. The mediated effect

According to control-value theory (CVT), there is a close link between emotions and appraisals of achievement-related control and value. The theory proposes that emotions are impacted by control and value by way of simple, independent effects, and also by way of joint, synergistic effects [64]. As self-concept supports players with perceived value and leads to a desire for continuous improvement [41], individuals who have an incremental mindset are more likely to see their abilities as flexible, to attribute their failures to their ability, and to continue facing challenges [74]. As such, ability belief may mean that emotions have an influence on learning progress when performing tasks in technology-based learning environments [53]. Accordingly, to explore the mediated effect of incremental belief of rhythm on learning progress when playing Jazz-Drum-VR, the following hypothesis was proposed:

H6: Incremental belief of rhythm is positively related to learning progress mediated by gameplay anxiety and flow experience.

2. Method

The Hawthorne Effect refers to behavioral changes resulting from the awareness of being observed [30,45]. If there is a Hawthorne effect, it could result in bias, and it would have profound implications for the research [9]. Schmid et al. [73] argued that when technology is involved in an experiment, the results are usually more significant than when it is not used or when it is only used in part. Besides, the current study focused on the relations between the participants' cognitive and affective factors when they played Jazz-Drum-VR. Accordingly, the present study used a single group quasi-experiment to examine the research hypotheses and did not adopt a control group to compare with the experimental group's affective factors in the relationship analysis.

2.1. Research model

Virtual reality is an emerging technology that can be used in education and learning [56]. Drawing on the CATLM, differences in user experiences are likely partly driven by differences in cognitive and affective states when they are immersed in different VR designs [82]. Accordingly, the present study drew on the CATLM to form a theoretical framework to explore the correlates between cognitive factors (e.g., flow experience), affective factors (e.g., gameplay anxiety), and learning performance when practicing with Jazz-Drum-VR. The research model shown in Fig. 1 was developed accordingly.

2.2. Game design

2.2.1. The features of Jazz-Drum-VR

The research team developed "Jazz-Drum-VR" as part of a project with funding from [disclosure after acceptance]. The Jazz-Drum-VR system was designed to include learning scaffolding, which means that when learners play the VR game, it will give them some feedback so that they can correct their errors. In the Jazz-Drum-VR system, learners perform rhythm through virtual percussion.

2.2.2. How to play Jazz-Drum-VR

In the Jazz-Drum-VR system, players see a set of jazz drums on a stage, and can use the VR controllers as drumsticks to play the drums (see Fig. 2). While listening to the melody, the player can see the drum tabs in front of the drum, and there is a hint which moves according to the melody and points out which drum or cymbal the player needs to beat. There is also a blue light to indicate which drum or cymbal is to be played. If players would like to beat the drum, they only need to tap the controller to tap the drumsticks. When they beat the drum, it makes the corresponding sound and the VR screen will show instant feedback such as "excellent," "great," or "good" to assess the timing of the beat. Finally, the VR system will count the correct rate of the player beating the drum

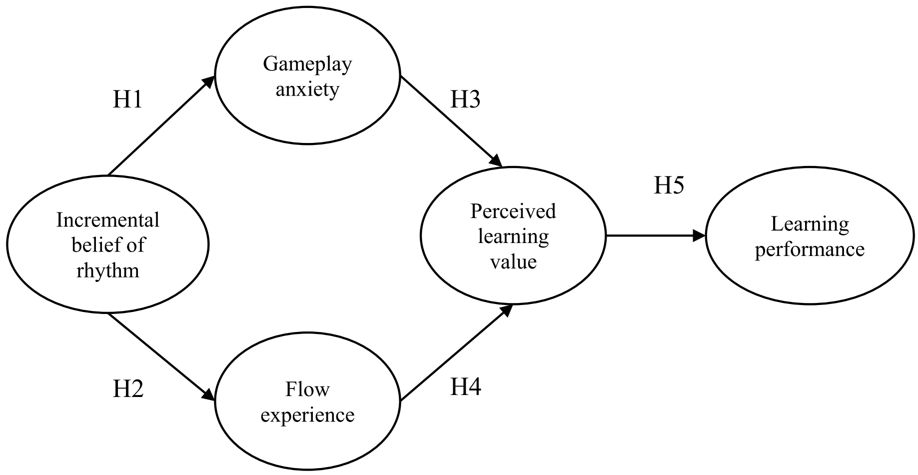

Fig. 1. Research model.

