i-PERCEPTION

a Pion publication

i-Perception (2012) volume 3, pages 495–498

dx.doi.org/10.1068/i0509sas ISSN 2041-6695 perceptionweb.com/i-perception

SHORT AND SWEET

Prevalence effect in haptic search

Kazuya Ishibashi*
Department of Psychology, Kobe University, Nada-ku, Kobe, Japan; e-mail: isibasi@lit.kobe-u.ac.jp

Ken Watanabe
Graduate School of Science and Technology, Niigata University, Nishi-ku, Niigata, Japan; e-mail: f10c125j@mail.cc.niigata-u.ac.jp

Yutaka Takaoka
Kobe University Hospital, Chuo-ku, Kobe, Japan; e-mail: ytakaoka@ebraille.med.kobe-u.ac.jp

Tetsuya Watanabe
Faculty of Engineering, Niigata University, Nishi-ku, Niigata, Japan; e-mail: t2.nabe@eng.niigata-u.ac.jp

Shinichi Kita
Department of Psychology, Kobe University, Nada-ku, Kobe, Japan; email: kita@lit.kobe-u.ac.jp

Received 15 February 2012, in revised form 12 July 2012; published 31 July 2012.

Abstract. In visual search tasks, the ratio of target-present to target-absent trials has important effects on miss rates. In this study, we examined whether the target prevalence effect occurs in a haptic search task by using artificial tactile maps. The results indicated that target prevalence has effects on miss rates, sensitivity, and criterion. Moreover, an increase in miss rates in the low-prevalence condition (10%) was strongly correlated with a decrease in search termination times (target-absent reaction times). These results suggest that the prevalence effect on haptic search is caused by a decrease in the search termination time and a shift in decision criterion and a decrease in sensitivity.

Keywords: haptic search, prevalence effect, search termination time, criterion, sensitivity.

In our daily lives, we commonly perform haptic searches when we reach into our pockets to take out our keys, for instance, or if we try to find our iPhones in our bags. In laboratory haptic search experiments, participants usually perform dozens of search trials in which targets are presented 50% of the time. However, the ratio of target-present to target-absent trials (target prevalence) in socially important haptic search tasks (e.g., security searches at the airport) is typically much lower than it is in laboratory haptic search tasks.

In visual search tasks, target prevalence affects miss rates. We are more likely to miss (or a fail to detect) a target when a target is presented rarely than frequently, such as in airport security or medical screening tasks. This phenomenon is termed the "prevalence effect" (Wolfe, Horowitz, & Kenner, 2005). Previous research has demonstrated that miss rates are far higher for 6% target prevalence than for 50% prevalence when participants search for dangerous items (e.g., a gun or a knife) in displays similar to baggage X-ray displays (Ishibashi, Kita, & Wolfe, 2012). Thus, rare items are often missed in visual searches, but it is not clear whether the same is true for haptic searches.

In the current study, we tested whether the target prevalence effect occurs in haptic searches. We compared performance in low- (10%) and high- (50%) prevalence versions of an artificial tactile map task. Tactile maps are read with the fingers, and we made a laboratory version of tactile maps by using the Tactile Map Automated Creation System (Minatani et al., 2010). The tactile maps were constructed using small dots, as in the Braille reading system, and we set a small circle (9.0 mm) of dots as the target. Figure 1 shows a sample tactile map.

In the experiment, 20 sighted people (ages 19–27 years, mean age = 22.7 years, *SD* = 2.1 years; 8 women, 12 men), who had never touched a tactile map, were tested in the 10% and 50% conditions. By self-report, they had no muscle or haptic disorders. After 90 training trials, each participant was tested for 80 trials (broken into 10-trial blocks) in the 10% and 50% conditions. The experimental block

*Corresponding author.

