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5

Evaluation of a VR language learning environment: Effect of feedback on learners' flow state

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Abstract

Language learning motivation may be fostered by inducing a "flow state" in learners. This is characterised by a state of deep immersion in an activity, such as feeling enjoyment and satisfaction in the activity itself. In this study, the potential of virtual reality (VR) to produce learners' flow state is the research focus. Investigations relate to whether adding audiovisual feedback to a pairwork speaking activity can promote flow. A pairwork spot-the-difference activity that utilized the playful and interactive affordances of VR was created. Two versions of the environment were created: one with audiovisual feedback, and the other without. 22 participants, separated into two groups experienced the VR environment with (n = 12) and without feedback (n = 10). A questionnaire with 10 measures was used to determine whether the VR environments facilitated flow (based on Cho, 2018). Results of the questionnaire suggested that there was no significant difference in the flow state of the participants with and without feedback. However, examination of individual measures revealed significant differences in mean scores for two measures: both "enjoyment" and "satisfaction" were higher in the group that experienced the VR environment with feedback, suggesting that feedback in VR may promote motivation. However, due to the low number of participants in this study, the generalization of results is difficult.

言語学習の動機付けは、学習者の「フロー状態」を誘発することで促進される可能性がある。フロー状態とは、ある活動に深く没頭し、その活動自体に楽しさや満足感を感じる状態のことである。そこで本研究では、学習者のフロー状態を作り出すバーチャルリアリティ（VR）の可能性に着目し、ペアワークでのスピーキング活動に視聴覚フィードバックを加えることで、フローを促進できるかどうかを調査した。本研究ではVRの遊び心とインタラクティブ性を活用したペアワークでの間違い探しシステムを開発した。

本実験では、視聴覚フィードバックがあるものと無いものの2種類のVR環境を開発した。22名の参加者

は2つのグループに分かれ、フィードバックあり（n = 12）とフィードバック無し（n = 10）のVR環境を体験した。VR環境がフローを促進したかどうかを判断するために、10の尺度で構成されたアンケート(Cho , 2018)を使用した。

アンケートの結果、フィードバックの有無による参加者のフロー状態に有意な差はないことが示唆された。しかし、尺度を個別に検討した結果、2つの尺度の平均値に有意差があり、「楽しさ」「満足感」ともにフィードバックありのＶＲ環境を体験したグループで高く、ＶＲにおけるフィードバックがモチベーションを促進する可能性が示唆された。

本研究は参加人数が少ないため、結果の一般化は困難である。

Keywords: virtual reality, flow state, game-based learning, motivation

Introduction

English, as a global lingua franca is being used increasingly within Japan. Additionally, the recent hosting of the Olympic and Paralympic Games in Tokyo has influenced the importance of improving English proficiency for Japanese nationals. Indeed, the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) has pushed for the further development of Japanese students' communication skills (MEXT, 2014). However, many Japanese students still have a poor command of English and struggle to find the motivation to learn.

Although there are various methods of measuring learner motivation (see Dornyei & Ushida, 2011), this study focuses on the development of a *flow state* using the affordances of a specific technology (Csikszentmihalyi, 1990). The flow state is a condition of deep immersion in an activity (Nakamura & Csikszentmihalyi, 2014). It results in a high level of concentration and a feeling of enjoyment and satisfaction. It is also characterized by a distortion of the sense of time such that the time experienced by an individual feels shorter than the actual elapsed time. There are three theorized ways in which flow may be promoted (Csikszentmihalyi, 1996):

1. **Balancing** the level of **challenge** with a participant's skill level,
2. the provision of **immediate feedback** on an activity performed by the participant,
3. and making sure the participant is aware of the goal they are working towards. Hence, the provision of **clear goals.**

Flow in learning and education research

Flow is considered an important construct within educational contexts for the following reasons. First, flow may promote increased task engagement as students exert attention on learning activities. This is hypothesized to lead to better learning outcomes (Christenson et al., 2012). Secondly, flow, which occurs when learners are provided with a balanced level of challenge in accordance with their skill level, may be considered the optimal condition for effective, deep learning (Hamari et al., 2016). Thirdly, as flow provides learners with a positive experience, it is also hypothesized that those who have experienced flow will want

to experience it again and will therefore set higher challenges for themselves (keeping the skill-challenge balance optimal), and thus work harder (Engeser & Rheinberg, 2008). In summary, flow theory claims that if the underlying triggers for flow are provided, people push themselves to "higher levels of performance" (Csikszentmihalyi, 1990, p. 74).

