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Reaction Time Analyses of Repetition Blindness

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Abstract

Repetition blindness (RB) usually refers to the inability to detect or recall a repeated item as opposed to an unrepeated item in rapid serial visual presentation (RSVP). Using a category counting task (i.e., to count how many times a given category appears in an RSVP list), Experiment 1 found RB for repeated Chinese characters in RSVP lists. In Experiment 2, subjects were required to respond only to the second occurrence of a given category in RSVP lists. RB occurred under the fast display rate (117ms/item) but not under the slow rate (200ms/item). Moreover, longer response latencies were found in the repeated condition relative to the unrepeated condition under the fast rate, whereas a reverse pattern was shown under the slow rate. Implications of the present methodology and findings on the processing of repeatedly presented stimuli are discussed in the paper.

Introduction

In recent years, there has been an increasing interest in the study of the way in which identical stimuli are processed and recognized in the visual system. This interest was largely stimulated by the work of Kanwisher (1987) on repetition blindness (RB), which refers to the failure to detect/recall repetitions of stimuli in rapid serial visual presentation (RSVP).

RB has been shown to be a reasonably robust phenomenon. However, in addition to the unsuccessful responses to repeated stimuli in the conditions in which an RB effect is typically observed, there is actually a substantial amount of successful response in the same conditions. It is therefore surprising that the nature of the successful responses in various RB-induced conditions has not been systematically investigated. Is this because the occurrence of RB is assumed to be an all-or-none phenomenon (i.e., a repeated item can occasionally be normally processed just like an unrepeated item and leads to a successful response, but it can also not to be properly processed and results in a case of failure)? If so, then it is critical to ask why, in the same condition when the repeated stimuli are presented, some responses can be done successfully, while others cannot. The answer(s) to these important questions are not readily available, because these issues have not been discussed or addressed, at least not explicitly, in the RB literature.

One way to verify whether RB is an all-or-none phenomenon or not is to compare the successful responses to the repeated stimuli and those to the unrepeated ones. If the two types of response are highly comparable, then it is plausible that RB is all-or-none. If not, the repeated and unrepeated stimuli may be processed differently. However, most, if not all, of the past research on RB have measured the effect in terms of accuracy (e.g., Armstrong & Mewhort, 1995; Bavelier, 1994; Kanwisher, 1987; Kanwisher & Potter, 1989; Luo & Caramazza, 1996; MacKay & Miller, 1994) or sensitivity (e.g., Fagot & Pashler, 1995; Hochhaus & Johnston, 1996; Kanwisher, Kim, & Wickens, 1996; Park & Kanwisher, 1994). In other words, the focus of prior research has been on the unsuccessful responses to the repeated stimuli and therefore can not inform us about the comparability of the two types of successful responses in the RB-induced conditions.

To our knowledge, there is only one research in the RB literature that has collected reaction times as the dependent variable (i.e., Whittlesea, Dorken, & Podrouzek, 1995, Experiments 3a-3d). In the experiments of Whittlesea et al., subjects had to name the final word in an RSVP list and indicate whether or not it was repeated in the list. These experiments therefore seem to have the potential to inform us about the comparability of the successful responses to the repeated stimuli and those to the unrepeated ones. Unfortunately, none of the experiments demonstrated an RB effect in errors. Hence, it is doubtful whether or not the results in these experiments can be generalized to those in other studies that have shown the RB effect. Moreover, the reaction time (RT) data in the study of Whittlesea et al. did not show consistent results, probably because the four experiments varied in more than one aspect (e.g., the way in which the last item in a list was presented, the display duration for the last item, and the display duration for other items). Thus, it is reasonable to conclude that the question of whether or not the successful responses to the repeated stimuli and those to the unrepeated ones in the typical RB research are qualitatively the same has not yet been directly or systematically investigated.

We report here two experiments designed to investigate how visually presented identical stimuli are processed. Unlike most RB studies, we focus especially on successful responses to the repeated stimuli in an attempt to address whether or not RB is an all-or-none phenomenon. This was done by applying reaction time analyses to a RB task. Furthermore, unlike other RB research with verbal materials, which typically use English as the stimuli, logographic Chinese was used in the experiments presented below to see if RB would generalize to a distinctively different writing system.