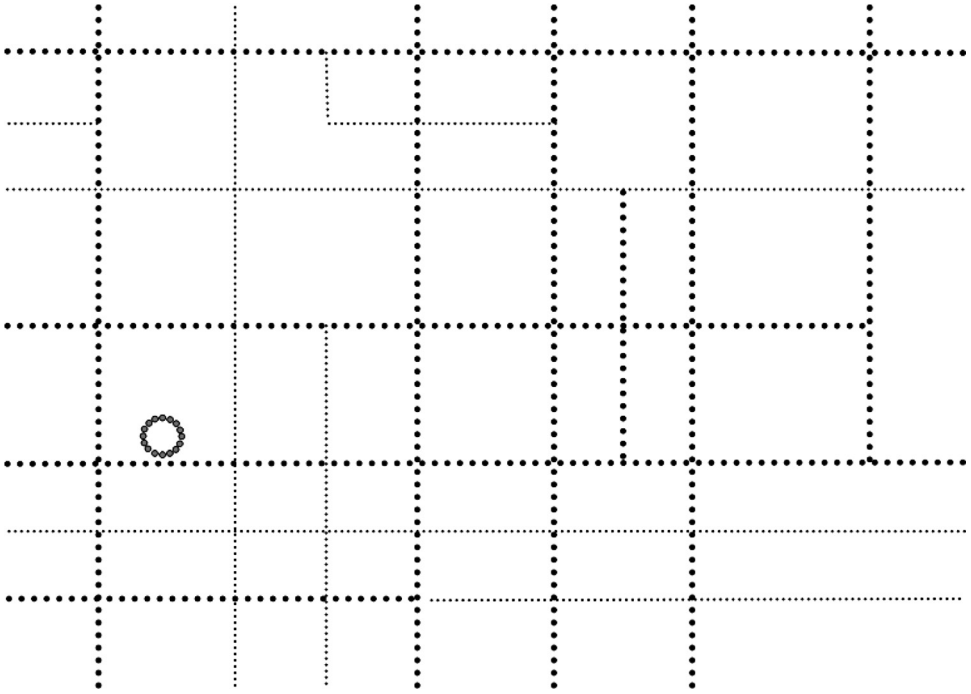

Figure 1. An example of an artificial tactile map used in this experiment. The roads were constructed with 1.5 and 1.7 mm dots, as in the Braille reading system. The target was the small circle of dots (9.0 mm).

order was counterbalanced across participants. Participants wore blinders, and for each trial, they clicked the left mouse button to indicate target presence and another button if they felt there was no target. They searched for the target using only the index finger of their dominant arm. They were allowed to slide their finger freely across the map. They received accurate feedback after each trial. Three and 39 trials were removed for below 1 and over 100s, respectively. Thirty of 39 removed trials for over 100 s were committee by three participants, and outliers of the three participants exceeded 5% of their trials, so we removed their data for analysis.

Figure 2 shows the results for this experiment. The miss rate in the 50% prevalence condition was 12% whereas the miss rate in the 10% prevalence condition was 22%. It indicated that miss rates increased as prevalence decreased [$t(16) = 2.95$, $p = .01$]. False alarm rates, RT for target-present trials, and RT for target-absent trials did not show significant differences between 10% and 50% prevalence conditions [$t(16) = 1.66$, $p = .12$ for false alarm rates; $t(16) = 0.42$, $p = .68$ for RT for target-present trials; $t(16) = 0.05$, $p = .96$ for RT for target-absent trials]. Sensitivity (d') decreased as target prevalence decreased [$t(16) = 2.53$, $p = .02$]. Criterion (C) increased as target prevalence decreased [$t(16) = 4.74$, $p < .01$]. These results suggest that the prevalence effect in haptic search was partly due to a decrease in sensitivity and to a shift in a decision criterion related to search termination.

