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Effects of Post Feedback Intervals on Hypotheses Testing Behavior in Concept Identification Learning[1)]

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In learning, the goal which is attained through consecutive trials, there exist three intervals within each trial: Stimulus Interval, Feedback Delay and Post Feedback Interval. Stimulus interval is a response time, Feedback Delay is an interval between a response and its feedback, and Post Feedback Interval (PFI for short) is the time between a feedback and the next trial (i.e., the presentation of the next task stimulus).

Bourne (1957) investigated the relation between Feedback Delay and performance in a concept identification task, and found a negative relationship between the two varibales. In his study, the effects of six kinds of Delay on performance were compared, while PFI was inserted within each trial in order to keep the whole length of each trial among the six conditions constant. Bourne interpreted that the better performance did not come from shorter Feedback Delays but from longer PFIs. It was anticipated that PFI was an influencial factor on performance in the context of concept learning because PFI was the most suitable interval for processing concepts in accordance with the feedback received around a response made by a learner. This interpretation about the effect of PFI was clarified by Bourne and Bunderson (1963), showing the positive relation between the length of PFI and the task performance.

A successive study (Bourne, Guy, Dodd and Justesen, 1965) indicated that there existed an optimal PFI according to the degree of task difficulty. This study shows that the more demanding a task is (i.e., the more information a learner has to process), the longer PFI needed to identify the relevant concept.

The length of PFI has been also investigated with respect to 'correct' feedback and 'error' feedback. Bourne, Dodd, Guy and Justesen (1968) found that PFI needed after 'correct' feedback was just as long as the PFI after 'error' feedback. Different results were obtained, however, by White (1972a, 1972b), suggesting that the length of PFI after 'correct' or 'error' feedback was affected by a learner's strategy. White (1972a) noted that subjects who had received training in approaching concept identification task solving with systematic hypotheses testing needed longer PFI after 'error' than after 'correct,' while their counterparts with no antecedent training (i.e., they were assumed to solve the task with associative manner) required equal durations of PFI after both types of feedback. From the above findings, it could be concluded that an associative solver would need an equal amount of time after both types of feedback, while a systematic hypotheses tester would need relatively longer time after 'error' rather than 'correct' feedback.

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Levine (1966) showed, in the context of no PFI, that the most effective hypotheses testing behavior (his notion of "perfect processing") was seen in the particular sequential combination of 'correct' and 'error' feedbacks. He argued that a perfect processing subject would build up a set of hypotheses which were currently relevant after the first feedback, and at the same time he/she would be monitoring the alternative set of hypotheses. Upon the next feedback, whether it be 'correct' or 'error,' the subject would be able to eliminate irrelevant hypotheses and to focus his/her attention on half of the relevant hypotheses from either set. Levine noted, moreover, that as 'error' requires rejecting the working set of hypotheses encountered to that point and selecting an alternative set, it would demand more processing than 'correct' feedback which requires just eliminating irrelevant hypotheses (Levine, 1969; Levine, 1975).

Although the studies by Levine were conducted with no PFI condition, they suggest that a learner, as a hypotheses tester, will need longer time for rejecting and selecting hypotheses after 'error' feedback, and that he/she will need relatively less time for the case of 'correct' feedback, as it involves merely a reduction of viable hypotheses. This assumption was in accordance with the Gilhooly's (1974) study with PFI condition, implying that the PFIs determined by subjects after 'error' were longer than the PFIs determined by them after 'correct.' In addition, as the number of hypotheses tested or monitored decreases over trials, a longer PFI seems to be required at early trials than at later ones. This possibility was also clarlified by Gilhooly (1975).

If we assume that PFI in each trial provides a learner an adequate opportunity for testing hypotheses systematically or effectively in a concept identification task, there must be an optimal PFI according to the feedback type (e.g., correct or error) and to the trial order (e.g., earlier or later) as noted by Gilhooly (1974, 1975).

