Effects on Performance of Interpolated Tasks During the KR Delay or the Post-KR Delay Interval

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Abstract: The present study was designed to investigate the nature of motor information processing in the intertrial intervals of a discrete motor task. In Experiment 1, the subjects were given the task of grasping the dynamometer with an intensity yielding a value as close as possible to the target value (40% of the subject's maximum grasping power). The exercise session consisted of 5 trials without Knowledge of Results (NO-KR phase), and 30 trials with Knowledge of Results (KR phase). In the KR phase, one of the two interpolated tasks, one was a verbal task and the other was a motor task, was given during the KR delay interval or the post-KR delay interval. Performance level in the exercise session was measured by constant error and variable error. In Experiment 2, the degrees of difficulty in the two types of interpolated tasks used in Experiment 1 were measured. The main results of our experiments were as follows; (1) Although the results of Experiment 2 showed that the difficulty of the verbal interpolated task was exceeded that of the motor interpolated task, only variable errors of the groups which had executed the motor interpolated task were increased. If the kinetic sense was changed by executing the motor interpolated task, constant error should have increased. The results of Experiment 1, however, showed no difference in constant error, suggesting that the occurrence of interference by the motor interpolated task is related to the capacity of the motor short term memory space. (2) In the latter period of the KR phase, variable error of the group in which the motor task was interpolated during the KR delay interval was at the same level as that of the control group. Whereas variable error of the group in which the motor task was interpolated during the post-KR delay interval exceeded that of the control group over the whole of the KR phase. These results suggest information processing during the post-KR delay interval has more influence on performance than that during the KR delay interval.

Key words: motor performance, interpolated task, KR delay interval, post-KR delay interval

The present study was designed to investigate the nature of information processing in the acquisition phase of a motor task by an experiment using interpolated tasks. The acquisition phase of a discrete motor task consists of period for the subject's response to the task and the intertrial intervals, and usually Knowledge of Results (KR) is presented between the intertrial intervals. The delay from the subject's response until the presentation of KR is termed the KR delay interval, and the delay from the presentation of KR until the next response is termed the post-KR delay interval. There have been some studies in which interpolated tasks were given in the KR delay interval or the post-KR delay interval¹.². Salmoni et al. reviewed these early studies and predicted that interference occurs when both the exercise task and the interpolated task are relatively difficult³. However, the effects of difference in the modalities of interpolated tasks have not been fully investigated. Thereafter, Marteniuk⁴ conducted an experiment according to the transfer design devised by Schmidt⁵, in which an interpolated motor task and a number-solving task into the KR delay interval, and reported that interference with learning occurred with each interpolated task used. Swinnen⁶ also has reported that interference with learning occurred when cognitive tasks (without actual exercise) were given in the KR delay interval.
However, the influence of interpolated tasks on performance in the acquisition phase in the experiment by Marteniuk is different from that in the experiment by Swinnen. In the Marteniuk’s experiment interpolated tasks reduced performance, while none of them influenced the performance in the Swinnen’s experiment. According to Schmidt, performance in the acquisition phase may be apparently promoted by motivating and guiding function of KR. In the Marteniuk’s experiment, it seems that suppression of performance by interpolated tasks is superior to promotion of performance by KR, but it doesn’t apply to Swinnen’s experiment.

The present study was designed to clarify the nature of information processing in the acquisition phase from mechanisms of suppression of performance by interpolated tasks. In Experiment 1, two types of interpolated tasks with different modalities were given to the KR delay interval or the post-KR delay interval, and changes in performance were investigated. In Experiment 2, which was designed to supplement results of experiment 1, the degrees of difficulty in the two types of interpolated tasks used in Experiment 1 was measured.

**Experiment 1**

**Purpose**

The purpose of Experiment 1 was to determine changes in performance in the acquisition phase by one of the two types of interpolated tasks to the KR delay interval or the post-KR delay interval.

**Methods**

Subjects: Fifty college undergraduates (aged 19 to 32 years; mean age: 20.8 years).

