Title
Working Memory and Persistent Inhibitory Set: An Individual Differences Investigation

Permalink
https://escholarship.org/uc/item/4gh486qg

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 28(28)

ISSN
1069-7977

Authors
Bai, Chen
Iwasaki, Syoichi
Kotozaki, Yuka

Publication Date
2006

Peer reviewed

Working Memory and Persistent Inhibitory Set: An Individual Differences Investigation

Syoichi Iwasaki (siwasaki@cog.is.tohoku.ac.jp)
Cognitive Psychology, Graduate School of Information Sciences
Tohoku University, Sendai, Japan

Yuka Kotozaki
Cognitive Psychology, Graduate School of Information Sciences
Tohoku University, Sendai, Japan

Chen Bai
Cognitive Psychology, Graduate School of Information Sciences
Tohoku University, Sendai, Japan

Abstract

Inhibition of task-irrelevant interference is important component of executive attention. In this study, the participants were divided into high working memory (WM) and low WM groups and the persistent inhibitory task inertia after the Stroop color-naming task was tested by measuring naming latencies for neutral colored stimuli. The high WM group tended to show persistent stronger inertia than the low WM group. It is suggested that the inhibitory control is an involuntary process that is mobilized when attention is voluntarily directed to a task that involves automatic activation of competing responses like the Stroop effect.

Working memory (WM) is an important mental faculty, enabling us to stick to our current task in spite of so many intrusions or allurements. It is believed to be main part of executive control of attention (Engle, 2002). The executive control is, at least partly, made possible by suppressing interferences from task-irrelevant stimulations from surrounding environment. Exclusion of task irrelevant signals is made possible by inhibition exerted on them when we have to concentrate on our task.

That exclusion of irrelevant signals is part of the working memory capacity is demonstrated by the study reported by Conway, Cowan, and Bunting (2001). In this study, these researchers divided their participants into two groups according to their WM capacity and asked them to attend to one message presented to one ear while ignoring another one coming from the other ear. While they were repeating a message (the procedure is called shadowing) presented to the attended ear, their names were presented to the other, unattended ear unknowingly to them. It has been known that an important message like one's own name can break through the barrier set by attention. Thus, about one third of the participants were reported to be able to detect their own name presented to the unattended ear (Moray, 1959). However, when participants were divided into high and low WM groups, 65% of the low WM participants could detect their own name in the unattended message, while only 20 % of the high WM participants did so.

These results suggest that those with high WM capacity are less vulnerable to the task-irrelevant intrusions from both outside world and from within their own mind (Teasdale, Dritschel, Taylor, Proctor, Lloyd, Nimmo-Smith, Baddeley, 1995).

What is less clearly understood is whether inhibition is a voluntary process under the control of executive attention or it is an automatically mobilized by-product beyond its control. For example, when they attend to one ear, do people impose inhibitory barrier to the other ear by their own voluntary control? Or is it automatically set in place when they voluntarily attend to the message presented to the attended ear?

In this study, we explored this issue of voluntariness of the inhibitory control using the inhibitory task set inertia. The inhibitory task set inertia is the persistent residual cost that accompanies task switch (Wylie and Allport, 2000). Task switch is a manifestation of executive control encountered when one task is switched to another, like the one you undergo when you respond to phone-call during writing sentences with word processor. Just after the switch, performance of the new task declines usually for a short period after the switch. Eventually it will return to the level of operation performed before such a switch. However, there is a residual effect of inhibition lasting much longer than the usual task switching cost. This is called the task-set inertia and ascribed to proactive interference arising from the performance of a prior, competing task (Wylie and

Allport, 2000). Thus, when participants switched from highly interfering color-naming task in the Stroop task (Stroop, 1935) to word reading task that usually causes little interference, there was found a large word-reading performance decline (called reverse Stroop effect that does not occur for the usual word reading task), which lasted for several trials.

If inhibitory task-set is under voluntary control, then people with high WM capacity (that is, those with high executive control capacity) would show less inhibitory inertia than those with low WM capacity. On the other hand, if inhibitory task-set is an involuntary component of executive attention, it may be predicted that those with high WM capacity would show higher inhibitory inertia after the task switch, resulting in less efficient performance after the task switch.

