NON-PERSISTENT EFFECT OF PRIOR EXPERIENCE ON CHANGE BLINDNESS: INVESTIGATION ON NAIVE OBSERVERS

Kohske TAKAHASHI¹⁾ and Katsumi WATANABE^{1),2)}

¹⁾*ERATO, Japan Science and Technology, Japan*, ²⁾*The University of Tokyo, Japan*

The effects of prior experience often persist despite their futility. For example, vision scientists who have a long experience of a particular change blindness display are compelled to look at the location of the expected change even when they know that a change will not occur at the same location (Takahashi & Watanabe, 2008). Here, we investigated the types of experience that are required to form the persistent bias. Naive observers performed a typical change blindness task. Before the task, they repeatedly experienced the detection of a change in an identical display. The prior experience produced a gaze bias toward the experienced target. However, the bias decreased after the observers became aware that a change would not occur at the same location. These results suggest that prior experience immediately modulates visual search; however, repetitive detection was not sufficient for producing the persistent bias as observed in the case of vision scientists.

Key words: Change blindness, Eye movement, Prior experience, Visual search

Experience forms expectation, which, in turn, affects eye movements (Yarbus, 1967). Therefore, what we see is influenced by what we have experienced (Ryan, Althoff, Whitlow, & Cohen, 2000; Smith, Hopkins, & Squire, 2006). During visual search, the eye movements are modulated by both the bottom-up processes based on the physical attributes of a visual input (e.g., saliency, Koch & Ullman, 1985) and the top-down processes based on contextual information derived from prior experience (Peterson & Kramer, 2001; Torralba, Oliva, Castelhana, & Henderson, 2006). However, it remains unclear as to how the top-down and bottom-up processes work together in the efficient detection of targets. Change blindness, which demonstrates that the detection of visual changes is extremely difficult and takes a considerable amount of time (Rensink, O'Regan, & Clark, 1997; Simons & Levin, 1997; Simons, 2000; Rensink, 2002; Simons & Rensink, 2005), is possibly a useful tool for investigating the top-down modulations on visual search.

Recently, Takahashi and Watanabe (2008) used the change blindness paradigm to investigate the effects of prior experience on eye movements during visual search, and found that the top-down modulations were even stronger than expected. In their research, vision scientists and naive observers performed a typical change blindness task, and their

This work was supported by Shimojo Implicit Brain Function Project, ERATO, Japan Science and Technology Agency, Japan. We thank the anonymous reviewers for helpful comments and Hirokazu Ogawa for improving this manuscript.

Correspondence to Kohske Takahashi, Research Center for Advanced Science and Technology, University of Tokyo, 4-6-1, Komaba, Meguro-ku, Tokyo 153-8904, Japan (e-mail: ktakahashi@fennel.rcast.u-tokyo.ac.jp).

eye movements were recorded. The stimuli were airplane pictures, which have been widely used in change blindness tasks (Rensink, 1997). Many vision scientists are aware that in the change blindness paradigm, the engine of the airplane in the picture appears and disappears. However, a trick lay in that the changes did not occur at the location of the engine. Instead, four different stimuli consisting of the same airplane picture without its engine were used, and in each picture, the change occurred at different locations. Moreover, eight stimuli consisting of the pictures of novel natural scenes were presented. The analyses of the eye movements during visual search revealed the strong modulation of the prior experience of the vision scientists. First, during searches for the airplane pictures, the vision scientists looked at the location of the engine for a longer duration than did the naive observers. This was despite the fact that the engine was never shown during the experiment. Second, during searches for the novel pictures, the gaze bias toward the location of the engine, which was near the center of the picture, was not observed in both the vision scientists and naive observers. This suggested that the gaze bias was specific for the airplane pictures and was derived from prior experience. Third, the gaze bias toward the location of the engine was replicated when the other vision scientists performed the same task using the airplane pictures that had their engines, indicating the robust modulation of prior experience. The fourth and most interesting observation is that the gaze bias toward the location of the engine persisted throughout the four repetitions of visual search for the airplane pictures. The vision scientists were biased to look at the location of the engine even after they had experienced the changes at a location other than that of the engine. These results suggested that the top-down modulation caused by prior experience on visual search was rather strong and difficult to inhibit.