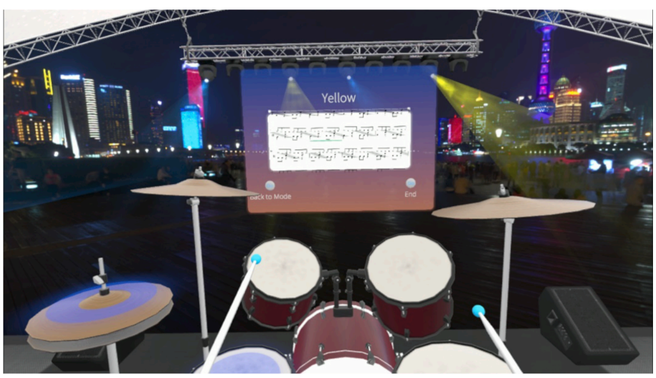

Fig. 2. Jazz-Drum-VR player interface.

and will show the corresponding score.

2.3. Procedure and participants

By adopting a quasi-experimental single-group time serial study, this research course was conducted over a period of 4 weeks. Following is a brief description of the procedure. Phase 1 Preparation period: confirm the course location and the completeness of the hardware. In addition, to ensure the smooth implementation of the test activities, a special anti-failure mechanism was set up as a backup in case of network failure. The agreement statement of participating in this research was given to target participants. If they agreed, they could join the next stages of this study. Phase 2 Rehearsal period: In the first week, participants were given opportunities to practice by selecting rehearsal mode to tap the rhythm on their desks for 3 min five times. Phase 3 Practice period: Jazz-Drum-VR practice on the assigned song for 15 min per practice over 3 weeks. Phase 4 Feedback period: Participants filled out the questionnaire.

Considering ethical issues, written informed consent was obtained from each participant before participation in the study. The study was approved by the Ethical Committee of [disclosure after accepted] with research ethics committee number 201812HS020, indicating that students were aware that they were taking part in an evaluation study and that the data they provided were anonymous.

Purposive sampling was adopted in this study, and the 67 participants were high school students in Northern Taipei. In terms of gender, participants comprised 37 (55.2%) males and 30 (44.8%) females. As for grade level, the distribution was 29 (43.3%) 10th graders, 28 (41.8%) 11th graders, and 10 (14.9%) 12th graders.

2.4. Data analysis

In this study, learning progress was assessed by comparing the correct rate of the first trial and the fifth trial, where 5th − 1st = practice progress. Accordingly, we used the paired sample *t* test for the examination [27]. In addition, since Hair et al. [34] pointed out that PLS-SEM can exemplify the relationships between constructs, we used smart-PLS to be the bridge to do the PLS-SEM examination.

2.5. Questionnaires

The questionnaires in this study were modified and extended with reference to previous questionnaires on related theories. Three domain experts were involved in checking the face validity, and 10 students were invited to conduct content validity for revising the item statements. A 5-point Likert scale was used as the standard of measurement, with five options ranging from *strongly disagree* to *strongly agree*, scored from 1 to 5. SPSS23 was used to conduct the construct reliability and validity analysis to confirm the credibility of the questionnaires.

2.5.1. Measurement

2.5.1.1. Incremental belief of rhythm intelligence. The incremental belief of rhythm scale in this study was adapted from the intelligence scale developed by Dweck [17], and was modified to fit the topic of musical rhythm in this study, with eight questions designed as follows: “Even though I was not born with a good sense of rhythm, I can change it” and “I can change my ability of rhythm through practice.”

