The Psychological Effects of Feedback on Students: Experimental Research Using a Psychophysiological Approach

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(Received 30 November 2019 and accepted in revised form 24 June 2020)

Abstract Research on feedback has shown teachers’ feedback to be more interactive. There is a heightened need to investigate how students perceive feedback. Researchers have increasingly explored this topic with interviews and questionnaires. In addition to these conventional methods, it is necessary to study the effects of feedback on psychological characteristics because conventional methods cannot reveal aspects that students cannot easily verbalize. This study examined the psychological effects of the difference between two types of feedback: that which encourages participants (Encouraging-FB), and that which pushes participants (Pushing-FB). To this end, we measured the skin conductance, respiration, and pulse wave of participants as they solved puzzles. Their skin conductance data showed that arousal was higher during Pushing-FB than Encouraging-FB, while respiration and pulse wave data suggest that stress was higher during Pushing-FB. These data can reveal psychological situations that are difficult for many teachers to grasp.

Keywords: feedback, student, teacher, skin conductance, respiration, pulse wave

1. Introduction

1.1 Feedback in Education

Feedback is information provided by an agent such as a teacher or peer regarding aspects of one’s performance or understanding, and is also viewed as a consequence of performance(1). In school, teachers’ feedback toward students during the learning process, both verbal and written, is a typical teaching activity intended to guide students’ learning in a better direction.

The dominant conception of teacher feedback has traditionally been as a one-way message from a sender to a receiver(2, 3). However, in recent years, teacher feedback has been recognized as more interactive, and an increasing number of studies have examined how students receive this feedback(4–6). For example, Van der Kleij(7) explored feedback perceptions of both teachers and students and the relationship between students’ characteristics and their perceptions of feedback. In addition, the psychological impact of feedback on students is becoming more important and research on this topic has been increasing. Mahfoodh(8) investigated students’ emotional responses to teachers’ feedback by analyzing the data of think-aloud protocols and semi-structured interviews, pointing out that some emotional responses from students could be due to characteristics of teachers’ feedback such as harsh criticism and negative evaluation. Guo et al.(9) explored the relationship between teachers’ feedback and students’ learning at a high-achieving school and a low-achieving school by administering questionnaires and holding interviews. The study found that teachers at the high-achieving school gave more praise feedback and less criticism than at the low-achieving school and that students at the high-achieving school had greater motivation. In addition, it will be necessary to study the effects of different types of feedback on students’ psychological status, including arousal and stress. In order to design better feedback, these aspects are important because they allow the analysis of students’ body and mental states that the students cannot easily verbalize.

One method of acquiring psychological data from students is the psychophysiological method of measuring biological information(10). In particular, skin conductance, respiration, and pulse wave are excellent methods for measuring arousal, relaxation, and stress level without burdening the student during measurement while maintaining high reliability. Some studies have suggested that students experience psychological changes when receiving feedback, while others have suggested that feedback does not have a major impact on learning improvement in everyday classroom practice(2, 4). These changes can be important factors for teachers to consider when providing feedback in an actual classroom.
1.2 Aim of the Study

This study attempts to measure the psychological effects of feedback on learners from the psychophysiological perspective. We focus on different kinds of feedback, especially feedback encouraging participants (Encouraging-FB) and feedback pushing participants (Pushing-FB), because previous research conducted through questionnaire surveys and interviews indicates that praise feedback or negative feedback can affect students’ responses or achievement, and it is assumed that using more objective methods to examine the emotional effects of feedback is important. The purpose of the present study is to examine the differences between the psychological effects of Encouraging-FB and Pushing-FB. To this end, we measured the skin conductance, respiration, and pulse wave of participants as they solved puzzles through trial and error. These data could express aspects that teachers cannot grasp through observations of students, think-aloud protocols, interviews, or questionnaires. Such data would be effective for more deeply understanding students and can be considered improved feedback.