Since the flow state is an intrinsic motivator and a factor that promotes the growth and development of abilities, examinations of how flow can be generated in students as they engage with educational content have been explored in various research fields. In relation to the current study, we are particularly interested in how interactive environments or "games" may be developed to promote flow. Perttula, et al., (2017) conducted a systematic literature review of "game-based learning" (henceforth: GBL) studies. One of the major findings of their review was that flow had a positive effect on enhancing players' performance, overall learning gains, and engagement with environments. Additionally, of the 19 studies they examined, "there was not a consistent way to be found to measure the flow experience among the papers" (p. 62). In general, however, flow was measured via a questionnaire given to participants after playing a game.

Language learning and flow

In keeping with the goal of the current study, there are also a number of papers that have explored the generation of flow in foreign language learning contexts.

Egbert (2003) compared the experience of flow to that of Krashen's (1982, p. 66) Forgetting Principle which states that "the best input is so interesting and relevant that the acquirer may even 'forget' that the message is encoded in a foreign language." This early paper on flow in SLA also mentions the use of games and simulations as a promoter of flow due to the user-controlled pace and content as well as its immersive nature which hooks learners into the learning world. Egbert also created a highly detailed model of how flow may be generated through the design of language tasks including the following (p. 502):

- Appropriate challenge
- Making the task interesting for learners
- Providing enough time for completion
- Providing immediate feedback
- Making sure learners feel that they are in control
- Giving learners the opportunity to focus without interruption

Note that many of these elements overlap with factors in Robinson's (2007) Triadic Componential Framework such as planning time (task complexity factor) and task motivation and openness to completing the task (learner factors). Thus, flow and task design are intimately entwined in that designing tasks to meet certain learner characteristics are the same foundations for generating flow.

Continuing with Egbert's study, flow was measured in terms of a learner's *control* over a task, *attention* paid towards the task, and *interest* in completing the task itself where results suggest that certain tasks promoted flow more than others;

yet Egbert was left with the observation that "it is also clear that we cannot fully explain [flow generation]" (p. 513) in that it was difficult to ascertain which task elements promoted flow.

Subsequently, Cho (2018) used four argumentative tasks of different task complexity and modality (spoken and written modes) to measure how task design affected flow. The level of challenge for each task was operationalized in terms of the number of elements that students had to manipulate (+/- number of elements, a *task difficulty* factor in Robinson's Triadic Componential Framework) as well as by the modality of the tasks. Flow was measured based on the same constructs as Egbert: control, attention, and interest in a task. 141 learners conducted the four tasks where it was found that rather than the task design construct, only modality had a statistically significant effect on whether participants experienced flow. Specifically, the writing tasks elicited a sense of challenge-skill balance which was found to be the most significant predictor of flow in this study. Thus, and in conclusion, the speaking tasks in Cho may have been more effective in generating flow if their task difficulty was reduced in comparison to the written tasks as the written mode is less cognitively demanding and may therefore allow learners to commit more attentional resources towards task goals (Kormos, 2014; York, 2019).

Virtual reality and flow

The present study is concerned with the effect of virtual reality (VR) technology on flow in language learning. Previous studies have examined how VR may alleviate foreign language anxiety (York et al., 2021), as well as its effect on learners' oral output (Tokutake et al., 2021) and motivation towards studying English (Shibata & York, 2021). In the present study, an environment very similar to that of York et al., (2021) was created. Results of that study suggested that compared to other modes of communication (audio-only, and video-based chat), participants found the VR domain to be 1) the easiest mode within which to communicate with an interlocutor, 2) the most enjoyable, and 3) the most effective of three domains for language learning.