From the standpoint of these various optimal PFIs, the most effective learning seems to occur when PFI is determined by the amont of time required by the subjects in order to test hypotheses. Gilhooly's research was based on such a viewpoint, but it did not compare the effect between fixed PFI and subject-paced PFI. This present study will do just that, using a concept identification task.

This study also aims at clarifying the effect of PFI on strategic aspects in hypotheses testing behavior. Research about developmental changes in strategies in the situation without PFI showed that adults solved tasks by using focussing (perfect processing) or dimension checking, while most primary school pupils did so by dimension checking, and kindergarten children by strategies which would never lead to a solution (Gholson, Levine & Phillips, 1972; Gholson,1980). Pausing enough after a feedback may induce the subjects to pay attention to the informational aspect, resulting in taking effective or systematic strategy. On the other hand, it may be that the subjects will use non-systematic or associative strategy if it were not for the time after feedbacks, because they will not make full use of the information from feedbacks.

This assumption about strategic differences coming from with and without PFI will also have some effect on the response time of the next trial.A learner will have to check the structure of a new stimulus if he/she is processing a lot of hypotheses systematically. On the contrary, when a learner pays attention to only a dimension or a single hypothesis, he/she will easily respond merely by recognizing it in the new stimulus. Therefore it can be anticipated that a systematic hypotheses tester provided with PFI will require relatively more time in responding than an associative solver without PFI.

The purpose of this study is to clarify the following four anticipations in the context of a concept identification task.

(1)Within the limited trials, the number of achievers in the PFI condition (fixed as well as subject-paced) will be more than that of achievers in the non-PFI condition because the subjects with PFI can extract more information from feedbacks than the subjects without PFI.

(2)Changes in hypotheses reduction over trials in the subject-paced PFI condition will most closely resemble those of perfect processing as compared with fixed PFI as well as with non-PFI conditions because subject-paced PFI is most flexible toward the amount of time demanded from feedback type or trial order.

(3) PFI determined by subjects after 'error' feedback will be longer than that after 'correct' if the subjects in this treatment group are the sytematic hypothses testers, because perfect processing requires both rejecting an irrelevant set of hypotheses and selecting a relevant one at the same time after 'error' feedback and it requires merely reducing the number of hypotheses in the same set after 'correct' feedback.

(4)Response times in groups with PFI will be longer than those in the non-PFI group, because processing a substantial number of hypotheses during PFI requires checking the stimulus structure of the next trial.

Method

SUBJECTS

Thirty-six pupils in the eighth grade (19 males and 17 females) were subjects in the experiment, and were assigned randomly to the following three treatment groups: Non-PFI group (N-PFI), in which PFI was not given to subjects at all; Fixed PEI group (F-PFI), in which constant PFI was given to subjects over all trials; Subject-paced PFI group (S-PFI), where the length of PFI was flexibly determined by the subjects themelves. As for the latter two treatment groups, a task stimulus consisting of a pair of figures remained on the CRT (computer screen) and was available to the subjects during PFI.

PROCEDURE

A concept identification task was used and the stimulus was presented through the 'Blank Trial Method' used by Levine (1975). A sample of stimulus sequence in the Blank Trial Method is shown