This study proposes the following hypotheses: (1) Skin conductance would be higher during Pushing-FB trials than Encouraging-FB trials. (2) Respiration rates would be higher during Pushing-FB trials than Encouraging-FB trials. (3) The pulse wave of the high-frequency power would be higher during Encouraging-FB trials than Pushing-FB trials. (4) The low-frequency/high-frequency power would be higher during Pushing-FB trials than Encouraging-FB trials.

2. Methods

2.1 Participants

Ten healthy right-handed university students participated in this experiment. However, one participant did not receive feedback as they were unable to correctly place any pieces in the Encouraging-FB trials, for which feedback was provided only if participants placed the pieces correctly and were also able to correctly place all pieces without any mistakes in the Pushing-FB trials, for which feedback was provided only if participants placed the pieces incorrectly (see Section 2.4, for details of the Encouraging-FB and Pushing-FB trials). Therefore, 9 students (3 female, 6 male; mean age±SD=21.4±1.74) were included in the analysis. The use of the experimental data was approved by the research ethics committee of the university where the experiment was conducted, and the experimental data collection methods were explained to all participants before the experiment. All participants provided written informed consent.

2.2 Psychophysiological Markers

Skin conductance, respiration, and pulse wave were measured as psychophysiological markers. Skin conductance response, which is also known as galvanic skin response, is a marker of arousal determined by measuring changes in sweat gland activity\(^{11}\). This marker does not differentiate between positive emotion and negative emotion but reflects the arousal level for both.

Respiration is a marker of stress level because respiratory volume increases in stressful situations. Specifically, the respiration rate increases or respirations become deeper in stressful situations\(^{12}\).

The pulse wave is dependent on heart rate and has a rhythmical pattern connected to heart rate. Common frequencies are the power of the low-frequency (LF) band (0.04–0.15 Hz) and the power of the high-frequency (HF) band (0.15–0.4 Hz). HF power and the LF-to-HF power ratio (LF/HF) are commonly used as relaxation level and stress level markers, respectively. The value of HF power increases when people feel relaxed because HF is affected by the parasympathetic nervous system, which is activated when the body is relaxing\(^{13}\). Therefore, HF power is used as a relaxation level marker. On the other hand, LF reflects both the parasympathetic and sympathetic nervous system, which is activated under stressful situations. Thus, LF/HF increases under stressful situations\(^{14}\).

2.3 Measurement

The ProComp Infiniti monitor (Thought Technology Ltd.) was used for measurement. Sensors for skin conductance with a sampling rate of 256 per second were placed on the index finger and ring finger of the left hand. Sensors for the pulse wave with a sampling rate of 2,048 per second were placed on the middle finger of the left hand. The sensor for respiration, with a sampling rate of 256 per second, was placed on the abdomen.

The experimenter instructed participants to sit in the chairs, relax, place their palms up on the table, and not press the sensor placed on their fingers. Room temper-
perature was set to 23°C in order to restrain thermal perspiration caused by increasing temperature(15).

2.4 Procedure

A tangram (a puzzle in which seven triangular, square, and parallelogram-shaped pieces are arranged into a set shape) was used for the experimental task. The participants were required to manipulate the puzzle using their right hand because they wore the sensors on the fingers of their left hand. Each trial had one problem, and there were four trials used (Trials 1–4) in this experiment (Figure 1). The experimental task was to create four shapes (one shape per trial) that have been shown to take approximately the same time to complete in an unpublished preliminary experiment targeting university students. In each trial, the participants were requested to create a shape printed on a piece of paper by correctly placing the seven pieces on the printed shape. Each printed shape was the same size as the shape formed by the seven pieces, allowing the experimenter to determine whether the participant had placed each piece correctly. The time limit for each trial was 120 seconds. The rest time between trials was at least 90 seconds or until the participant was in a resting condition. Before the experiment, participants’ physiological data were measured for 120 seconds under resting conditions.

In order to examine the effect of feedback, feedback was given to participants in all trials. The feedback was provided using an artificial voice created using the software AI TALK (AI, Inc.). A female voice was used to make the accent and intonation sound natural in Japanese.