Experiment 1

The first experiment examines whether RB can be demonstrated using a category counting task in which subjects were asked to report how many times a specific category (i.e., animal) occurs in an RSVP list. The reason we adopted this task to study RB but not the typically used recall task (i.e., to recall all the items in an RSVP list after the list is displayed) is because the recall task puts a relatively large demand on subjects' memory and can presumably be affected by the retrieval stage of operations, whereas the category counting task demands less off-line retrieval and more on-line processing of the repeated stimuli.

The second goal of the experiment is to investigate whether RB can be generalized to logographic Chinese (for reviews of language processing in Chinese, see, e.g., Chen, 1996). Note that the Chinese orthography is constructed mainly on the logographic principle, that is, the characters basically represent morphemes. This drastically contrast with the alphabetic principle that symbols (i.e., letters) are made essentially to correspond to basic units in speech, that is, phonemes. Since it has been shown that script differences can affect relevant lexical processing and memory (e.g., Chen & Juola, 1982; Frost, Katz, & Bentin, 1987; Simpson & Kang, 1994), it is essential to demonstrate RB for Chinese in RSVP before we can move on to study other aspects of the effect using Chinese characters as stimuli.

Finally, all the items in the present experiment were presented using two different rates (i.e., 117 and 133 ms per item). Both of these rates have been frequently used in prior RB research and were therefore adopted to examine which could more reliably demonstrate an RB effect in Chinese.

Materials

Each stimulus consisted of an RSVP list of six Chinese characters. There were altogether 240 experimental trials: 80 containing only non-target characters, 80 containing one target (a character representing an animal), and 80 containing two targets. In addition to the experimental trials, there were also 30 practice trials. The experimental trials containing two targets were further divided into two subgroups (i.e., repeated vs. unrepeated), with 40 trials in each. The first and second targets (T1 and T2) appeared in either the 2nd and 4th or 3rd and 5th serial positions, respectively. Five animal characters (i.e., translation equivalents of dog, fish, mouse, horse, and chicken in Chinese) were used as targets in the experiment, whereas the non-animal characters (frequency range=100-400 per million) were selected from a Chinese corpus (Hong Kong Education Department, 1986).

Subjects and Procedure

Fourteen students at the Chinese University of Hong Kong were tested individually in the experiment; all were native speakers of Cantonese with normal or corrected vision. They were instructed (1) to count the number of characters representing an animal in each RSVP list, regardless whether or not the character was repeated in the list; (2) each list could contain up to two target characters; and (3) after the display of each list they had to type their response into the computer keyboard. For half of the subjects, all characters in the experimental trials were displayed at a rate of 117 ms per item, whereas for the other half, all were displayed at 133 ms per item. To familiarize the subjects with the procedure, all items in the practice trials were shown for 300 ms. All trials were displayed with a black background on a VGA monitor. Stimulus presentation and data collection were controlled by a PC486 computer.

Results and Discussion

The results as shown in Table 1 are clear-cut. There is a significant repetition effect for the stimuli containing two targets, $F(1, 12)=4.85$, $p<0.05$. The lists with two repeated targets were more likely to be judged as containing only one target than those with two unrepeated targets. Moreover, more counting errors tended to be made under the 117-ms display rate than under the 133-ms rate. However, the difference between the two conditions was not statistically significant, $F(1,12)=3.09$, $p=0.10$. No reliable interaction between display duration and repetition was found ($F<1$). Finally, the mean error rates for the no-target condition and the one-target condition were 1.8% and 1.7%, respectively.

Display duration	Repeated	Unrepeated
117ms	7.2%	4.4%
133ms	2.6%	0.7%

Table 1: Percentage of trials in which subjects detected one target in the two-target lists as a function of repetition status and character display duration in Experiment 1.