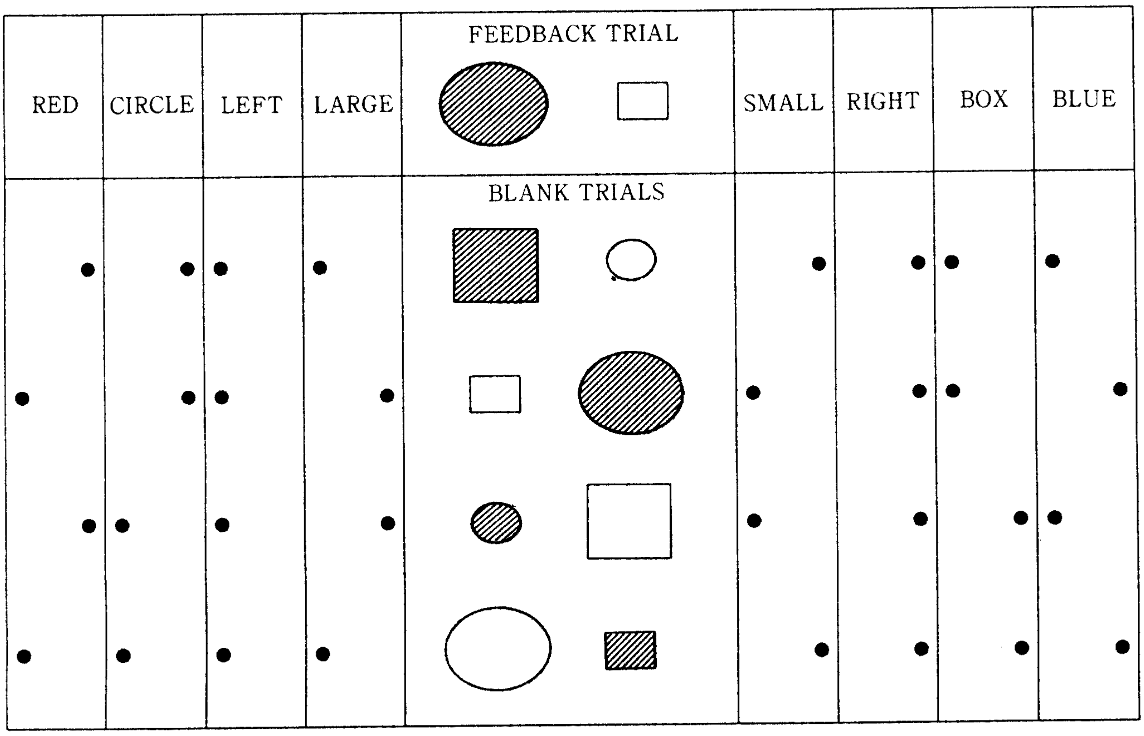

Figure 1　Stimulus sample and response patterns of the 'Blank Trial Method.'

in **Fig.1**. The stimulus was composed of eight concepts (four dimensions, each of which had two values) and only one value (e.g., concept or hypothesis) had been determined as relevant in advance. Subjects were required to identify this relevant value and to select the correct figure containing the relevant one from the pair of figures given. When a selection was made, 'correct' or 'error' feedback was given to the subjects at the first Feedback Trial. In the following four Blank Trials no feedbacks were given to the subjects. Therefore the first, the sixth, the eleventh ...... trials were Feedback Trials and four trials between them were Blank Trials. As shown in **Fig.1**, the response pattern in Blank Trials indicates the value (hypothesis) a subject selects (from a choice of eight values) on the basis of information from the previous Feedback Trial.

Measures that were taken were the response patterns and response times just after the Feedback Trials. As for S-PFI, PFI was also measured at each Feedback Trial. Concerning both groups provided with PFI, PFIs were given only just after the Feedback Trials.

Before the experiment, the subjects were given the stimulus structure and informed of four dimensions and the eight values. They were also told that they were required to identify only one relevant value within 40 trials (eight Feedback Trials and 32 Blank Trials), and that they should not change their current hypotheses during a Blank Trial. In addition to these instructions, the subjects in F-PFI were told that six-second PFI[3] would be given at each Feedback Trial, and those in S-PFI were told that they were free to go ahead onto the next trial by pressing the key after each Feedback Trial.

The criterion of achivement was the extent to which the last value identified from the response pattern of the eighth Blank Trial was consistent with the concept determined as relevant in advance.

3) Six seconds of fixed PFI was derived from the means of PFIs determined by all the subjects over all the feedback trials.

