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ORIGINAL ARTICLE

Measuring Inhibitory Control without Requiring Reading Skill

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ABSTRACT

For two paper–pencil versions of inhibitory tasks that require no reading skill, this study investigated the performance of young adults with no disability. Experiment 1 examined performance on same–different tasks by 42 participants. Three conditions were administered, all of which used geometric shapes: the same (no interference) condition, which asked each participant to check the same items as the target stimuli; the different (interference) condition, which asked to check the different items from the target stimuli while inhibiting the prepotent tendency of checking the same; and the motor condition, which measured motor speed. Results showed the highest performance in the motor condition and the lowest in the different condition. Experiment 2 examined performances of 43 participants on the flanker task, which asked participants to check the same arrow as the target placed in the middle of five arrows in line. Four conditions were administered: the same (no interference) condition, in which all five arrows pointed to the same direction; the different (interference) condition, in which the four arrows flanking the target pointed to the opposite direction against it; the partially different (interference) condition, in which one of the four arrows flanking pointed to the opposite direction; and the motor condition, which measured motor speed. Results showed the highest performance for the motor condition and the lowest for the different and partially different conditions, among which the differences were not significant. These results suggest that the two inhibitory tasks developed in this study are easy to administer and useful for people with little or no reading ability. Results demonstrate that the same–different task might be more inhibitory–demanding than the flanker task.

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Ⅰ. Introduction

Inhibitory control, one aspect of executive function that coordinates our goal-directed behaviors, is the ability to suppress inappropriate impulses, thoughts, and actions (Miyake, Friedman, Emerson et al., 2000). Among various measures, the classic one is the Stroop color–word test. In this test, participants are presented with incongruent color–word stimuli, e.g., the word *red* printed in blue ink. They are requested to name the ink color while inhibiting the prepotent tendency of word reading. Since the first report by Stroop, J. R. in 1935 (Stroop, 1935), several studies have investigated attentional mechanisms, developmental trends, and relations with developmental disabilities (Ikeda, Hirata, Maeda et al., 2013; Ikeda, Hirata, Okuzumi et al., 2010; Ikeda, Okuzumi & Kokubun, 2013b, 2014c; Ikeda, Okuzumi, Kokubun et al., 2011, 2013; MacLeod, 1991).

Because the Stroop color–word test requires well-developed reading skills, it cannot be used by people who have little or no reading ability. Accordingly, attempts have been made to develop new measures to investigate inhibitory control: animal size tests (Ikeda, Okuzumi & Kokubun, 2013a, 2014e, 2014f), the fruit Stroop task (Archibald & Kerns, 1999), the flanker task (Eriksen & Eriksen, 1974), the day-night task (Gerstadt, Hong & Diamond, 1994), the happy–sad task (Ikeda, Okuzumi & Kokubun, 2014d), and the big–small task (Ikeda, Okuzumi & Kokubun, 2014a). Nevertheless, these measures are not necessarily easy to administer because they are sometimes computerized and require specific apparatus.

This study was conducted to investigate performance on two paper–pencil versions of inhibitory tasks that require no reading skill. This study particularly examined normative data in young adults with no disability. Experiment 1 used the same–different task, which involves two competing stimuli, developed based on the day–night task, the happy–sad task, and the big–small task. Experiment 2 used the flanker task, in which individuals are requested to identify a target shape while resisting interference from the irrelevant shapes flanking it.

Ⅱ. Experiment 1: paper–pencil version of the same–different task

1. Methods

1) Participants

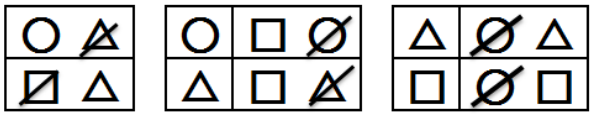
Participants were 42 right-handed young adults with no disability (mean age 21.6±1.0, 25 women), who were recruited from a university. Informed consent was obtained from all participants before the assessment session.

2) Measures

The same–different task included three conditions: same, different, and motor conditions. In the same condition, four geometric shapes (a circle, triangle, square, and

diamond) were presented one-by-one, requiring participants to select and check the same shape from the two geometric shapes printed on the right side of the test sheet. In the different condition, the same four geometric shapes above were presented one-by-one; participants were asked to check the different shape from the two geometric shapes printed on the right side of the test sheet while inhibiting the prepotent tendency of choosing the same shape. In the motor condition, participants were presented with only the right side of the test sheet. They were required to check either of the two shapes alternately (left, right, left, right, etc.).

Test sheets (A3) included 60 response sets arranged in 5 rows and 12 columns. Each response set consisted of one target presented on the left side and two shapes presented on the right side (see Fig. 1). Each of four geometric shapes was presented 15 times as the target. Among the 60 response sets, half of the correct answers were arranged on the left and the other half on the right.



<Figure 1> Examples of three same–different task conditions (motor condition on the left, same condition in the middle, and the different condition on the right)

3) Procedures

For each condition, 10 practice trials were administered before the test trials. The participants were asked to perform the practice and test trials as quickly and as accurately as possible. In addition, participants were asked not to correct errors when detecting errors. The order of the three conditions was randomized among participants.

For each condition, the number of errors and the time to complete the task, measured using a stopwatch, were recorded. Performance scores (PS) were calculated using the formula shown below:

PS = (number of correct responses / number of total items) × (number of correct responses / time to complete the task) (1)

Higher scores reflect more efficient performance. For statistical analyses, software (SPSS Statistics Ver. 22.0 for Windows; IBM Corp.) was used.