Given that an RB effect has been successfully demonstrated by adopting the category counting task, which has relatively small demand on memory, the results are in line with the notion that the locus of RB is not likely at the storage or retrieval stage (e.g., Kanwisher, 1987; Luo & Caramazza, 1995). The present findings also indicate that RB can be generalized to Chinese stimuli. We can therefore proceed with reasonable confidence to the study of whether or not RB is an all-or-none phenomenon, under the assumption that the kind of task and stimuli used here are comparable with those in previous RB research.

Experiment 2

The category counting task adopted in Exp. 1 was modified in order to apply reaction time analyses to study RB in the second experiment. This was done by asking subjects to respond only to the second occurrence of an animal category in RSVP lists. Note that this modified task not only enables us to obtain immediate, on-line responses to the repeated stimuli, it also allows us to compare directly the successful responses to both the repeated and unrepeated targets.

If RB is an all-or-none phenomenon, then response latencies to the repeated stimuli should be comparable to those to the unrepeated ones. If, on the contrary, processing difficulties induced by a repeated stimulus are not all-or-none, successful responses to the repeated targets should take longer to make than those to the unrepeated ones.

The stimuli in the present experiment were displayed at two different rates. A fast display rate (117 ms per item) was adopted because, based on the results of Exp. 1, it could generate a reliable RB effect. However, this rate of stimulus presentation was relatively fast, because in normal reading situations the average fixation duration is about 250 ms in English (Rayner & Pollatsek, 1989) and approximately 190 or 220 ms in Chinese (Inhoff & Liu, in press). In order to explore how the repeated stimuli is processed in a situation which more closely resembles conventional reading, a relatively slow rate of stimulus display (200 ms per item) was also included in the second experiment.

Materials, Subjects and Procedure

The experimental materials were basically the same as those in Exp. 1, except that the experimental trials included only those lists which contained one or two targets. In addition to the 160 experimental trials, there were also 16 practice trials.

Twenty subjects from the same population participated in the experiment; none of which had taken part in Exp. 1. They were instructed to respond only to the second occurrence of any character representing an animal in RSVP lists by pressing the space key on the keyboard as quickly and accurately as possible. Other aspects of the procedure were the same as those in Exp. 1.

Results and Discussion

Both response latencies (for correct trials only) and errors to the second occurrence of the given category were analyzed as for Exp. 1. In the error analysis, both main effects and the two-way interaction were significant at $p<0.05$: For repetition status, $F(1, 18)=24.67$; for display rate, $F(1,18)=15.62$; for the repetition x rate interaction, $F(1, 18)=24.91$. The reaction time analysis revealed basically the same pattern, but only the two-way interaction achieved the fixed level of significance: $F(1, 18)=17.12$. The results, as summarized in Figure 1, are straightforward.

Again, as in Exp. 1, there was a reliable RB effect in errors under the fast display rate, $t(9)=4.97$, $p<0.05$. More importantly, as shown in Fig. 1, the repeated targets were also responded to more slowly as compared to the unrepeated targets under the fast display rate, $t(9)=2.69$, $p<0.05$. These results indicate clearly that RB is not an all-or-none phenomenon. The repeated stimuli apparently created some general processing difficulties in the visual system when the display rate was relatively fast. Hence, even when a repeated item is successfully recognized, longer processing time is needed relative to an unrepeated item. Furthermore, because the task used in the present experiment requires minimum memory load, the results indicate that RB is not likely due to the retrieval stage of operations.

Another striking finding of the present experiment was the enhanced performance in response to a repeated target as opposed to an unrepeated one under the relatively slow rate of stimulus presentation. As also shown in Fig. 1, when the stimuli were displayed at 200 ms per item, the repeated targets were responded to faster than those unrepeated ones, $t(9)=2.93$, $p<0.05$. A similar trend was also found in the errors, though the difference between the repeated and unrepeated conditions did not reach significance. These results stand in interesting contrast to findings of Exp. 1 and to those in prior RB research in which relatively fast rates of stimulus display were typically used, indicating that stimulus exposure duration is an important determinant in processing repeated stimuli.