Results

NUMBER OF ACHIEVERS

There were four achievers in N-PFI, eight in both F-PFI and S-PFI respectively. This distribution of the achievers was significantly different ($\chi^2=8.0$, $df=2$, $p<.05$) This result indicates that the existence of PFIs in concecutive trials is influential toward performance in the context of concept learning.

REDUCTION OF HYPOTHESES

In perfect processing, the eight values (hypothees) would be reduced to four hypotheses after the first feedback. If six out of twelve subjects responded according to one of the potentially relevant hypotheses during the first Blank Trials, the calculated number of reduced hypotheses would be eight ($4/6/12=8$). This suggests that no reduction occured because the subjects who could reduce the hypotheses successfully may just have well done so by chance. In this way, the tendency of hypotheses reduction over eight Feedback Trials was investigated for each treatment group, and the result is shown in **Fig.2**. The broken line in the figure represents the tendency anticpated from perfect processing. **Fig.2** indicates that the order in which the reduction tendencies resemble perfect processing: S-PFI, F-PFI and N-PFI.

PFIs AFTER CORRECT OR ERROR IN S-PFI

Out of twelve subjects in S-PFI, there was one subject who received no 'correct' feedbacks and there was one who did not received any 'error' feedbacks. Therefore the data of the two subjects were eliminated from the analysis. Also deleted were the data during the post-solution period, because the subjects did not need much PFI during the criterion run.[4] The mean PFI after 'correct'