Apparatus: The main apparatus consisted of a hand dynamometer and a time controller. The hand dynamometer indicates the output peak level of grasping power at .5 kgw intervals. The display of the indicator and the signal light, which instruct the subjects to start and to stop the task movement, were controlled with a time control device. In addition, an EMG biofeedback device was used for the interpolated motor task, as described in procedures.

Procedures: The subject sat on a chair and grasped the hand dynamometer, which had been placed on the table, with the dominant hand. Before exercise sessions, each subject was asked to grasp the dynamometer three times as firmly as possible, and the maximum value of three trials was regarded as the subject’s maximum grasping power. Then, the target value, 40 percent of the maximum value, was displayed on the upper part of the indicator of the hand dynamometer. The subjects were given the task of grasping the dynamometer with an intensity yielding a value as close as possible to the target value.

The exercise session consisted of 5 trials without KR (NO-KR phase), and 30 trials with KR (KR phase). The NO-KR phase began after the following instructions:

When the signal light is on, grasp the hand dynamometer for one second at the intensity that you consider to be 40 percent of your maximum grasping power.

In the NO-KR phase, the trial was one second, the intertrial interval being 10 seconds, and there was no KR. Then, the KR phase was carried out after the following instructions:

Five seconds after completing the grasp, the value for the power of your grasp will be displayed on the indicator. Adjust the power of your next grasp by comparing your target value and the value on the indicator.

In the KR phase, each trial lasted for a second, and the intertrial interval was 10 seconds. Five seconds after the end of the trial, the value of the subject’s grasping power was displayed for one second. This procedure provided the subjects with KR. The KR delay interval and the post-KR delay interval were both 5 seconds.

Two types of tasks were used as interpolated tasks; one was a verbal task, and the other was a motor task. For the verbal interpolated task, the experimenter read out random four digit numbers, and soon after that the subjects were asked to recite the numbers in the reverse order. The motor interpolated task was isometric elbow flexion of the nondominant arm. After the subject had flexed his/her elbow to 90 degrees, a cuff was placed on the distal part of the forearm. The cuff was then anchored to the floor with a chain. The subject was asked to pull the chain up, and an EMG was monitored on the brachioradialis using the biofeedback device. In this way, each subject’s maximum voluntary contraction (MVC) was measured by EMG prior to the exercise session. The interpolated motor task was to maintain 60% of the brachioradialis MVC, although the subjects were not told that the target EMG value was 60% of MVC. EMG feedback was not provided to the subjects visually, but rather by a bell set to ring when the EMG coincided with the target value. The interpolated motor task assigned to the subjects was thus to adjust isometric elbow flexion movement based on auditory feedback.

In this experiment, one of the two interpolated tasks was given during the KR delay interval or the post-KR delay interval. For the control group, there was no interpolated task.

Conditions: Five groups were formed, each group consisting of 10 subjects. Each group was assigned the following activities:

- Group 1: motor task interpolated during the KR delay interval.
- Group 2: verbal task interpolated during the KR delay interval.
- Group 3: motor task interpolated during the post-KR delay interval.
- Group 4: verbal task interpolated during the post-KR delay interval.

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**Results**

The subjects who were assigned the experimental group 2 and group 4 made full use of the KR delay interval or the post-KR delay interval to perform the verbal interpolated task, and outcomes were generally accurate. The subjects given the interpolated motor task were also generally able to maintain 60% of MVC, as demonstrated by EMG.

To analyze the data, the entire NO-KR phase was regarded as a single trial block (NO-KR block). The KR phase was divided into three trial blocks (KR block 1, 2 and 3), each block consisting of ten sequential trials, and motor performance levels among KR blocks were compared. In addition, marked variability in maximum grasping power among subjects was noted. To normalize the data, the difference between each grasping power value and the target value in each subject was divided by the maximum grasping power value of each subject. Finally, two dependent variables, the absolute constant error (ACE) and the variable error (VE) were calculated. ACE is the absolute value of the average of errors for each trial block, and indicates the average deviation of a subject’s response from the target value. VE is the standard deviation of the errors for each trial block, and indicates the variability in the subject’s responses.