Another issue explored in this study is the stage or mechanism of inhibitory inertia. Since in the Stroop task automatic tendency to read color-words is the target of inhibition, there are several ways of doing so. One possibility is to inhibit perceptual processing of the stimulus itself. In the conventional compound Stroop stimuli in which words themselves are colored and the participants are asked to name the color of the words, however, it seems difficult to selectively inhibit perceptual processing of words without at the same time inhibiting processing of colors.

Another possibility is to inhibit semantic processing of words. If semantic processing of words can be voluntarily suppressed, color words would become neutral stimuli like a string of X's. Through post-hypnotic suggestion it was demonstrated that such a suppression of semantic processing could be achieved (Raz, Landzberg, Schweizer, Zephrani, Shapiro, Fan, & Posner, 2003). Therefore, it was hypothesized that if participants would have tried to suppress semantic processing of color-words the suppression would produce graded inhibitory effect on semantic processing of words with higher inhibitory effect found for the color words used in the Stroop task, followed by their semantic associates and by concrete words and so on, just has been the case for the Stroop interference effect itself (Klein, 1964). To check this point, we used three types of non-Stroop stimuli (i.e., concrete non-color words, abstract words, and non-words or icons; see Method for the details).

A third possibility is general slowing of response execution. In this case, response execution that follows perceptual processing is delayed until checking of appropriate response selection is over. Thus, general slowing would be found irrespective of the type of the non-Stroop stimuli.

Method

Participants

The participants were 61 undergraduate students of Tohoku University. They were native Japanese speakers. All were right-handed and had normal color vision. They were paid for their service.

Working memory task

Reading span was used to measure WM capacity. In this task, the participants were shown sentences one by one. In each sentence there was a word that was marked with a red underline. They were asked to remember the underlined words while reading each sentence. After two to 5 sentences were read, they were asked to repeat the underlined words. Working memory capacity was measured as the total number of words they could recall.

The switch task

The task switching occurred between the Stroop color naming and neutral (i.e., non-color words and icons) color-naming tasks. In the Stroop color-naming task, the participants named the color used for printing words. The words themselves were color words. In the present study four colors (red, green, blue, yellow) were used. In the neutral color task, non-color Kanji words and icons were shown one by one and the participants were asked to name the colors of these stimuli.

In the Stroop task, words were either congruent with the meanings of the words or incongruent with them (i.e., 50% incongruence). When word meanings were different from the colors naming latency is known to slow down. This is the Stroop effect. When the colors and words are congruent, the naming latency is reduced somewhat relative to a control condition (usually non-word stimuli like repeated symbols were used as neutral stimuli). In this study, the difference between these two conditions was taken to be the amount of the Stroop interference.

In the neutral color condition, words were non-color terms or icons (taken from the Wingdings font of Windows XP). There were two non-color word categories, one being composed of concrete words and the other, of abstract words. All the words (6 for each category) were one-character Kanji words. The concrete words were the Kanji characters corresponding to ear, river, dress, *Koto* (a Japanese musical instrument), brush, and twig in English. The abstract words were truth, righteousness, courtesy, wisdom, model, and charity. The colors to be named were the same four colors as the Stroop condition.

In this "switching" task, the responses made by the participants were always that of naming colors. Only the types of words changed between the conventional Stroop block that included trials with both congruent and incongruent color-words and the non-Stroop block that was composed of trials with non-color related Kanji words and icons.

Procedure

The participants were individually tested. They underwent three types of tasks. The results of the two of these tasks (WM and task switching) were reported here. The third task was a verbal fluency task, which was adopted for other purpose and will not be described here. The order of the tasks was counterbalanced among the participants.

The switching task consisted of two parts. The initial part was the neutral color task and was adopted for obtaining base-line color-naming latencies. After this base-line task, the switching part followed. In this switching part, the Stroop and the neutral-color blocks alternated with each other. This part started with the 8-trial Stroop block, which was followed by 12-trial neutral-color block. The start of each block was indicated by the cues ("Stroop condition" for the Stroop block, "non-Stroop condition" for the neutral color block). These blocks alternated with each other for ten times.