Regarding flow in particular, one study found that VR amplifies the flow state (Kim & Ko, 2019), and another showed that compared to playing a game on a 2D screen, in the VR domain time passed faster for participants (Rutrecht, et al., 2021). This aligns well with previous literature on flow where, as mentioned in the introduction, individuals perceive elapsed time to be shorter than the elapsed time when experiencing a flow state. Additionally, in relation to York, et al., (2021), the results of Rutrecht et al. (2021) suggest that the immersive and fun, game-like nature of VR may be more effective than other modes in promoting a flow state.

Research questions

Based on a review of the literature on flow, VR, and language learning contexts, the following research questions were formulated:

1. Does the provision of feedback in a language learning VR game promote a flow state?
2. Do participants' perceptions of elapsed time and actual elapsed time differ between the two environments?
3. What are participants' perceptions of learning English with a VR environment?

Method

The purpose of this study is to compare the state of concentration and other aspects of English learning in VR between environments with and without built-in feedback functions and to determine which environment is better able to promote a flow state, thus informing the future design of environments that may enhance learning opportunities.

Participants

This experiment was conducted at a science and engineering university in Saitama, Japan. 11 pairs of participants were created (thus, 22 participants). The participants ranged in age from 20 to 27, with an average age of 21.6. All participants were Japanese.

Environment overview

Game-like environments with and without built-in feedback functions were constructed to measure flow. The equipment and software used to develop these environments and the details of the construction of each are described below.

Equipment and software used

The following equipment and software were used in this study.

1) Head-mounted display (HMD) A head-mounted display (HMD) is a display device worn on the head and capable of projecting three-dimensional images by utilizing the parallax between the left and right eyes. In this study, we used the Vive (Figure 1). This is an HMD for VR jointly developed by HTC and Valve. This HMD is equipped with two motion-tracking sensors that determine the user's exact position in space, allowing the user to move around and not just sit down. In this study, we controlled the movement of the avatar in the VR space by using the positional information of the HMD and controllers.

Figure 1
The HTC Vive head-mounted display, controllers, and sensors.

2) Game production engine Unity, developed by Unity Technologies, was used as the game production engine for this study. Unity is a game engine that can be used on a variety of platforms, including mobile, desktop, game consoles, and the web. Since it was originally developed for 3D games, it was easy to create VR environments for the study.

3) Voice call software In this study, Discord developed by Discord, Inc. was used as the voice call software.

4) 3D models Liam, created by AKISHAQS, was used as the 3D avatar. It is a model of an adult male without facial expressions and can be used for animation, games, and VR/AR projects. Additional assets were downloaded from the Unity Asset Store.

Environment contents

Two VR environments were created for this study; in both environments, pairs of participants performed a spot-the-difference task. In each environment, participants were presented with a dollhouse in which a variety of objects were placed (Figure 2). Some of the objects in each room were placed in the same location, while others were placed in different locations. The environment was designed so that through communicating with each other participants find some objects in different locations and, work together to place them in the same location within their respective dollhouses. Five levels of difficulty were created. Level difficulty was operationalized via the number of objects in different locations (in terms of Robinson's framework: +/- number of elements to be manipulated).

Figure 2

Dollhouse presented to each participant in a dyad.

Participants can see their own room, but cannot see the contents of their interlocutor's room. This was achieved by placing the rooms separately and of opposite orientations to each other (see Figure 3).

Figure 3

Subject's point of view showing that their interlocutor's dollhouse content is obscured.

Wearing an HMD enables an immersive VR experience. participants can move their heads to understand what is going on in the room and gesture to others by moving the controller (Figure 4).

Figure 4

Experiencing the VR environment

Of the three elements considered essential for promoting flow, this experiment is

concerned with manipulating the second: feedback. Thus, the experiment utilized two versions of the same VR environment: one with feedback and one without. The specific differences between the two environments are described below.

The environment with feedback

Both visual and audio feedback was added to this environment, making it more game-like than the no-feedback version. Visual feedback was provided via a score (10 points per object placed in a correct position) and elapsed time for each level displayed in the subject's field of vision. In addition, audio feedback was utilized. First, a sound effect plays when participants place objects in the same location, and secondly, a different sound effect plays when participants complete a level. These effects indicate whether participants have made a correct or incorrect decision and whether the task is completed (Figure. 5).