2.5.1.2. Gameplay anxiety. The gameplay anxiety scale was adapted from Hong et al. [38] scale and was modified to fit the topic. Eight items were designed for this construct; example items are: “I am anxious when I make a mistake in practicing Jazz-Drum-VR” and “I got into a panic when I couldn’t follow the tempo when playing Jazz-Drum-VR.”

2.5.1.3. Flow experience. Flow experience is characterized by an individual’s cognitive absorption, sense of enjoyment, and sense of time distortion [13]. Referring to this, six items were designed for this study, for example, “I experienced forgetfulness when playing Jazz-Drum-VR,” and “I was unaware of what was going on around me when I was playing Jazz-Drum-VR.”

2.5.1.4. Perceived learning value. The perceived learning value scale in this study was based on Hong et al. [37] scale and was adjusted to include eight items related to Jazz-Drum-VR; example items are:

"Through Jazz-Drum-VR, I was able to increase my accuracy of playing drums in rhythm," and "I learn about the drum set knowledge introduced in Jazz-Drum-VR."

2.5.2. Reliability and validity analysis

Questionnaire item analysis involves internal and external validity analysis. The results of a test administration can identify which items can be retained and which need to be discarded [60]. Internal validity was ascertained by assessing the value of the factor loadings, and those items in each construct with a factor loading value of less than 0.5 were removed [35]. Table 1 shows that all factor loading of items in each construct were over 0.7. Then, retained items in each construct were subjected to reliability and validity analysis.

To understand whether a questionnaire construct is reliable and stable, reliability tests are needed to understand the consistency of the items within the questionnaire constructs. Emerson [23] proposed that Cronbach's α values and composite reliability (CR) should be higher than 0.70 to be considered highly reliable. Table 1 shows that all Cronbach's α values were over 0.88, and the CR values were over 0.83, indicating that all constructs had good reliability.

In the study, convergent validity and construct discriminant validity were examined by average variance extracted (AVE) and factor loadings (FL) which should be higher than 0.5. Table 1 indicates that AVE ranged from 0.72 to 0.77 and FL ranged from 0.72 to 0.83, which means that each component of the questionnaire scale in this study had convergent validity [23].

Construct discriminant validity is mainly used to verify whether there is a difference in the correlation between two structures. The absolute value of Pearson correlation between constructs should be lower than the square root of AVE [23]. Table 2 indicates that the research instrument of this study has construct discriminative validity.

3. Result

3.1. Learning progress

Learning progress can be calculated by comparing the first practice to the last practice. In this study, the correct rate was recorded for each practice in the system of Jazz-Drum-VR. The correct rates of the first and fifth practices of Jazz-Drum-VR were analyzed and were found to be 21.63 with a standard deviation of 14.34 for the first practice and 50.09 with a standard deviation of 14.34 for the fifth practice. Most of the participants in this study had a mode of 18% in the first round. After five practice sessions, most of them had a mode of 52% in the fifth round. To test the learning progress, we performed the t test and found that students had made great improvement (t = 20.91***, p <.001) (see Table 3).

3.2. Path analysis

After the deletion of the questions and the correction of the model, path analysis was used to test whether the research hypotheses presented in the previous section were valid.

According to SEM, incremental belief of rhythm was negatively related to gameplay anxiety (β = −0.54***, t = −5.43); incremental belief of rhythm was positively related to flow experience (β = 0.41*, t = 2.56); gameplay anxiety was not significantly related to perceived learning value (β = −0.10, t = −0.47); flow experience was positively related to perceived learning value (β = 0.50*, t = 2.26); and perceived learning value was positively related to learning progress (β = 0.39**, t = 2.70).