2. Results

Table 1 presents means and standard deviations of the number of errors, time to complete the task, and the PS in each condition. One-way within-subjects ANOVA was conducted on the PS. The analysis revealed a significant main effect for the condition ($F_{2,82}$ = 454.959, p < .01, η_p^2 = .917). Post hoc Bonferroni tests were used to infer significance for all between-condition comparisons (p < .05). Results showed that

performance was the highest in the motor condition and the lowest in the different condition.

<Table 1> Means and standard deviations of number of errors, time to complete the task, and the PS in the same–different task

	Motor		Same		Different	
	M	*SD*	*M*	*SD*	*M*	*SD*
Number of errors	0.17	0.44	0.21	0.47	1.31	1.42
Time to complete task (s)	24.02	3.43	39.52	5.54	51.67	9.59
Performance score	2.53	0.37	1.53	0.20	1.15	0.22

Note: Motor = motor condition, Same = same condition, and Different = different condition.

Ⅲ. Experiment 2: paper–pencil version of the flanker task

1. Methods

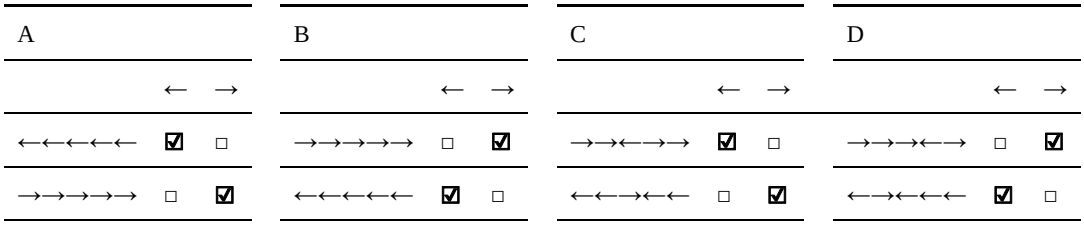
1) Participants

Participants were 43 right-handed young adults with no disability (mean age 21.3±0.9, 27 women), who were recruited from a university. Informed consent was obtained from all participants before the assessment session.

2) Measures

In a paper–pencil version of the flanker task, stimuli were left-directed arrows (←) and right-directed arrows (→). The 60 response sets were arranged in 3 rows and 20 columns on a test sheet. Each response set consists of five stimuli in line on the left panel and two boxes on the right panel (see Fig. 2). Participants were requested to check either of the boxes on the right panel, matching the direction of the middle arrow (the target) on the left side. They were requested to check the left box if the target was the left-directed arrows and the right box if the target was the right-directed arrows. Among the 60 response sets, half of the correct answers were arranged in the left boxes; the other half were in the right boxes.

The task had four conditions: same (no interference) condition, different (interference) condition, partially different (interference) condition, and motor condition. In the same condition, the five arrows on the left panel pointed to the same direction. In the different condition, the four arrows flanking the target (middle arrow) pointed to the opposite direction. In the partially different condition, one of the four arrows flanking pointed to the opposite direction. In the motor condition, participants were requested to check either of the two arrows on the right panel alternately (left, right, left, right, etc.).



<Figure 2> Examples of the four flanker task conditions: A, motor condition; B, same condition; C, different condition; and D, partially different condition.

3) Procedures

For each condition, 10 practice trials were administered before the test trials. The participants were asked to perform the practice and test trials as quickly and as accurately as possible. In addition, participants were asked not to correct errors when detecting errors. The order of the three conditions was randomized among participants.

For each condition, the number of errors and the time to complete the task, measured using a stopwatch, were recorded. The performance scores (PS) were calculated using the formula presented above. Higher scores reflect more efficient performance. For statistical analyses, software (SPSS Statistics Version 22.0 for Windows; IBM Corp.) was used.

2. Results

Table 2 presents means and standard deviations of number of errors, the time to complete the task, and the PS in each condition. One-way within-subjects ANOVA was conducted on the PS. The analysis revealed a significant main effect for the condition ($F_{3,126}$ = 123.451, p < .01, η_p^2 = .746). Post hoc Bonferroni tests revealed significant differences between the motor condition and the other three conditions (p < .05) and between the same condition and the two interference conditions (p < .05). The difference between the different and the partially different conditions was not significant (n.s.). Results showed that performance was the highest in the motor condition and the lowest in the different and partially different conditions, among which the differences were not significant.

Ⅳ. Discussion

This study investigated normative data of young adults with no disability on paper–pencil versions of the two inhibitory tasks that require no reading ability, the same–different task and the flanker task. Experiment 1 showed that a paper–pencil version of the same–different task elicits significant interference as in the card version or the computerized version of similar tasks, the day–night task (Gerstadt, Hong & Diamond, 1994), the happy–sad task (Ikeda, Okuzumi & Kokubun, 2014d), and the

big–small task (Ikeda, Okuzumi & Kokubun, 2014a). Results of Experiment 2 showed that a paper–pencil version of the flanker task elicits significant interference as in the original flanker task (Eriksen & Eriksen, 1974). These results suggest that the two inhibitory tasks developed in this study are easy to administer and that they are useful for people who have little or no reading ability. Results of Experiment 2 also suggest that only one irrelevant stimulus causes the same level of interference as the four irrelevant stimuli did. Results showed a tendency by which the same–different task is more inhibitory-demanding than the flanker task. Future studies are expected to compare performances of the two tasks directly among identical participants.

<Table 2> Means and standard deviations of number of errors, time to complete the task, and the PS in the flanker task

	Motor		Same		Different		Partially Different	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Number of errors	0	0	0.74	1	1.07	1.42	1.02	2.44
Time to complete task (s)	32.88	6.87	47.81	10.2	51.19	9.15	52.19	11.40
Performance score	1.90	0.37	1.28	0.29	1.16	0.19	1.16	0.25

Note: Motor = motor condition, Same = same condition, Different = different condition, and Partially different = partially different condition.

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