Difference in ACE and that in VE were not significant among the groups in the NO-KR phase. For the analysis of the KR phase, the analysis of variance for a two-factor mixed design was performed. Figure 1 depicts the transition in ACE. ANOVA for ACE showed that only the main KR block effect was significant ($F=4.27$, df=2/90, $p<.05$). The Newman-Keuls test revealed ACE in KR block 1 to be significantly higher than ACE in KR block 3. There were no other significant differences in ACE among the KR blocks. The VE transition in the KR phase is shown in Figure 2. ANOVA for VE revealed two significant effects: the main effect of the KR block ($F=41.41$, df=2/90, $p<.01$) and the interaction ($F=2.83$, df=8/90, $p<.01$). In the analysis of simple effects, there were significant differences between groups in KR block 1 and KR block 3 ($F=3.26$ and $F=2.57$, respectively; df=4/45, $p<.05$ in both blocks). The Newman-Keuls test for both blocks showed that the VE of group 1 was significantly higher than those of groups 2, 4, and 5 in KR block 1, and that the VE of group 3 was significantly higher than that of group 5 in KR block 3.

**Discussion**

In this experiment, only the interpolated motor task interfered with the motor performance of the grasping task. According to Salmoni et al.3), in this type of experiment it appears that if the task to be exercised is somewhat complex and the interpolated tasks are sufficiently demanding, interfering activities will tend to produce deterioration of the motor performance of the exercise. Thus, it is possible to interpret our results as the subjects in the motor interpolated task groups experiencing a heavier processing load than those in the verbal interpolated task groups, despite the exercise tasks being the same. This point will be assessed in Experiment 2.

**Experiment 2**

**Purpose**

The purpose of Experiment 2 was to measure the degrees of difficulty in the two types of interpolated tasks used in Experiment 1. We used the secondary task method (or the probe technique) in Experiment 2$.^b$). When the secondary task method is used, the attention used in man is assumed to be limited in quantity. If the amount of the attention required for the primary main task is large, it may take a lot of time for a response to the secondary probe task to be made. If the amount of the attention required for the primary task is small.

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**Fig. 1** Transition of absolute constant error in each experimental group
in reverse, a response to the probe task is made quickly. On the basis of such a hypothesis, the degrees of difficulty in the interpolated tasks were measured in Experiment 2.

Methods

Subjects: Thirty college undergraduates (age 19 to 31 years; mean age: 20.5 years).

Apparatus: The main apparatuses were a personal computer and an EMG biofeedback device as used in Experiment 1. In order to measure simple reaction times, we used a computer program by means of BASIC in which the timer function was incorporated.

Procedures: The subjects were induced, in advance, to perform either of the two types of interpolated tasks as the main task, which were used in Experiment 1. They were given the probe task as well, simultaneously with the main task. Since a simple reaction to light or sound is usually requested in the probe task in many settings, Experiment 2 also followed this condition. The subjects were instructed to press a key as soon as they saw a fixed symbol (character “A”), which appeared as stimuli on the computer display at random intervals. Demonstration of the display of the character “A” was preliminarily performed on the subjects. The character “A” was interpreted to be merely a symbol and to have no meaning as letter, in addition to the explanation that none of the symbols other than “A” was displayed. Each subject was given 40 trials for the measurement. All experimental groups were commonly given only simple reaction task in the first 10 trials. In the subsequent 11-40 trials, the subjects were divided into three groups, each of which consisted of 10 subjects, according to the load of task. The verbal interpolated task similar to that in Experiment 1 was assigned in parallel with the simple reaction task in the verbal task group. The motor interpolated task similar to that in Experiment 1 was assigned in parallel with the simple reaction task in the motor task group. Only the motor interpolated task was assigned in the control group.

Results

The results of measurement in 40 trials were averaged according to blocks, each of which consisted of 10 sequential trials. Table 1 shows rates of the average values to the average reaction time in the trial block 1. The analysis of variance of the results revealed that only the main effect of the experimental conditions was significant ($F=21.82$, $df=2/27$, $p<.001$) and the main effect of the trial block factor was not significant. The differences in average reaction time among the three groups were significant by the Newman-Keuls test.