Figure 5

Environment with feedback

The environment without feedback

In the environment without feedback, participants do not receive a score or see their elapsed time, and instructions to proceed to the next level are displayed only when the level is completed. In addition, no sound is played when an object is placed in the same location, meaning that participants must confirm the location of objects orally (Figure 6).

Figure 6

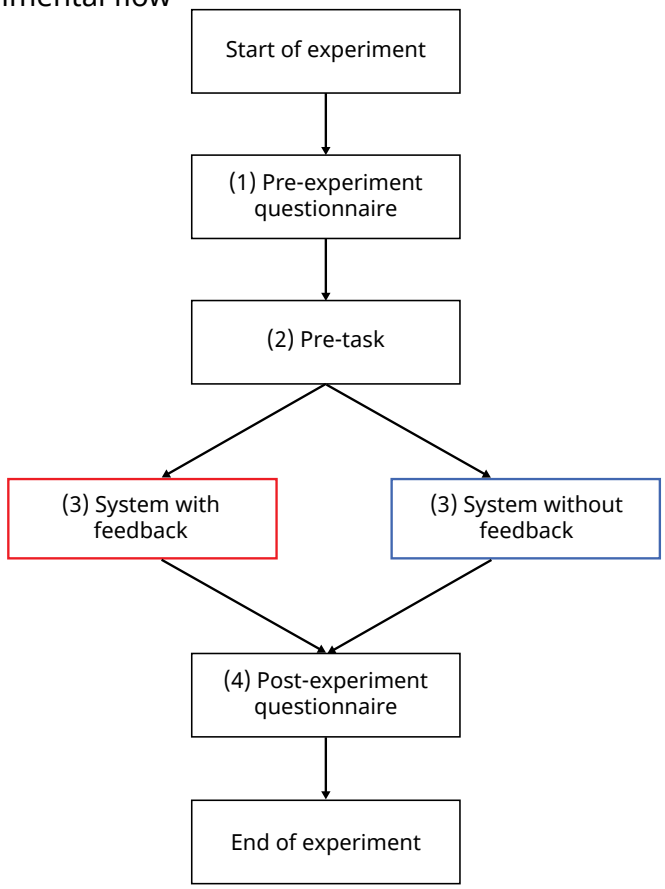
Environment without feedback

Experimental procedure

The experiment followed the flow shown in Figure 7 below.

Figure 7

Overall experimental flow



(1) Preliminary Questionnaire

Before performing the task, a questionnaire was administered to determine participant demographics such as age and gender.

(2) Pretask

A pre-task worksheet was employed to prime the participants to use vocabulary and prepositions which appear within the environment. Participants completed cloze questions which used the same graphics as those within the environment as an additional way to acclimatize participants to the upcoming communication task. The pre-task was employed to mimimize the effect of English proficiency on oral performance.

(3) Task cycle for both environments

Each task cycle was performed as follows.

1. **Operation Confirmation:** Participants were given time to acclimatize to the environment and test the HMD, microphones, and earphones.
2. **Spot-the-difference Task:** Participants completed five levels within one of the two environments.

(4) Post-assessment questionnaire

A questionnaire was used to measure flow. Details are described below. In order to examine the sense of time distortion as found with a flow state, participants were prompted to indicate the amount of time they experienced from the start to the end of the activity.

Questionnaire content

Participants were asked to complete a questionnaire to investigate the degree of their flow state after experiencing the spot-the-difference activity (Table 1). The questionnaire was based on Cho (2018) and is intended to uncover which of three constructs (interest, attention, and control) were positively affected during an activity. Ratings on the items were measured on a 6-point scale to avoid central effects.

Results and discussion

RQ1: Flow state data

The questionnaire was categorized into three items, interest, attention, and control, which are considered the fundamental elements to promote a flow state. To these three items, we added one additional item, the flow score, which is the average score for all three elements. This gave a total of four items. We analyzed the questionnaire data using an unpaired t-test. Results are shown in Table 2.