Fig. 3 shows that the explanatory power R^2 of rhythm beliefs on gameplay anxiety was 0.29 and the effect size f^2 was 0.40, which was greater than 0.35 and so had a large effect; the explanatory power R^2 of incremental belief of rhythm on flow experience was 0.17 and the overall effect statistic f^2 was 0.20, which was greater than 0.15 and so had a moderate effect; the explanatory power of gameplay anxiety and flow experience on perceived learning value R^2 was 0.29. The collation effect statistic f^2 was 0.41, which was greater than 0.35 and so had a high effect; the explanatory power of perceived learning value on learning progress R^2 was 0.15, and the overall effect statistic f^2 was 0.18, which was greater than 0.15 and so had a moderate effect. If the R-squared value is low but has statistically significant predictors, it can still draw important conclusions and R^2 can be extremely predictable [57]; thus, as the values of R^2 were above 15% in this study, it indicated that the explanatory power between constructs was acceptable.

Table 1
Reliability and validity analysis.

Construct	M	SD	α	CR	FL	AVE	t-value
Incremental belief of rhythm	4.11	0.86	0.94	0.95	0.88	0.77	10.59–14.55
Gameplay anxiety	2.53	1.13	0.90	0.86	0.72	0.72	6.78–13.08
Flow experience	3.31	0.98	0.88	0.83	0.74	0.75	9.28–11.76
Perceived learning value	3.69	0.97	0.94	0.93	0.83	0.70	5.64–10.95

Table 2
Constituent discriminative validity.

Construct	Incremental belief of rhythm	Gameplay anxiety	Flow experience	Perceived learning value
Incremental belief of rhythm	(0.88)			
Gameplay anxiety	0.41	(0.72)		
Flow experience	0.26	0.18	(0.74)	
Perceived learning value	0.24	0.34	0.52	(0.83)

Table 3
Learning progress descriptive statistics analysis table.

Correct rate %	M	SD	Mode	Median	t-value
First correct rate	21.63	14.34	18	18	20.91***
Fifth correct rate	50.09	14.34	52	51	

Note: *** p <.001.

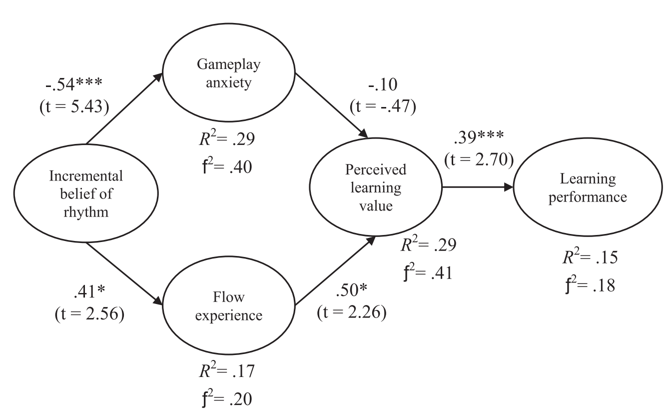

Fig. 3. Verification of the research model.

4. Discussion

Playing Jazz-Drum-VR is related to cognitive-motor dual tasks, and so CATLM can be used to explore the relations between an individual's characteristics, prior experience, user experience, knowledge transfer, and behavior involvement (e.g., [62,68,81]). To understand the relations between VR users' cognitive factors, affective factors, and learning performance which were raised in the VR environment, the results of the study were derived from the collected data. They are discussed as follows.

A previous study indicated that game-based learning might promote learners' flow experiences [85]. The results revealed that incremental belief of rhythm is negatively related to gameplay anxiety, but positively related to flow experience. People with incremental belief tend to believe that their devotion and insistence could lead to success or ability improvement [18]. Kiili et al. [46] proposed that flow could be generated based on the incremental beliefs of certainty in game play. Similarly, White et al. [84] suggested that flow experience can be guided by an individual's beliefs. Besides, the intelligence belief could be a powerful predictor of anxiety [74]. A previous study took computer science students as samples and found that their incremental belief could predict their self-regulated engagement profiles [25], while a green energy inquiry-based learning experiment found that technical high school students' incremental belief had an indirect negative effect on their flow experience [39]. The finding indicates that incremental belief of rhythm has a different effect on gameplay anxiety and flow experience [39]. These results support H1 and H2.