The experiment was conducted with an IBM compatible computer with 17-inch monitor. The monitor stood 57 cm in front of the participants. Naming responses were digitally recorded through microphone attached to a headset as Windows WAV files with the program that controlled the experiment. The voice onset latencies were determined later with another program that read the WAV files and searched for the waves that corresponded to the naming responses to calculate the latencies.

Results

The participants were divided into two groups (30 for each group) according to their WM scores. One participant who corresponded to the median was excluded from further analyses.

The Stroop effect

Two-way ANOVA with the between-group factor of WM capacity (high versus low WM groups) and the within-group factor of the Stroop condition (congruent versus incongruent conditions) was conducted on the naming latencies. As expected, the well-known Stroop effect was confirmed with highly significant RT differences between the congruent and incongruent conditions (F (1, 58) = 155.2, p < .001). Although there were no WM group differences in the naming latencies (F (1, 58) = 2.13, p. > 0.1), the expected better performance for the high WM group was found for the number of intrusions with more errors committed for the incongruent condition. The mean number of errors for the incongruent condition was 1.8 for the high WM group and 3.0 for the low WM group. Thus, for the number of errors the main effect of the group was significant (F (1, 58) = 5.41, p < .05) with marginally significant interaction (F (1, 58) = 3.45, p = .068) between the group and the Stroop condition. Thus, the high WM group participants were less susceptible to the intrusions of irrelevant words than the low WM group.

The switching effect

Three-way ANOVA with the between-group factor of WM capacity and the two within-group factors of stimulus category (icons, concrete words, and abstract words) and the Stroop inertia (base-line neutral color-naming block versus neutral color-naming blocks after the Stroop switch) was conducted on the naming latencies. There was a significant difference in the naming latencies between the WM groups with slower responses for the high WM group relative to those for the low WM group (F (1, 58) = 6.94, p < .05). Both the Stroop experience and the word type conditions significantly affected the naming latencies (F (1, 58) = 45.47, p < .001 for the Stroop experience; F (2, 116) = 35.81, p < .001 for the stimulus category). Thus, the type of the neutral words affected color-naming latencies. This finding was in accordance with a classical result reported by Klein (1964). More importantly, the significant main effect of the Stroop experience indicates that after experiencing the Stroop condition the participants slowed down their naming responses, perhaps due to the inhibitory inertia carried over from the preceding Stroop block.

As may be seen in Figure 1, the high WM group tended to show larger inertia effect. Mean increases of the naming latencies (i.e., differences between the base-line and the post-Stroop block latencies) of the high WM group were 61, 71, and 72 msec for the icon, concrete word, and abstract word stimuli respectively, whereas for the low WM group they were 26, 49, and 44 msec. Two-way ANOVA (WM group and Stroop condition) for the difference data indicated marginally significant main effect of the WM group (F (1, 58) = 3.11, p < .1) in addition to the stimulus category (F (2, 116) = 4.80, p. < .01). The interaction between these factors was not significant (F (2, 116) < 1.0).

That WM capacity is related to the inhibitory inertia was further confirmed with the correlation analyses between WM scores and the naming