During two of the four trials, the following five Encouraging-FB were played at random after the participants had placed the pieces correctly: “You are doing great so far,” “You are making great progress,” “Keep up the great work,” “Wonderful job,” and “You are solving these problems smoothly!” One piece of feedback was played for each piece that was placed correctly, along with a piece of feedback played for a series of correctly placed pieces.

During the other two trials, the following five pieces of voice feedback pushing participants to think more were played at random after the participants had placed the pieces incorrectly: “Why don’t we take another good look?,” “Why don’t we take a little more time to think about it?,” “Why don’t we try to solve it a little more carefully?,” “Why don’t we think a little harder?,” and “Why don’t we focus a little more and think about it?” One piece of feedback was played for each piece that was placed incorrectly, along with a piece of feedback played for a series of pieces being placed incorrectly.

The order of the two Encouraging-FB trials and two Pushing-FB was set at random. The experimenter told participants in advance that a voice would play during the experiment though they did not mention the contents of the voice message nor the intent of the experiment.

2.5 Data Analysis

BioGraph Infiniti (Thought Technology Ltd.) was used to analyze the data of skin conductance (μS), respiration rate (cpm), HF (ms²), and LF/HF of skin conductance. HF and LF/HF were calculated using the fast Fourier transform in power spectral analysis. The LF band and HF band were set as 0.04–0.15Hz and 0.15–0.4Hz, respectively.

Figure 1. The Experimental Task.
(The order of Encouraging-FB trials and Pushing-FB trials is an example)
3. Results

Considering that participants could have become habituated to the stimuli by the second trial, the analysis was conducted for each first trial of Encouraging-FB and Pushing-FB.

3.1 Behavioral Data

Figures 2 and 3 show the average number of feedback messages and the average time taken to solve the problems during both the Encouraging-FB trial and the Pushing-FB trial. For the trials that participants were not able to finish within the 120-second time limit, the required time was deemed to be 120 seconds.

As shown in Figures 2 and 3, for both Encouraging-FB and Pushing-FB trials, the average number of feedback messages was about three and the average time required was about 110 seconds. The frequency of feedback was about one every 35 seconds. T-tests conducted on both the average number of feedback messages and the time required showed no significant differences between the Encouraging-FB and Pushing-FB trials (the number of feedback messages: \( t(8) = 2.00, \text{n.s.} \), the time required: \( t(8) = 0.35, \text{n.s.} \)).

3.2 Psychophysiological Data

For the analyses of psychophysiological data, average values of skin conductance (\( \mu \text{S} \)), respiration rate (cpm), pulse wave’s HF (ms\(^2\)) and LF/HF were divided by the averages recorded during the 120-second resting conditions because of the large differences between participants.

Table 1 shows the data and results of the \( t \)-test between the two trials. For skin conductance, the data from the Pushing-FB trial were significantly higher than from the Encouraging-FB trial. The data for the respiration rate of the Pushing-FB trial were also significantly higher than those of the Encouraging-FB trial. For the HF of pulse wave and LF/HF of pulse wave, there were no significant differences between the Encouraging-FB and Pushing-FB trials. However, HF values tended to be lower and LF/HF values higher in the Pushing-FB trials than the Encouraging-FB trials.

4. Discussion

In this study, in order to examine the differences in the psychological effects of Encouraging-FB and Pushing-FB, which are difficult to grasp through outside observation, we measured skin conductance, respiration, and pulse waves as psychophysiological data.

The behavioral data showed no difference in the number of feedback messages between the Encouraging-FB and Pushing-FB trials because the two trials had the same number of feedback messages. By condition, there was no significant difference in the required time between the trials. It follows from this that the difference between Encouraging-FB and Pushing-FB did not influence the speed of problem-solving in this experiment.

Turning to the psychophysiological data, skin conductance data, which reflect arousal, show that skin conductance was significantly higher during the Pushing-FB trial than the Encouraging-FB trial. This result supports
Hypothesis (1). It is thought that the higher arousal during the Pushing-FB trials was caused by the demand for awareness of the contents of the feedback to which the participants’ attention was called. Namely, the Pushing-FB required participants to perform cognitive processing in reconsidering how to solve the problems.