Based on the observation of such strong and persistent modulation of prior experience on visual search, an intriguing aspect would be identifying the types of experience that lead to the persistent gaze bias. Currently, we have been unable to determine the types of experience because the environment of vision scientists for the visual search for airplane pictures is usually uncontrolled (i.e., in scientific conferences, public lectures, class rooms, etc). Therefore, in the present study, we sought the source of the strong and persistent effects of prior experience by using a heuristic approach. We considered two possible situations: repetitive detection (Experiment 1) and surprise upon failure in detection (Experiment 2). As the picture set of the airplane is widely used as a typical demonstration of change blindness, many vision scientists have been repeatedly exposed to these airplane pictures, and they attempt to detect the change in the location of the engine. Such repetition may reinforce the memory that the engine in the picture would change (Scarborough, Cortese, & Scarborough, 1977). The other possibility—surprise upon failure in detection—is based on the first experience of vision scientists with regard to the airplane picture. The duration of the demonstration of the change blindness is usually too short for the audiences to detect the change by themselves. Assuming that vision scientists could detect the change only after the demonstrator informed them that the engine of the airplane in the picture changes, a surprise would accompany the experience of change detection. This is because the change is rather large and appears to be easy to detect after it is identified. The surprise may lead the observers to consider the

experience to be impressive, and it may be reinforced in their memory as prior experience (e.g., Bayesian surprise, Itti & Baldi, 2006).

In the present study, we measured the eye movements of naive observers during the change blindness task after the experiences of repeated success or one failure in detection. The experiments began with the experience sessions. In Experiment 1, the same airplane pictures where the changes always occur in the location of the engine were repeatedly presented six times. In Experiment 2, the airplane picture in which the location of the engine was changed was only presented once, and the experimenter revealed the change in the location after the observers failed to detect the change by themselves. In the subsequent test session, the four different airplane stimuli, wherein the changes occur at a location other than that of the engine, and eight novel stimuli were presented. The test session was completely identical to the experiments in Takahashi and Watanabe (2008), in which the vision scientists had tested. We investigated the strength and time course of the modulation of prior experience on eye movements during visual search.

EXPERIMENT 1

METHOD

Ten undergraduate students with normal or corrected normal vision participated in Experiment 1. They were naive to the aim of this study and had never seen the change blindness display with the airplane picture. Visual stimuli were presented on a CRT monitor (100 Hz) in a dark room at a viewing distance of 50 cm. The eye movements were recorded by EyeLink II Tracker (SR Research, Ontario, Canada) at a sampling rate of 250 Hz. The observers employed a typical change blindness task (Fig. 1a). Each trial began with a calibration session of the eye tracker: the observers pressed the spacebar while they were looking at a central fixation point. After the success of the calibration session, a uniform gray field replaced the fixation point for 1000 ms. Then, the first image appeared for 1000 ms and a gray mask replaced the first image for 250 ms. Then, the second (changed) image appeared for 1000 ms and another gray mask replaced the second image for 250 ms. The stimulus presentation was looped until either the observer pressed the spacebar to indicate the detection of a change or until 90 s had elapsed. In case of successful detection, the observer reported the location of the change by using a mouse pointer.