A previous study suggests that target prevalence influences two parameters (Wolfe & Van Wert, 2010): the decision criterion governing the series of perceptual decisions about each attended item, and the quitting threshold that governs search termination times. Wolfe and Van Wert suggest that both of these parameters influence miss rates. To test whether or not search termination time influences miss rates, we calculated the change in miss rate (miss rate in 10% − miss rate in 50%), search termination time (search termination times in 10% − search termination times in 50%). The panel in Figure 2d shows the correlation between miss rates and search termination times (RT for correct rejection trials). The increase in miss rates in the 10% condition was strongly correlated with the decrease in search termination times ($r = –.51$, $p = .038$). This result suggests that the prevalence effect on haptic search was partly caused by a change in the quitting threshold.

In this study, we found the prevalence effect for a haptic search task. Prevalence effect in haptic search has some similarities to target frequency effect in the vigilance literature (e.g., Baddeley & Colquhoun, 1969). If the increase in target misses in the low-prevalence block is mainly caused by failures of vigilance, we would expect that participants are more likely to miss a target as time goes on. To examine the vigilance effect on miss rate, we did further analysis about the miss rate. We conducted 2

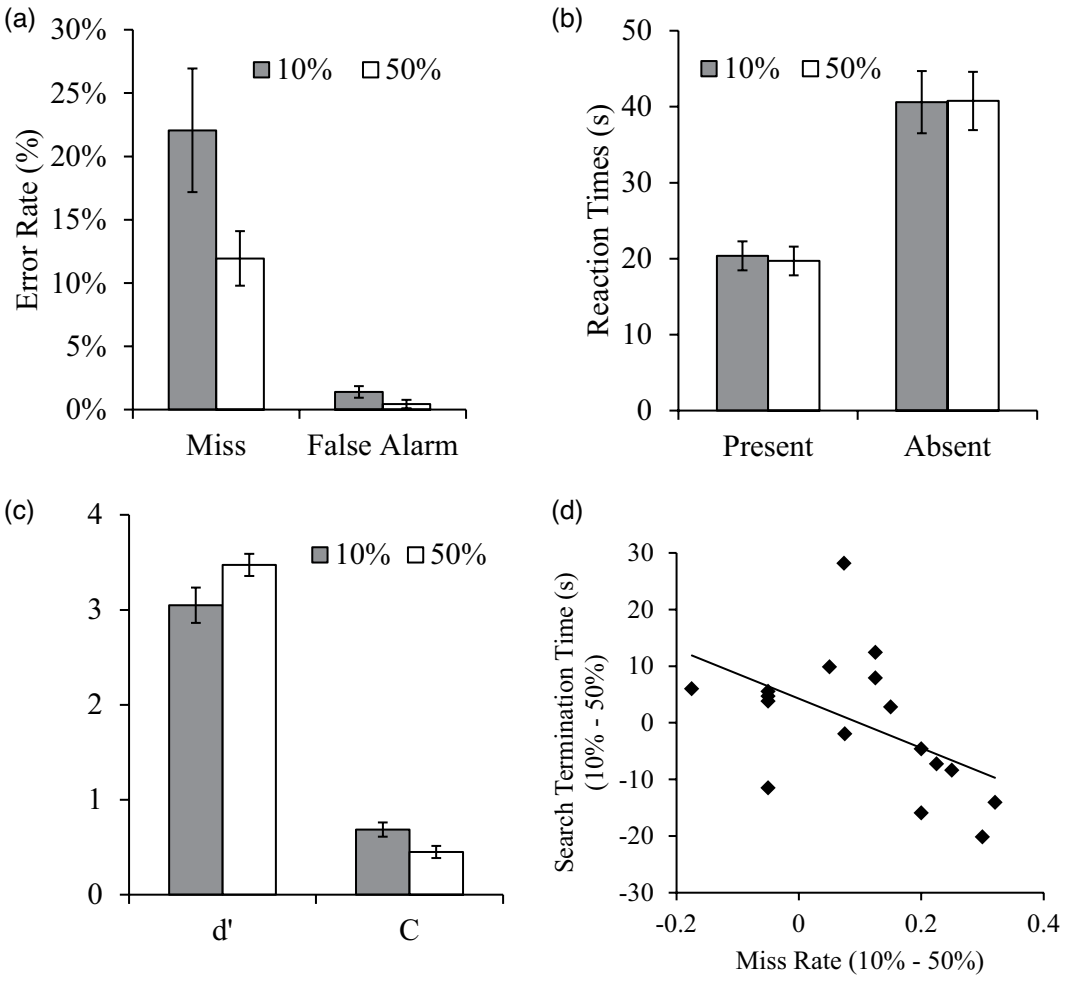

Figure 2. (a) Error rates, (b) Reaction times, (c) Sensitivity and Criterion. Error bars represent ±1 *SEM*. (d) Correlation between miss rate and search termination times.

(target prevalence: 10% and 50%) × 2 (time sequence: the first 40 trials and the second 40 trials) ANOVA. We found a significant main effect on target prevalence [$F(1, 16) = 9.13$, $p = .01$]. However, the main effect of time sequence on miss rates was not statistically significant [$F(1, 16) = 1.28$, $p = .27$], nor was the target prevalence × time sequence interaction [$F(1, 16) = 0.40$, $p = .54$]. These results suggest that the prevalence effect in haptic search was not mainly caused by failures of vigilance.

