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Original Article

Inhibitory control measured using the Stroop color–word test in people with intellectual disabilities

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ABSTRACT

Objectives: Inhibitory control is a key cognitive process of typical and atypical cognitive development. This study was undertaken to examine features of inhibitory control in people with intellectual disabilities (ID) from unspecified causes.

Methods: This study examined 14 people with ID (6 female, 8 male; mean CA = 34.36 years, SD = 8.22, range 15–45; mean MA = 87.96 months, SD = 20.70, range 57–132; mean IQ = 43.49, SD = 10.90, range 30–70). The Stroop color–word test was administered. In this test, individuals are presented with incongruent color–word stimuli, such as a word red printed in blue ink. They are then requested to name the ink color while inhibiting the prepotent tendency of word reading. The response time (RT) cost in color naming of the incongruent stimuli versus neutral stimuli, such as a blue rectangle, reflects the Stroop interference. A greater Stroop interference has been regarded as an index of less inhibitory control.

Results: Stroop interference was observed robustly in people with ID in terms of both error rates and RTs. Intelligence (intelligence quotient and mental age) correlated with RTs of the test, but not with the Stroop interference.

Conclusion: Results of this study suggest that the general speed of information processing is an important factor of intelligence, and suggest that inhibitory control should be assessed along with a standard intelligence scale to implement necessary support for people with ID who suffer from impaired inhibitory control.

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Introduction

Inhibitory control refers to the ability to suppress inappropriate impulses, thoughts, and actions (Garavan, Ross, & Stein, 1999). Such control has been implicated as playing a crucially important role in executive function: higher-order cognitive processes that control and regulate thoughts and actions (M. Anderson, 2001; P. Anderson, 2002; Harnishfeger & Bjorklund, 1994; Miyake et al., 2000; Miyake & Friedman, 2012). Deficits in inhibitory control have been implicated in behavioral problems associated with several developmental disorders such as attention deficit hyperactivity disorder (ADHD), Tourette syndrome, and phenylketonuria (Barkley, 1997; Channon, Sinclair, Waller, Healey, & Robertson, 2004; Diamond, Prevor, Callender, & Druin, 1997; Ozonoff & Jensen, 1999; Song & Hakoda, 2011; Spronk, Jonkman, & Kemner, 2008). Inhibitory control is a key cognitive process of typical and atypical cognitive development.

The Stroop color–word test (MacLeod, 1991; Stroop, 1935) is a classic measure of inhibitory control. In this test, individuals are presented with incongruent color–word stimuli, such as the word red printed in blue ink. They are then requested to name the ink color while inhibiting the prepotent tendency of word reading. The response time (RT) cost in color naming of the incongruent stimuli versus neutral stimuli, such as a blue rectangle, indicates the Stroop interference, also known as the Stroop effect. Higher Stroop interference has been regarded as an index of less inhibitory control.

Some investigation of inhibitory control has been done in people with intellectual disabilities (ID) using the Stroop color–word test (Das, 1970, 1969; Ellis, Woodley-Zanthos, Dulaney, & Palmer, 1989). Earlier research reported greater Stroop interference in people with ID than mental age (MA)-matched children (Das, 1970) and chronological age (CA)-matched adults (Ellis et al., 1989), suggesting weak inhibitory control in people with ID. In contrast, Das (1969) reported less Stroop interference in children with ID compared to CA-matched children, although children with ID had a wider range of intelligence quotient (IQ) between 35 and 65. Some children with ID presumably did not have a reading ability sufficient to show robust Stroop interference.
Additionally, previous reports describe that the Stroop interference increased concomitantly with MA accompanied by an increase in reading proficiency (Das, 1970). However, the relation might not be caused solely by an increase in reading proficiency, but also by other factors. The blocked card-like format (i.e., stimuli of the same type are presented simultaneously on a card or a sheet of paper), which Das (1970) used, involves more of a shift of attention from one stimulus to the next than the item-by-item format

does (Ludwig, Borella, Tettamanti, & de Ribaupierre, 2010; Salo, Henik, & Robertson, 2001). It might be trued that a shift of attention limited attentional resources used for resolving the Stroop interference and that such resources increased as a shift of attention becomes automated with ages. Consequently, additional research must be undertaken to accumulate sufficient data for meaningful conclusions about the relation between performance on the Stroop color–word test and intelligence.