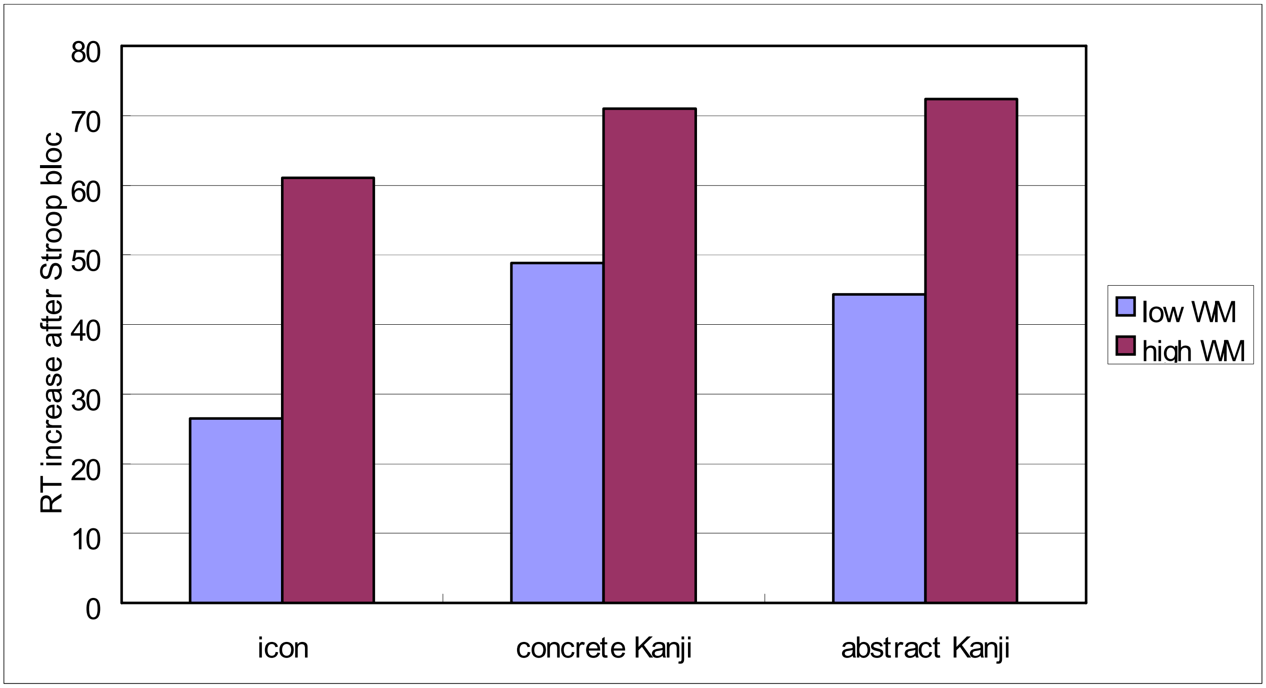

Figure 1: RT increases after introduction of the Stroop block

latencies. As shown in Table 1, the WM scores significantly correlated with naming latencies only after the Stroop blocks. In contrast to the post-Stroop blocks the base-line naming latencies did not correlate with the WM scores.

Visual inspection of the trial-by-trial average data suggested that the amount of the inertia was relatively constant across non-Stroop block. However, since the non-Stroop block randomly contained three types of stimuli (i.e., concrete Kanji words, abstract Kanji words, and icons), no formal statistical anaylis was performed.

Table 1: Correlation coefficients (N = 61) between WM scores and naming latencies of non-color words.

	stimulus type	
icon	concrete Kanji	abstract Kanji
base-line naming latencies		
0.12	0.06	0.09
after Stroop block		
0.29*	0.24 *	0.26*

* : p < .05

Discussion

The present study investigated the question of whether the inhibitory task set mobilized by the executive attention (as reflected in the WM capacity) can be cancelled immediately after it ceased to be of use. It was found that the participants (especially those with high WM capacity) could not do so for some period (over more than 10 trials). The naming latencies could not return to the base-line level once they were exposed to the Stroop interference effect. The high WM participants could successfully suppress irrelevant responses from entering into their response selection stage with a result of fewer intrusion errors. However, the inhibitory set activated during the Stroop task, even if it could be voluntarily turned on, could not be turned off immediately after the task.

It may be argued that the persistent inhibitory set was a result of the particular task switch condition used in the present study. Actually it is possible to argue that there was no task switch involved in the present study because the required responses were always naming the stimulus colors. In the original study of the inhibitory inertia (Wylie and Allport, 2000), task switch did involve the change in response types with response being switched from color naming to word reading. However, it did not abolish the inertia. So it is unlikely that the lack of response switch was the sole reason for the persistent inertia found in the present study.

Another objection may argue that the reason why the high WM participants showed higher inhibitory inertia was simply due to the lack of necessity for them to turn off the inhibitory set because the non-Stroop task was still somewhat interfering, especially when they responded to the concrete and abstract words, which were found to be slower in response than the icons. This argument, however, assumes that the non-Stroop condition used in this study was felt to be interfering by the participants, especially those with high WM capacity. If they could sense the interference during the non-Stroop base-line condition, they would have activated the inhibitory set during the first encounter. This would have made the RT increases after the introduction of the Stroop block minimal, especially for those who had high WM capacity. Furthermore, there was significant correlations between the naming latencies and WM capacities only after the introduction of the Stroop block (see Table 1). These results and the subjective impression we got during being run under the non-Stroop condition that the non-Stroop conditions were not interfering suggest that the non-Stroop condition could be clearly distinguishable from the Stroop condition in terms of amount of interference. Therefore, the participants, especially those with high WM capacity, could have taken advantage of this difference and would have turned off the inhibitory set voluntarily, if they could do so. The fact that they could not do so suggests that the turning-off of the inhibitory set was not under the voluntary control of the executive attention.