Although there are many differences between visual and haptic searches (e.g., search termination time, serial/parallel search), the fact that the prevalence effect occurs for both types of search suggests that people use the same search termination strategy for haptic and visual searches. Fleck and Mitroff (2007) suggest that the prevalence effect in visual search can be eliminated by allowing participants to correct their responses. Another study reports that the prevalence effect in visual search disappears when there are more than two response alternatives (Rich et al., 2008). If we use the same search termination strategy for haptic and visual searches, we would expect to eliminate the prevalence effect in haptic search by correcting participants' response and/or providing response alternatives.

Acknowledgments. This research was supported by grants from the Japan Society for the Promotion of Science (22300091) and Strategic Information and Communications R&D Promotion Programme (101707012). The authors thank Hiromi Mizuta and Satoshi Watanabe for their help in conducting the experiments and Takemasa Yokoyama for his valuable comments on an earlier draft.

References

Baddeley, A. D., & Colquhoun, W. P. (1969). Signal probability and vigilance: a reappraisal of the 'signal-rate' effect. *British Journal of Psychology, 60*, 169–178. doi:10.1111/j.2044-8295.1969.tb01189.x.

Fleck, M. S., & Mitroff, S. R. (2007). Rare targets rarely missed in correctable search. *Psychological Science, 18*, 943–947. doi:10.1111/j.1467-9280.2007.02006.x.

Ishibashi, K., Kita, S., & Wolfe, J. M. (2012). The effects of local prevalence and explicit expectations on search termination times. *Attention, Perception & Psychophysics, 74*, 115–123. doi:10.3758/s13414-011-0225-4.

Minatani, K., Watanabe, T., Yamaguchi, T., Watanabe, K., Akiyama, J., Miyagi, M., et al. (2010). Tactile map automated creation system to enhance the mobility of blind persons—Its design concept and evaluation through experiment. *Lecture Notes in Computer Science, 6180*, 534–540.

Rich, A. N., Kunar, M. A., Van Wert, M. J., Hidalgo-Sotelo, B., Horowitz, T. S., & Wolfe, J. M. (2008). Why do we miss rate targets? Exploring the boundaries of the low prevalence effect. *Journal of Vision, 8*, 1–17. doi:10.1167/8.15.15.

Wolfe, J. M., Horowitz, T. S., & Kenner, N. M. (2005). Rare items often missed in visual searches. *Nature, 435*, 439–440. doi:10.1038/435439a.

Wolfe, J. M., & Van Wert, M. J. (2010). Varying target prevalence reveals two dissociable decision criteria in visual search. *Current Biology, 20*, 121–124. doi:10.1016/j.cub.2009.11.066.

Copyright 2012 K Ishibashi, K Watanabe, Y Takaoka, T Watanabe, S Kita
Published under a Creative Commons Licence BY-NC-ND

a Pion publication