This study was conducted to examine features of inhibitory control in people with ID. Specifically, a computerized item-by-item version of the Stroop color–word test, a purer measure of inhibitory control, was administered people with ID to assess the relation between performance on the Stroop color–word test and intelligence.

Method

Participants

Participants were 14 people with unspecified causes of ID (6 female, 8 male; mean CA = 34.36 years, SD = 8.22, range 15–45; mean MA = 87.96 months, SD = 20.70, range 57–132; mean IQ = 43.49, SD = 10.90, range 30–70) who had been recruited from a residential care facility in Japan. For each participant, IQ and MA were assessed through administration of the Tanaka–Binet intelligence scale, which is a standardized and widely used intelligence test in Japan that has been validated sufficiently against the Wechsler Scale. Criteria for inclusion were IQ under 70, absence of bilingualism, and absence of sensory deficits. Informed consent was obtained from a guardian of each participant before the assessment session. Ethical approval for the study was obtained from the Research Ethics Board at Tokyo Gakugei University.

Measures

All participants were administered a computerized item-by-item version of the Stroop color–word test. SuperLab 4.0 for Windows (Cedrus Corp., San Pedro, CA, USA) controlled the test and recorded oral responses. The test comprised three tasks: a word-reading task in which participants read aloud four words (red, blue, yellow, and green) written in black ink in Japanese Hiragana characters (one type of phonetic character); a color-naming task in which participants named the colors of squares of the four colors; and an incongruent color-naming task in which participants named the color of an incongruent stimulus, i.e., the Stroop condition. In the incongruent color-naming task, the stimuli were four words (red, blue, yellow, and green) in Japanese Hiragana characters, printed in a nonmatching color of the same four colors.

Procedure

Participants were tested individually in quiet rooms at their respective schools. At arrival, a participant was asked to be seated with a microphone. Then, each was asked to respond as quickly and accurately as possible to a series of eight stimuli displayed on a monitor placed before the participant for each task. All stimuli were presented one at a time and randomly at the center of the white screen, followed by an interstimulus interval during which a fixation cross was presented for 500 ms. All stimuli were replaced by the fixation cross at the time a participant's voice key was input. The interval in milliseconds between the presentation of a stimulus and the onset of the participant's vocal response by the microphone was measured as the RT. Two pretrials were administered before each task, and the order of the three tasks was counterbalanced among participants.

In word-reading, color-naming, and incongruent color-naming tasks, the number of correct responses for eight trials and the mean RT for correct responses were calculated. Furthermore, an interference score was calculated using the formulas presented below, which exclude any influence of an individual's performance level (Ikeda, Hirata, Okuzumi, & Kokubun, 2010; Ikeda, Okuzumi, Kokubun, & Haishi, 2011; Ikeda, Okuzumi, & Kokubun, 2013; Ludwig et al., 2010; Song & Hakoda, 2011):

Interference score = (incongruent color-naming time – color-naming time) / color-naming time × 100.

A lower interference ratio reflects higher inhibitory control.

Results

Performance on the Stroop color–word test

Table 1 shows means and standard deviations for error rates, RTs, and the interference score. Error rates were higher and RT was longer in the incongruent color-naming task than in other tasks.

One-way analysis of variance conducted for error rates showed a significant main effect for the task ($F_{2,26}$ = 5.06, p < .05; partial η^2 = 0.28). Post hoc Bonferroni tests revealed significant difference between the incongruent color-naming task and the word-reading task and between the incongruent color-naming task and the color-naming task (p < .05). No significant difference was found between the word-reading task and the color-naming task. The results of error rates therefore indicate that error rates were higher in the incongruent color-naming task than in the word-reading task or the color-naming task.