In examining H3 and H4, the result revealed that participants' gameplay anxiety had no relation to perceived learning value, but flow experience had a positive relation to perceived learning value. VR provides a better sense of presence and immersion than traditional PC environments, further enhancing the perceived learning value of the individual [65]. Moreover, VR enhances the individual's flow experience through a vivid and interactive experiential process [47]. In a situation with cognitive complexity, participants' anxiety can increase, but their learning value may improve if they outperform others [74]. An empirical study explored the relations between game experience and perceived value of playing Switch, and the results indicated that gameplay anxiety did not significantly predict perceived value [42]. Another previous study aimed to explore the relations between impacts of flow experience and perceived value on competitive game playing, and the result found that flow experience could affect part of perceived value [10]. Thus, gameplay anxiety could not predict perceived learning value, but flow experience has a positive relation to perceived learning value. Accordingly, H3 was rejected, whereas H4 was supported.

As for H5, the result verified that there was a positive relation between perceived learning value and learning performance. The control-value theory asserts that a person's performance and degree of participation may be affected by the effects of value judgments [61]. Correspondingly, many studies suggest that an individual's belief can enhance their flow experience and improve their learning progress in digital game-based learning contexts (e.g., [46;85]). Haryana et al.'s [36] empirical research aimed to explore how learning outcomes were affected by traditional multimedia and VR accounting equation learning materials. According to their findings, the VR group had the lowest cognitive load and outperformed the standard multimedia group in terms of learning performance. In a related study [5], visitors to zoos and aquariums were asked to reflect on their own values and how those values affected their learning, reflective engagement, and self-reported changes in post-visit environmental behavior. The findings indicated that via the process of on-site reflective interaction, visitors' personal values were associated with their post-visit environmental behavior. Thus, the previous studies supported that perceived learning value has a positive relation to learning performance, thus also supporting H5.

Those people who tend to have a fixed mindset are more likely to attribute their failures to their lack of ability, and to see their abilities as fixed [74]. Such an ability belief may lead to the influence of emotions on learning performance for task purposes in technology-based learning environments [53]. Moreover, CVT proposes that value is related to emotions by exerting joint, synergistic effects [64]. Accordingly, students' cognitive abilities affected the process of the Rhythm-drum mechanisms. Greater cognitive abilities belief facilitated the detection of drum practice errors and overrode their responses. That is, value and emotion had a mediating effect between incremental belief of rhythm and learning progress when playing Jazz-Drum-VR, indicating that H6 was positively supported.

5. Conclusion

The present study explored the relations between incremental belief of rhythm, gameplay anxiety, flow experience, perceived learning value, and learning performance based on CATLM-VR. The statistical results revealed that incremental belief of rhythm was negatively related to gameplay anxiety, but positively related to flow experience. Gameplay anxiety was not significantly related to perceived learning value, but flow experience was positively related to perceived learning value. Additionally, perceived learning value was positively related to learning performance. To sum up, the findings of the present study suggest that the main contributions of the study are as follows. First, this study extended CATLM to a VR learning context, and provided empirical evidence to explore the relations between individuals' epistemic characteristics, affective factors, and learning performance. Second, the present study proposed a new learning approach to learn jazz drumming via VR. The learners' flow experience, perceived learning value, and final learning performance were all higher as long as they had a better incremental conviction of rhythm. Additionally, the anxiety associated with VR had no impact on how valuable learning was regarded, suggesting that teachers might feel at ease even if certain students experience anxiety when utilizing VR.

5.1. Implications

Based on the results of this study, it is suggested that before using VR to assist in teaching, music teachers must build up learners' positive self-beliefs of domain knowledge and lead them to understand the uncertainty of the learning context, so that they can be more confident in the process of learning rhythm by using VR, which can improve the perceptions of learning value and learning performance. Thus, Jazz-Drum-VR may be used for students who would like to learn how to play the jazz drums.