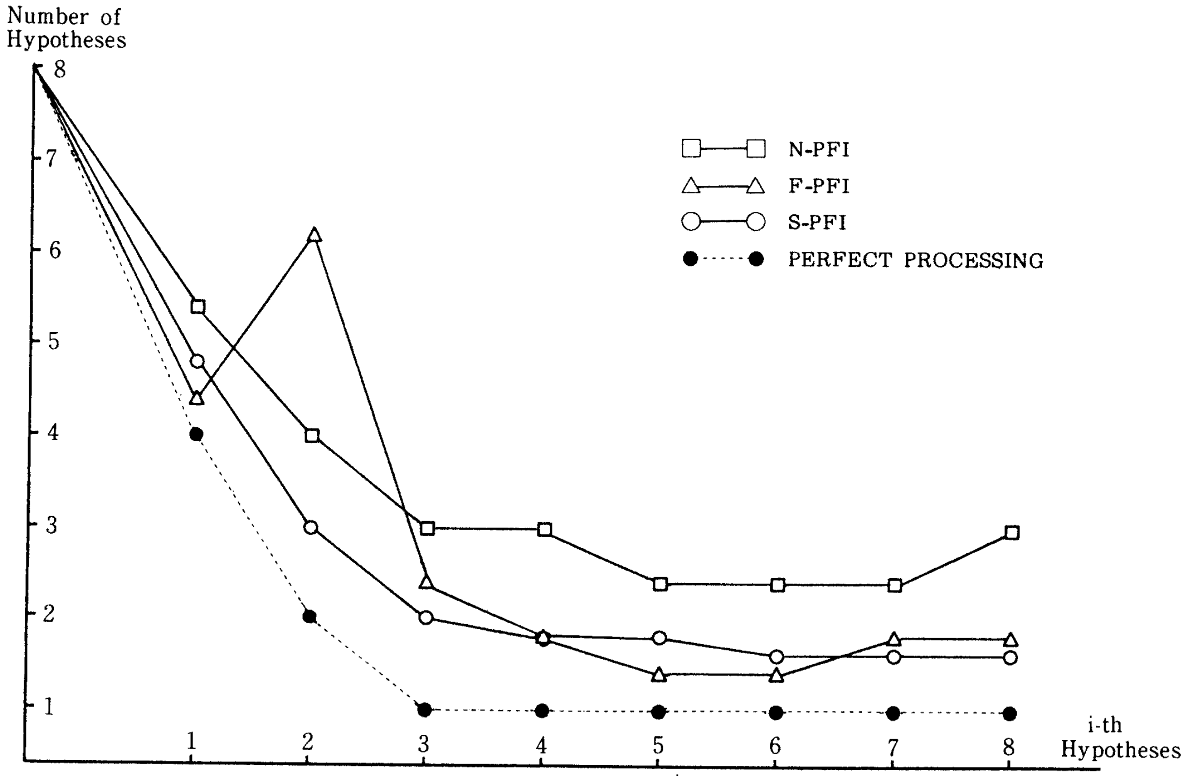

Figure 2　Tendencies of hypotheses reduction of the three treatment groups and of the perfect processing.

was 6.62 sec., while 4.80 sec. was that of PFI after 'error.' A t-test[5] showed a significant difference between 'correct' and 'error' ($t=3.00$, $df=9$, $p<.05$), and this result suggests that subjects in S-PFI processed relatively more information after 'correct' feedback than after 'error' feedback.

RESPONCE TIMES AFTER CORRECT OR ERROR AMONG THREE GROUPS

Response time in the first trial of every Blank Trial during the pre-solution period was analyzed. In the three groups, there were two subjects who received no 'correct' feedbacks and two subjects who did not receive any 'error.' Therefore the data of these four subjects were excluded from the analysis. Fig.3 shows the mean response times of which previous trials were accompanied with 'correct' or 'error' feedbacks. The two way ANOVA[5] (treatment groups(3) × feedback type(2)) showed a

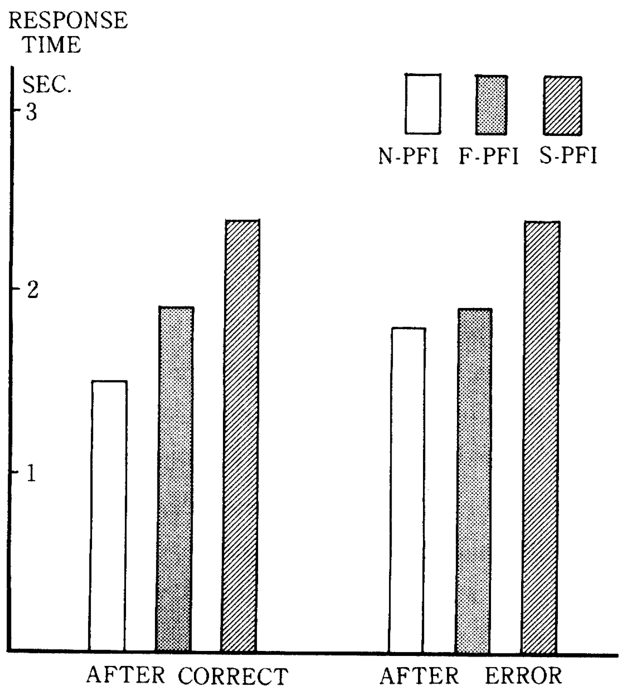

Figure 3　Mean response times after the eight Feedback Trials among the three treatment groups.

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4) A criterion run or post-solution was defined as the period immediately after the subject had achieved the three correct responses, which indicates a stage where he/she grasped the solution pattern.

significant interactional effect ($F(2,29)=4.81$, $p<.05$), and the analyses of single effects expressed significant differences among the three groups in each feedback type (for 'error,' ($F(2,32)=42.67$, $p<.01$; for 'error,' $F(2,32)=15.17$, $p<.01$). Significant differences in the sigle effects between the feedback types in each treatment group, however, were not obtained. This result means that response times after both types of feedback in S-PFI were the longest in the three groups, implying that the subjects in S-PFI paid attention not to a sigle hypothesis or dimension but to the stimulus structure during the stimulus interval because of the several hypotheses tested.