In a recent study (Kane and Engle, 2003), Kane and Engle suggested that there are two processes involved in the Stroop interference. One is goal maintenance, failure of which is responsible for momentarily lapse of attention leading to intrusion errors. And the second process is competition resolution, which is responsible for latency increase in the incongruent condition. They pointed out that two processes were under the influence of task set. Thus, when participants first tested under all-incongruent condition, WM capacity did not differentiate error rates but it was correlated with response latencies. However, when the high-congruent condition in which 75% trials were congruent and the remaining 25% were incongruent ones was the first one tested in the experiment, WM capacity was related to the error rates, implying that low WM led to the failure of goal maintenance. This was attributed to the fact that in the high-congruent condition there were only sporadic incongruent trials scattered among mostly congruent ones, which would have made it difficult to maintain the goal of suppressing irrelevant responses to words, especially among low-WM participants. The goal maintenance was made easier for the low WM participants by their preceding experience of the all-incongruent condition.

The task set effect found in their study may be related to the task switch inertia found in this study. Both seem to be automatic in that they are outside of the executive control, being set when experiencing a highly interfering task. There is a difference, however. The task set of Kane and Engle affected the low WM participants by helping them maintain task goal in their working memory and contributed to reducing errors, while the task switch inertia induced inhibitory set among high WM participants leading to slower response latencies. Perhaps, the task set of Kane and Engle may be a long-term effect, whereas the task switch inertia in this study may be a short-term effect. Clarification of this point needs further research efforts.

Another point to note was the inhibitory stage or mechanism. Initially, we assumed that the inhibition of the processing of words was achieved at the semantic stage. However, the inhibition seems not to be exerted at this stage since there were no graded increases in RT across the non-Stroop stimuli (see Figure 1), although, it may be still possible to argue that inhibition was exerted at the semantic processing stage, but the inhibition was a general, non-selective one, suppressing extraction of word meaning irrespective of the distance from the color-words used in the experiment.

Acknowledgment

A part of this work was carried out in the Kansei Fukushi Research Center of Tohoku Fukushi University, Sendai, Japan, supported by “Academic Frontiers” Project for Private Universities : matching fund subsidy from the Ministry of Education, Culture, Sports, Science and Technology（2004～2008）.

References

Conway, A.R.A., Cowan, N., & Bunting, M.F. (2001) The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review*, *8*, 331-335.

Engle, R.W. (2002) Working memory capacity as executive attention. *Current Directions in Psychological Science*, *11*, 19-23.

Kane, M.J. and Engle, R.W. (2003) Working-memory capacity and the control of attention: The contribution of goal neglect, response competition, and task set to Stroop interference. *Journal of Experimental Psychology: General, 132*, 47-70.

Klein, G.S. (1964) Semantic power measured through the interference of words with color-naming. *American Journal of Psychology*, *77*, 576-588

Moray, N. (1959) Attention in dichotic listening: Affective cues and the influence of instructions. *Quarterly Journal of Experimental Psychology*, *11*, 56-60.

Raz, A., Landzberg, K.S., Schweizer, H.R., Zephrani, Z.R., Shapiro, T., Fan, J., & Posner, M.I. (2003) Posthypnotic suggestion and the modulation of Stroop interference under cycloplegia. *Consciousness and Cognition, 12*, 332-346.

Stroop, J.R. (1935) Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*, 643-662.

Teasdale, J.D., Dritschel, B.H., Taylor, M.J., Proctor, L., Lloyd, C.A., Nimmo-Smith, I., & Baddeley, A.D. (1995) Stimulus-independent thought depends on central executive resources. *Memory and Cognition*, *23*, 551-559.

Wylie, G. & Allport, A. (2000) Task switch and the measurement of "switch costs" *Psychological Research*, *63*, 212-233.