Considering VR as a major type of multimedia, complexity in playing content may be a dominating factor for students to achieve better practice with less anxiety and more flow experience. For example, an "Augmented Practice Room" was developed for users to practice different instruments in VR acoustic environments, and it was found that it had impacts on the users' musical expressiveness, level of attention or arousal, instrument-specific technical issues, and emotional state [48]. According to the results of this study, when playing Jazz-Drum-VR, VR did not greatly raise users' anxiety, but they did experience flow. Thus, Jazz-Drum-VR can be applied to jazz drum virtual practice before students begin real drum playing.

5.2. Limitations and future study

In a previous study, Hong et al. [40] investigated the situational interest in triggered interest effect on maintaining interest. However, as control value theory emphasizes that emotion can influence achievement, the present study performed a summative evaluation of anxiety and flow at the end of the experiment. Future studies may adopt a quasi-experimental approach to compare two types of emotion from beginning practice to last practice to understand what kinds of emotions maintain learning value and performance.

Using VR devices for students to practice needs more room to avoid interference during the experiment. Also, more time and teachers' assistance are needed when participants play Jazz-Drum-VR. In line with this, only 67 students were involved in this study. Increasing the number of participants is expected to improve the credibility of the research model, so future studies may use more VR equipment or invite more high school students to take part.

Gameplay anxiety combines two types of anxiety: functional anxiety and cognitive anxiety, when playing Jazz-Drum-VR. However, functional anxiety is considered to be caused by the human-VR device interaction, whereas cognitive anxiety may be related to individual ability of reading sheet music and familiarity with the melody. Future studies may separate these two types of anxiety and compare them with different cognitive and affective factors that may affect students' practice progress.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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Appendix 1

The Research Questionnaire

Incremental Belief of Rhythm Intelligence
1. I believe that the sense of rhythm can be changed.
2. Even though I was not born with a good sense of rhythm, I can change it.
3. I can change my ability of rhythm through practice.
4. I believe that practice will make my rhythm better in the future.
5. The development of human sense of rhythm has infinite possibilities.
6. No matter what your original rhythm ability is, you can overcome the challenges as long as you keep learning.
Gameplay anxiety
1. I feel nervous because I have no basis of playing the jazz drums when I play Jazz-Drum-VR.
2. I'm worried that I cannot beat the drum according to the drum score when I play Jazz-Drum-VR.
3. I am anxious when I make a mistake while practicing Jazz-Drum-VR.
4. Even though I have the basic knowledge of music, I still worry about my performance of playing Jazz-Drum-VR.
5. I got into a panic when I couldn't follow the tempo when playing Jazz-Drum-VR.
6. I feel stressed and forget how to beat the rhythm when playing Jazz-Drum-VR.
Flow Experience
1. I experienced forgetfulness when playing Jazz-Drum-VR.
2. The experience of playing Jazz-Drum-VR makes me feel a threshold of transcendence.
3. I can engage in playing Jazz-Drum-VR and feel that everything is fine.
4. I feel zoned out after playing Jazz-Drum-VR.
5. I was unaware of what was going on around me when I played Jazz-Drum-VR.
6. When I play Jazz-Drum-VR, I lose track of where I am.
Perceived Learning Value
1. Practicing rhythm through Jazz-Drum-VR gives me a brand-new experience.
2. Through Jazz-Drum-VR, I was able to increase my accuracy of playing drums in rhythm.
3. Playing Jazz-Drum-VR through virtual reality technology me feel a sense of presence while playing Jazz-Drum-VR.
4. Playing the Jazz-Drum-VR game makes me feel it is fun to learn rhythm.
5. The hint of beating the drum increases my motivation to learn rhythm.
6. I learn about the drum set knowledge introduced in Jazz-Drum-VR.

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