Discussion

It was confirmed that PFI in concept learning has an effect on the number of achievers within the limited trials. PFI determined by subjects was anticipated to be optimal for variables such as feedback type and trial order, and the subjects in S-PFI were successful in reducing the hypotheses, indicating that they were very close to being perfect hypotheses testers. The result of the response times also indicated that the subjects in S-PFI were checking the next stimulus structure through systematic information processing during PFI.

As for the aspect of the determined length of PFI, however, it was found that the strategy in S-PFI was not an ideal one because of the shorter PFI after 'error' feedback. But it can not be readily concluded that subjects in S-PFI were associative solvers, because upon receiving 'correct' feedback, they are assumed to maintain simply the currently working hypotheses, resulting in a short term PFI. Levine (1966) reported that even half of his adult sample, who were aware of the perfect processing strategy, could not use it when the first and second feedbacks were 'error.' He found that the perfect processing were most likely to occur when the sequential feedback patterns of the earliest three trials are 'correct-correct-error.' This was explained by Levin (1966) as follows: as a learner must process a substantial number of hypotheses during the first and second trials, he/-she cannot easily replace the other relevant set of hypotheses when receiving 'error' feedback. When feedbacks are 'correct' during the first and second trials, a learner can reduce hypotheses without replacing them. On the contrary, the number of hypotheses tested upon the third trial is assumed to be very small, so replacing can be readily made even though a feedback is 'error.' In summary, half of the adults in Levine's (1966) study made progress after 'correct' feedback in earlier trials by a strategy of systematic reduction without replacement, which can be called 'quasi-perfect processing.' In this experiment, eighth graders in S-PFI used longer PFI after 'correct' feedback as already stated, and this result implies that they were quasi-perfect hypotheses testers.

In discussing the response times in N-PFI, it is generally thought that a learner would take longer time if he/she is not provided with PFI, because he/she is only given the opportunity for processing hypotheses in stimulus intervals. However, latencies in N-PFI were the shortest of the three groups.This indicates that the subjects are not wholly using the given response interval, subsequently arising in only a small number of achievers and a hypotheses reduction tendency which was least representative of perfect processing. These results show that restricting pauses after feedbacks leads to a learner's quick response as well as to a primitive strategy. Subjects in this condition may have felt that they were being controlled by the experimenter or the experiment itself. On the other hand, subjects in S-PFI may have felt that they could control the experimental situation, because they were provided with the freedom to prolong the onset of the next trial.

An interpretation of this possibility can be made

5) Reciprocal transformation was done in order to conduct the analyses.

through Deci's (1975) observation of intrinsic motivation decreasing when learners receive an external reward capable of manipulating them, and increasing when they receive an external one providing information about their quality of learning behavior.

It may be that a feedback is not necessarily recognized as informative by a learner in a context without PFI because no delays exist between a feedback and the presentation of the next stimuli such as to draw out a quick response, resulting in a strategy of a 'win-stay and lose-shift' pattern (i.e., associative strategy like hypotheses checking or dimension checking) with low intrinsic motivation. The fundamental principle of such a strategy comes from the mechanism in reinforcement theory in programed learning; a learner will keep close to or maintain the working hypotheses when a feedback is 'correct,' while he/she will avoid or replace the working hypotheses when it is 'error.' In other words, learners tend to appreciate the rewarding value in a feedback more when they are not provided with PFI.

Pausing just after a feedback, however, seems to have a function of inducing a learner to make sophisticated processing; learners will spontaneously mediate both the stimulus structure and the meaning of the feedback which they have just utilized. In other words, PFI gives learners opportunities to make use of the informational value extracted from feedback, and concequently, their intrinsic motivation will increase when PFIs are determined by them. Therefore it could be said that the different learning situations with and without PFI would make learners recognize different aspects of feedback and also induce them to utilize different strategies with different levels of intrinsic motivation.