Table 1

Statements in the post-experiment questionnaire (based on Cho, 2018)

Nº	Flow measurement	Statement
1	Interest	I would do this task even if it were not required.
2		This task was interesting in itself.
3		I found the experience very rewarding and felt good after completing it.
4		This task aroused my imagination.
5	Attention	It took no effort to keep my mind on the task.
6#		When doing this task, I was aware of distractions.
7		When doing this task, I was totally absorbed in what I was doing.
8	Control	When doing this task, I knew clearly what I wanted to do.
9		When doing this task, I had a feeling of control over what and how to write or speak.
10		When doing this task, I had a feeling of total control.

*Item 6# was reversed coded.

Table 2

T-test results for the four items

	With feedback		Without feedback				
	Mean score	SD	Mean score	SD	Mean difference	p-value	sig.
Interest	5.4	0.57	4.9	0.62	0.5	0.092	*
Attention	5.5	0.59	5.4	0.64	0.1	0.79	
Control	4.7	0.78	4.6	1.04	0.1	0.93	
Flow	5.2	0.54	5.0	0.60	0.2	0.46	

* $0.05 < p < 0.1$

Mean scores for the variable “flow” were higher than the mean of 3 for both environments (with feedback = 5.2, without feedback 5.0). However, there was no statistically significant difference between mean scores for the two environemnts for this measure ($p = 0.46$). This indicates that both environments were able to promote a flow state in participants, but that feedback did not play a significant role in promoting flow. Of the three individual elements (interest, attention, and control), there was a statistically significant difference between the mean scores for the Interest component ($p < 0.01$). This indicates that the provision of feedback

increased participants' level of interest in completing the language task. No statistically significant differences were found for the remaining two components.

Subsequently, individual items on the questionnaire were examined for potentially significant differences in mean scores between the two environments. Analysis was conducted using unpaired t-tests for each item. Results are provided in Table 3.

Table 3

Statistical results for each item on the flow questionnaire.

Item	With feedback		Without feedback		Mean diff.	*p*	Sig.
	Mean	SD	Mean	SD			
1. I would do this task even if it were not required.	5.08	1.00	4.60	0.97	0.48	0.26	
2. This task was interesting	5.92	0.29	5.50	0.53	0.42	0.03	**
3. I found the experience very rewarding and felt good after completing it.	5.92	0.29	5.10	0.88	0.82	0.01	**
4. This task aroused my imagination.	4.58	1.08	4.50	0.85	0.08	0.85	
5. It took no effort to keep my mind on the task	5.42	0.67	5.50	0.71	−0.08	0.78	
6#. When doing this task, I was aware of distractions.	5.42	0.79	5.10	1.45	0.32	0.52	
7. When doing this task, I was totally absorbed in what I was doing	5.58	0.51	5.60	0.70	−0.02	0.95	
8. When doing this task, I knew clearly what I wanted to do	5.67	0.49	5.00	1.49	0.67	0.16	
9. When doing this task, I had a feeling of control of what and how to write or speak	4.50	1.31	4.50	1.65	0.00	1.00	
10. When doing this task, I had a feeling of total control	3.83	1.11	4.40	1.17	−0.57	0.26	

Results for two items in the Interest category ("This task was interesting" and "This task was challenging and gave me a sense of accomplishment") were significantly higher when completing the task with feedback.

RQ2: Comparison of elapsed time and perceived time of completion

Participants were asked to respond to an item regarding their perception of elapsed time. These perceptions were then compared with the actual elapsed time in order to measure one of flow's main characteristics: a distortion regarding the sense of elapsed time during an activity. The environment with feedback was completed in a shorter time than the environment without feedback, and perceptions for this domain were also shorter. However, there was no significant difference found between mean scores (Table 4). Of note is that the elapsed time and perceived time for the task with feedback were shorter than the task without feedback. This is explored later in the discussion section.

Table 4

Mean (and standard deviation) of perceived time and elapsed time for both VR environments.

Environment	Perceived time		Elapsed time		Mean diff.	p-value	sig.
With feedback	7.0	(3.2)	7.1	(0.9)	0.1	0.92	
Without feedback	11.2	(4.3)	10.3	(1.8)	−0.9	0.57	

RQ3: Participant perceptions of the environments

Participants were also asked to respond to an open-ended question regarding their opinions of the VR environments. Comments are presented in Table 5 (translated from Japanese). Positive comments suggest that participants enjoyed learning with the VR environment regardless of the presence or absence of feedback. Enjoyment was promoted due to the immersive experience provided by the VR, and the sense of accomplishment in completing the tasks through physical movement. Negatively weighted comments mentioned that participants were confused about whether they were in charge of the questioning or answering and that they had trouble when they could not remember task-critical vocabulary.