One-way analysis of variance conducted for RT showed a significant main effect for the task ($F_{2,26}$ = 10.57, p < .001; partial η^2 = 0.45). Post hoc Bonferroni tests revealed a significant difference between the incongruent color-naming task and the color-naming task (p < .001). No significant difference between the word-reading task and the color-naming task and between the word-reading task and the incongruent color-naming task. Results of RT therefore show that RT was longer in the incongruent color-naming task than in the color-naming task.

Table 1
Means and standard deviations for error rates, response time, and interference score

	M	*SD*
Error rate (%)		
Word-reading	1	4
Color-naming	2	5
Incongruent color-naming	9	13
Response time (ms)		
Word-reading	1178	581
Color-naming	894	260
Incongruent color-naming	1389	309
Interference score	61	39

N = 14

Relation between task performance and individual data

Table 2 presents Pearson product-moment correlation coefficients between the performances of the Stroop color–word test and the individual data (IQ, MA, CA, and gender). Gender was coded as dummies: "0" for man and "1" for woman. The error rates of all three tasks did not correlate with any individual data series. The RTs of all three tasks correlated negatively with IQ and MA, but not with CA and gender. The interference score did not correlate with any single data series.

Table 2 Correlation between data and task performance

	IQ		MA		CA	Gender
Error rate (%)						
Word-reading	.240		.334		.372	-.240
Color-naming	-.174		-.292		.033	-.354
Incongruent color-naming	-.030		-.061		.404	-.488
Response time (ms)						
Word-reading	-.660	*	-.614	*	.026	.073
Color-naming	-.651	*	-.679	**	.295	-.353
Incongruent color-naming	-.677	**	-.628	*	.102	.150
Interference score	.039		.102		-.152	.520

N = 14

Note. IQ = intelligence quotient; MA = mental age; CA = chronological age

Gender coded as 1 = woman, 0 = man

* $p < .05$, ** $p < .01$

Discussion

This study investigated the relation between performances of the Stroop color–word test and intelligence in people with ID using a computerized item-by-item version of the test, a purer measure of inhibitory control. The following sections present discussion of the performances of the Stroop color–word test and their relations with individual data.

Performances of the Stroop color–word test

Results demonstrated a robust Stroop interference in people with ID in terms of error rates, RT, and the interference score. This result is consistent with earlier findings (Das, 1970, 1969; Ellis et al., 1989). Although RT is shorter in the word-reading task than in the color-naming task in typically developing children and adults (e.g., Ikeda et al., 2011), this trend was not observed in people with ID. Some earlier studies demonstrated that RT in the word-reading task is longer than in the color-naming task in groups of ID who included those with lower MA (Das, 1969, 1970). These results point to the inefficiency of reading ability in people with ID who have a lower intelligence.

Relation between task performance and individual data

The results demonstrated that RTs in all three tasks negatively correlated with intelligence, which is consistent with results of earlier studies (Das, 1969, 1970). These results might indicate a relation between the general speed of information processing and intelligence, given that a number of measures of speed of cognitive information-processing correlated with intelligence test scores (Sheppard & Vernon, 2008).

In contrast, the results demonstrated no relation between the interference score and intelligence, as opposed to previous findings with less pure blocked card-like format (Das, 1969) and a suggestion made by the result of an increment of reading ability concomitantly with intelligence. The results obtained in the present study imply that inhibitory control does not correlate with intelligence. In fact, it has been suggested that intelligence scales might not assess inhibitory control to a great degree, although inhibitory control is an important component of intelligent behavior (Friedman et al., 2006). Considering the variation of the interference score, it is important to assess a profile of inhibitory control in people with ID for additional implementation of proper and necessary support. It might be true that people with ID have impaired inhibitory control irrespective of intelligence.

The sample of this study was too small to produce a meaningful conclusion. This insufficiency was partly attributable to an important shortcoming of the Stroop color–word test. Its effectiveness is limited when used with people who have little or no reading ability because it requires well-developed reading skills to elicit the Stroop interference. Future research is expected to investigate inhibitory control using inhibitory tasks that require no reading ability.

In conclusion, results of this study suggest that the general speed of information processing is an important factor of intelligence. Results also suggest that inhibitory control should be assessed along with a standard intelligence scale to implement necessary support for people with ID who have impaired inhibitory control.

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