The learning situation where PFI is determined by a learner seems to have various important effects on human learning. Although PFI has already been applied practically in many ways in the context of CAI, the result in this study has some critical implications within a classroom setting with a teacher-pupil interaction. Suppose, for example, an underachiever has some compensatory education in the setting such as CAI or personal instruction, where he/she is able to control the learning pace within the context of self-determination and notice the informational aspects of feedback. When this pupil has caught up with his/her peers and is returned to his/her original classroom, he/she will have to repeat the remedy if the climate of the classroom emphasizes quick responses, accuracy in answers, high grades, and social judgements from others. This climate induces pupils into paying attention only to the rewarding value of feedbacks and subsequently making them feel that their learning activities are controlled by the judgements from others, such as teachers or peers.

What feedback aspect a teacher stresses or what aspect a pupil will recognize affects the educational process. Dweck (1986) noted that pupils whose achievement goal is attaining positive judgement and avoiding negative judgement from teachers and parents show an adaptive learning pattern when the result is positive, but that they would express a maladaptive pattern (e.g. helplessness) when the result is negative. She noted, moreover, that pupils whose achievement goal is to increase competence or to debug the learning processes, seem to behave adaptively whether the result be positive or negative, perhaps because they have some belief that intelligence is malleable through learing. Dweck called the former 'Performance Goal' and the latter 'Learning Goal.' Probably, pupils with a Performance Goal recognize feedbacks (judgements or grades) as rewarding, and the experience of repeated failures will keep them from the learning situations which may decrease their intrinsic motivation for learning. On the other hand, pupils with a Learning Goal recognize feedbacks as information for changing their learning strategies or aquiring new ways of learning in order to increase thier learning competence.

PFI in this study was merely a single experimental device to facilitate learners into noticing the informational aspect of feedbacks, and the most valuable and practical means in the context of teacher-pupil interaction should be investigated and discovered through searching for ways of making pupils pay attention toward the informative value from various sorts of feedbacks given to them in a classroom setting.

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概念同定学習における仮説検証行動に対するポスト・フィードバック・インターバルの効果

伊 藤　　篤

フィードバックは人の認知活動とかかわる重要な変数であるが，多くの研究が，このフィードバックの機能を，人の認知活動を外側から制御するものとして位置づけてきている。

本研究では，フィードバック後の時間間隔（PFI）という変数をとりあげ，この変数の認知的学習に対する効果が検討された。具体的には，概念同定課題にPFIを導入することによって，学習者がフィードバックの持つ統制的・報酬的側面ではなく，情報的な側面に注目し，その結果，効果的な情報処理が行われるであろうという仮説を検討した。PFI の与えられない条件（N-PFI），PFI が一律に与えられる条件（F-PFI），PFI を被験者が決めることのできる条件（S-PFI）の 3 群が比較された。4 次元各 2 値で構成される刺激が対呈示され，被験者（中学生）には 1 値に基づいて正事例を選択するように求めた。Levine による Blank Trial Method が使用され，40試行（この内フィードバック試行数は8）が行われた。ブランク試行から知ることのできる値と，被験者の実験後の報告が予め決められたレレバントな値と一致した場合に，その被験者を達成者とした。達成者数は，S-PFI および F-PFI が N-PFI より多く，ブランク試行から知ることのできる平均的な仮説数減少傾向の分析からは，S-PFI が最も理想的な仮説検証行動に近いことが示された。また，フィードバック試行後の反応時間は S-PF Iが最も長く，直前のフィードバック情報に基づく仮説検証行動によって，次の刺激の構造をチェックしていることが示唆された。S-PFI の PFI の分析から，正フィードバック後に多くの時間をとっていることから，正フィードバック後に効果的な仮説検証がなされていることが示された。この結果は，PFI のない条件での成人の被験者を対象とした学習方略に関する先行研究の結果とも一致している。本研究で扱われた PFI という実験変数は，学習者にフィードバックの持つ情報的な側面に注目させるためのひとつの方法である。なんらかのフィードバックがなされた時，自分のペースでそれが意味する情報を処理できるような機会を十分に与えることが学習にとって重要であることが示された。