Respiration rates, which are affected by stress, were significantly higher during the Pushing-FB than Encouraging-FB trials. This finding supports Hypothesis (2). It appears that the participants felt more stress during the Pushing-FB than the Encouraging-FB trials. We assume that the reason for stress is that as their mistakes were pointed out, participants recognized their mistakes and/or that they were only given negative feedback.

The pulse-wave data indicate that HF and LF/HF showed no significant differences between the Encouraging-FB and Pushing-FB trials. However, the value of HF, which reflects relaxation, was higher during the Encouraging-FB trials than the Pushing-FB trials. The value of LF/HF, which reflects stress, was higher during the Pushing-FB than the Encouraging-FB trials. These results support Hypotheses (3) and (4) to some extent. Taking the results for respiration into consideration, there is a possibility that the Pushing-FB made participants feel less relaxed and more stressed.

These findings regarding the psychophysiological measurements suggest that feedback to students can affect their psychological situation even when the performance on time required, which is captured through outside observation, is not affected. Psychophysiological measurements reveal an aspect of students’ psychological situations that is not easy for teachers to grasp because students are unaware of or cannot verbalize these effects.

The number of participants in this experiment was limited, and we could not find a significant difference between the two types of trials in the pulse wave data. Moreover, the feedback used an artificial voice recorded in advance, which differs from actual teachers’ feedback in classrooms. Teachers typically use a wider variety of sentences to offer flexible feedback, and they provide students feedback in person. It might be unnatural to hear a voice recording that only gives Encouraging-FB or Pushing-FB. In spite of these limitations, it is worth emphasizing the feedback’s effects on psychological situations. For example, Pushing-FB can be more effective than Encouraging-FB when teachers need to draw the student’s attention. Pushing-FB from the teacher—even simple one-word feedback—is effective in making students aware of problem areas that require their focus and in making them consider problems carefully. However, teachers should simultaneously bear in mind that Pushing-FB may create more stress among students that teachers may not notice. Although teachers may consider such feedback casual words or general instructional feedback delivered to the entire classroom, it may result in unexpected stress in some students.

In general, when a teacher provides feedback to a student, the teacher can only observe how their feedback influences the student in terms of the student’s behavioral changes, learning situations, and achievements; however, the student may experience significant psychological changes that cannot be observed by the teacher. Moreover, these changes may lead to further changes in the student’s behavior and learning. The important thing is not whether Encouraging-FB or Pushing-FB is better, but that teachers understand that even casual feedback can have a psychological influence on students. It is crucial that teachers reaffirm the significance and power of their feedback. The psychophysiological data from this study visually and objectively demonstrate the effects of invisible and small changes in students, which can contribute to teachers’ awareness. In addition, these data may lead to more detailed analyses of the mechanisms behind changes occurring in students’ learning due to feedback.

In the future, we will increase the number of partici-

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### Table 1. The Results of Psychophysiological Data.

|                        | Encouraging-FB |        |        | Pushing-FB |        |        | df | t-value | p-value |
|------------------------|----------------|--------|--------|------------|--------|--------|----|--------|---------|
|                        | Trial/Resting condition | Mean  | Standard error | Mean  | Standard error | df | t-value | p-value |
| Skin conductance       |                | 1.65   | 0.37   | 2.33      | 0.61   | 8      | 2.66| 0.03*   |         |
| Respiration rate       |                | 1.04   | 0.03   | 1.07      | 0.04   | 8      | 2.75| 0.03*   |         |
| Pulse wave HF          |                | 1.40   | 0.52   | 1.10      | 0.18   | 8      | 0.75| 0.48    |         |
| Pulse wave LF/HF       |                | 1.20   | 0.15   | 1.43      | 0.31   | 8      | 0.94| 0.38    |         |

* p<0.05
pants, acquire more stable data, and consider the findings along with detailed questionnaire data to clarify the details and factors of the participants’ psychological status.

Acknowledgment
This work was supported by JSPS KAKENHI Grants Numbers 16K13589 and 17H04793.

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