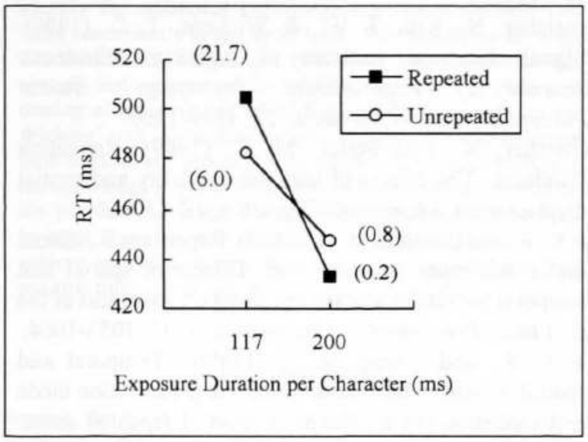

Figure 1: Mean response times (RTs) and percentages of error (in parentheses) as a function of repetition status and character display duration in Experiment 2.

It is worth noting that there are at least three factors underlying the manipulation of stimulus display rate in the present experiment, namely the exposure duration of the first target, the exposure duration of the second target, and the time lag between the two targets (i.e., the two targets were constantly separated by one intervening item in the experiment). It is not clear whether these factors could have independently or jointly contributed to the different findings found in the present experiment under different display rates. The possible effects of these factors on processing repeated stimuli are currently being examined in our laboratory.

Conclusions

The critical result is that we have obtained clear evidence that the successful responses to repeated stimuli are markedly different from those to unrepeated ones in an RB-induced situation (i.e., the former cases need more time to be done than the later), indicating that the effect is not an all-or-none phenomenon. It appears that, under a relatively fast display rate, a repeated item can possibly create problems to the visual system and may therefore not be recognized at all or it would need extra time to be processed.

The present results also provide new challenges to some of the hypotheses proposed to account for RB. For instance, the RB effects found in present studies with on-line tasks under minimum memory demand are hard to explain on the basis of those hypotheses which propose that memory load and/or retrieval operations are critical in producing the RB effects (e.g., Armstrong & Mewhort, 1995; Fagot & Pashler, 1995). In addition, our findings are not in line with the hypothesis that whether or not a repeated item would produce a priming or blindness effect is determined by the encoding effectiveness of the first occurrence of the item (e.g., Luo & Caramazza, 1995). This is because even the minimal display rate adopted in our experiments (i.e., 117ms per item) should be enough to allow the first occurrence of a character to be encoded. In fact, it has been shown that people can comprehend sentences and short passages at rates of 720 words per minute (i.e., about 83 ms per word; Potter, Kroll, & Harris, 1980). Hence, the encoding effectiveness of the first occurrence of a repeated item is not likely to be responsible for the priming and blindness effects demonstrated in Exp. 2 (for a similar conclusion and additional evidence, see Wong & Chen, this volume).

Moreover, can the observed RB results be explained in terms of response inhibition? Specifically, in Exp. 2, the subjects might need to inhibit a response to the first occurrence of a particular target item, but they were instructed to respond rapidly to the same item during its second occurrence. At short exposure durations this effect, if existed at all, could be more pronounced since the time intervals between presentations were reduced. We do not think this is the case because this sort of response inhibition hypothesis can simply not explain the RB results obtained in Exp. 1, in which no response was needed to be made before reaching the end of an RSVP list.

The present results further indicate that RB can be generalized to a rather unique writing system, namely Chinese. To our knowledge, our research is the first that has examined and demonstrated RB in Chinese. Our results, in conjunction with others using distinctively different types of stimuli, indicate collectively that RB is a very robust phenomenon and that the mechanisms underlying it are likely to be universal.

Apart from the theoretical concerns mentioned above, our methodology also has implications for studying how the repeated stimuli are processed. Foremost, the category counting/monitoring tasks adopted in the present experiments are valid and useful research tools in the sense that they are capable of generating reliable RB effects and can enable us to directly investigate the on-line processing of a repeated stimulus with minimum memory load.

Moreover, our methodology allows researchers to gather both errors and response latencies in processing repeated stimuli and can therefore provide additional and possibly more meaningful information (than just having the error/accuracy data) to the understanding of how repeated stimuli are processed. Applying reaction time analyses to study repetition blindness/priming is particular useful in those situations where error data can not effectively differentiate various conditions in a research.

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