Table 5
Comments from participants

Participant	Comment
With_01	It was my first time using VR and I think it was very enjoyable and educational.
With_02	It was fun.
With_03	I might have enjoyed studying English more if I had used this environment when I began to learn it.
Without_01	I was a little worried that I would bump into the desks and walls around me, but I was quite immersed in the work and enjoyed the activity without worrying about my surroundings.
Without_02	It was interesting. I thought that unifying the categories of nouns (animals, tools, etc.) would make it easier to understand and learn in a unified manner.
Without_03	Sometimes I'm not sure if I should be the one asking the questions or the one answering them.
Without_04	The task was a little easy and it seemed very doable with more variation. I also felt that a word cheat system would be useful for when I got stuck on a word.
Without_05	I was quite excited by my first VR game experience. I felt a sense of accomplishment in moving my body to complete tasks.
Without_06	It was easy to speak English because the group was small.

Discussion and conclusion

Data obtained from the post-experiment questionnaires revealed no significant difference between the two environments in terms of their ability to generate a flow state in participants. One reason for this may be that unlike in studies like Cho (2018) and York et al. (2021) where participants experienced multiple different environments, in this study each participant experienced only one environment, meaning that they were unable to compare their experiences to another mode. Therefore, having participants perform tasks in both environments may produce results of improved accuracy.

The flow questionnaire revealed statistically significantly higher results for two items on the interest measure when feedback was provided: that the task was more interesting and that it was more rewarding and provided a sense of accomplishment. Informal observations of participants completing the spot-the-difference tasks revealed that when feedback was not provided, they struggled to understand whether an object was correctly placed which created a state of

confusion regarding how they should proceed. This was alleviated with the environment which provided feedback as an audio cue sounded to indicate that an object was in the "correct" location prompting participants to move on to the next object. Based on these observations, an improved sense of control may be developed when feedback is provided, however, results did not show a significant difference in mean scores for control. Thus, further exploration is required.

Regarding the comparison of perceived and actual elapsed time, the results showed that both elapsed time and perceived time were shorter with feedback than without. The reason for this result may be that the task was easier to understand with feedback than without since the results of the activity were immediately apparent and there was less unnecessary confusion. Additionally, as part of the environment with feedback, a timer was provided on the screen to the participant so they could see the elapsed time of each level they completed. Thus, participants could have calculated the elapsed time by paying attention to the time they spent on each level. However, this was not explored in any significant way in this study.

Finally, participants' comments regarding the two environments revealed that it was generally enjoyable, but this could be attributed to a novelty effect. Indeed, one comment (With_01) mentioned explicitly that this was their first time experiencing VR. Of similar note is a negative comment from a participant that experienced the environment without feedback (Without_03). They mentioned that they were unsure whether they should be asking or answering questions. This comment connects to the feeling of confusion that was promoted by the environment without feedback.

Future research

The results of the present study showed significant differences in two items of Interest. However, due to conducting this experiment during the COVID pandemic, it was not possible to gather a sufficient number of participants to explore the generalizability of results further. In addition to the items for which significant differences were found, there were other items for which significant trends were found, and we believe that future experiments with a larger number of participants may yield more precise results.

Feedback in this study was operationalized in terms of audio feedback and the addition of a timer for each level. Exploration of other forms of feedback such as visual and tactile/haptic may help to further immerse learners in the VR domain and thus an improved state of flow. Additionally, as mentioned by participant *Without_04*, the difficulty-skill balance of the tasks may not have been calibrated well enough for the participants meaning that tasks were too easy. Task difficulty could be operationalized via the environment in a future study to ensure that the challenging nature of the tasks was optimized for the participants level of skill. This could be achieved by increasing or decreasing the number of elements that participants had to manipulate based on how quickly they completed a task.

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