Discussion

The results of Experiment 1 and 2 are comprehensively discussed. Some causes underlying the interference by the interpolated task are considered. The following two possibilities should be discussed first; one for the interpolated task having been adequately demanding, as indicated by Salmoni et al.3), and the other for the sensory threshold having changed after completion of the interpolated task. The results of Experiment 2 showed that the load of the verbal interpolated task was heavier than that of the motor interpolated task used in Experiment 1. Nevertheless, only the motor interpolated task, not the verbal interpolated task, selectively interfered with the motor performance of the.

Table 1 Reaction time in each trial block

<table>
<thead>
<tr>
<th>Group</th>
<th>BLOCK 1</th>
<th>BLOCK 2</th>
<th>BLOCK 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor Task Group</td>
<td>131 ± 25.0</td>
<td>133 ± 26.0</td>
<td>139 ± 31.1</td>
</tr>
<tr>
<td>Verbal Task Group</td>
<td>177 ± 40.0</td>
<td>173 ± 34.4</td>
<td>191 ± 62.8</td>
</tr>
<tr>
<td>Control Group</td>
<td>99 ± 7.4</td>
<td>97 ± 7.6</td>
<td>98 ± 5.8</td>
</tr>
</tbody>
</table>

Percentage for the average RT in trial 1-10; mean±SD.
grasping task in Experiment 1. When another motor task is added as an interpolated task to the exercising task (i.e., when both are tasks for adjusting the force strength, as in Experiment 1), the kinetic sense may be changed by performing the interpolated motor task. If such an activity had been present, errors in the motor interpolated task group should have uniformly inclined toward the positive area and the ACE should have increased eventually, because the exercise task needed 40% MVC and the interpolated task needed 60% MVC in Experiment 1. The results of Experiment 1, however, showed no difference in ACEs among the experimental groups, suggesting that the occurrence of interference by the motor interpolated task is not related to sensory modality.

The present experimental results apply well to the hypothesis of selective interference indicated by Brooks7). According to his hypothesis, the space assigned to linguistic information processing is different from the space assigned to motor information processing. Since each capacity is independent, mutual trade-off is believed to be impossible. It still remains unsolved how the conformity of secondary task technique used in Experiment 2 with the Brooks’ hypothesis will be determined, but for the time being, the presence of a phenomenon of selective interference is only indicated in this article.

In Experiment 1, when the interpolated motor task was given in the KR delay interval, VE increased only in the early acquisition phase. On the other hand, when the interpolated motor task was given in the post-KR delay interval, VE increased over the whole acquisition phase. These results suggest that information processing in the post-KR delay interval has more influence on performance in the acquisition phase than that in the KR delay interval.

Marteniuk4) used a motor task and a number-solving task as the interpolated tasks, and reported that both tasks interfered with the performance in the acquisition phase. In Marteniuk’s experiment, the subjects were instructed to produce movements that could be described as reaching a given displacement in a specified time. The task used by Marteniuk seems to include more cognitive elements than does the grasping power adjusting task used in the present experiment. This point may be responsible for the difference in results between the present experiment and the Marteniuk’s. In Swinnen’s experiment5), in which the learning task and the interpolated tasks were similar to those used by Marteniuk, the interference did not occur in the acquisition phase, and only the learning level changed on the transfer test. Since Marteniuk and Swinnen did not discuss the relationship between change in performance and change in learning, no conclusion will be drawn. However this topic is very interesting for elucidating the process of learning, and should be assessed in the future.

In conclusion, the association of this study with physical therapy will be described. The following are suggested from the present experimental results to the therapeutic exercise. In the case in which some exercises are planned to be used in the therapy, the patient’s performance will not improve, if different types of exercises are serially given to the patient without enough time for them to consider the previous exercise. However, it does not mean that it is wrong to train some exercises in parallel, or that only one type of exercise had better be intensively trained. With regard to the efficacy of long-term learning, a report has shown that it is more excellent to train some exercises in parallel, as compared to the intensive training of only one type of exercise8). It is important to provide patients with the time for his/her reconsidering the movement that the patients made previously. Since the subjects of the present experiments include healthy persons, the suggestion to patients with the disturbed motor-sensory system is restricted. However, we consider it very necessary to add the theory of motor learning and performance as a basic theory of physical therapy.

**References**