We prepared 13 different stimuli. Eight (new stimuli) were pictures of Japanese outdoor locations that were taken from the High-level Vision Database (<http://www.l.u-tokyo.ac.jp/AandC/HLV/S-archive>). The other five stimuli were the famous airplane pictures; however, the changes occurred at different locations: the jet engine (original), front cockpit window, flag mark on the tail wing, left foot of the front soldier, and cabin windows. The sequence of the experiment is illustrated in Fig. 1b. In the experience session, the same airplane stimuli, wherein the change occurred in the location of the jet engine, were repeatedly presented in the six successive trials. In the following test session, 12 different stimuli were presented. The airplane stimuli were presented during the third, sixth, ninth, and twelfth trials in the test session. The sequence of the stimulus displays was fixed for all observers in this experiment as well as in the previous experiments for vision scientists (Takahashi & Watanabe, 2008). Thus, the observers performed 18 change blindness trials. No instruction regarding the stimuli or the search strategy was provided. The experiments lasted for approximately 30 min, including the setup of the eye tracker.

Fig. 1. a. The sequence of a trial. b. The sequence of an experiments.

Fig. 2. Mean detection time (left) and the rate of looking at the location of the engine (right) in the experience session in Experiment 1. The error bars represent the standard errors of the means.

RESULTS AND DISCUSSION

One observer could not detect the change in all the six trials in the experience session and was excluded from the following analyses. The general performances of the eye movements did not change during the experience session. A one-way repeated measures ANOVA showed that the saccade frequency (mean = 1.8 times/s, $F(5, 40) = 1.21$, $p = 0.32$), saccade amplitude (3.1° , $F(5, 40) = 2.04$, $p = 0.11$), and fixation duration (486 ms, $F(5, 40) = 0.79$, $p = 0.47$) of the eye movements did not differ significantly across the six experience trials. However, the detection time was decreased, and the rate of looking at the location of the engine (i.e., the changed location) was increased immediately (Fig. 2). A one-way repeated measures ANOVA showed a significant main effect of the number of trials on the detection time ($F(5, 40) = 4.20$, $p < 0.05$) and on the rate of looking at the location of the engine ($F(5, 40) = 6.38$, $p < 0.01$). Post hoc multiple

Fig. 3. Mean rate of looking at the location of the engine for the airplane stimuli in the test session in Experiment 1. Left: the duration summed for the entire trial. Right: the duration summed for the initial 5 seconds. The error bars represent the standard errors of the means.

comparison (Ryan's methods; $\alpha = 0.05$) revealed that the detection time was significantly longer in the first trial than in the third to sixth trials. Moreover, the rate of looking at the location of the engine was significantly smaller in the first trial than in the other trials. These results suggested that the observers successfully acquired the prior experience regarding the location of the engine, and only one experience of detection appears to be sufficient to enhance the visual search efficiency.

In the test session, the saccade frequency (mean = 2.3 times/s, $F(1, 8) = 0.22$, $p = 0.65$) and saccade amplitude (3.5° , $F(1, 8) = 0.86$, $p = 0.38$) did not significantly differ between the airplane stimuli and the new stimuli. On the contrary, the fixation duration (366 ms for the airplane stimuli and 392 ms for the new stimuli, $F(1, 8) = 7.68$, $p < 0.05$) and detection time (22 s for the airplane stimuli and 39 s for the new stimuli, $F(1, 8) = 7.28$, $p < 0.05$) for the experienced pictures were significantly shorter than those for the novel pictures. The differences in the detection time and fixation duration may reflect that the observers could rapidly collect the information at the fixated location for the repeatedly experienced picture, because they have acquired the structure of the picture in their memory as contextual information (e.g., contextual cueing, Chun & Jiang, 1998).

The main purpose of Experiment 1 was to investigate the modulation of prior experience on eye movements during visual search, that is, how long the observers looked at the location of the engine they repeatedly detected a change. The results showed that the eye movements were biased toward the location of the engine. However, unlike vision scientists (Takahashi & Watanabe, 2008), the rate of looking at the location of the engine immediately decayed after the observers became aware that the location of the engine would not change (Fig. 3, left). This rapid decay was particularly evident in the initial periods of visual search (Fig. 3, right). A one-way repeated measures ANOVA showed a significant main effect of the number of trials ($F(3, 24) = 9.58$, $p < 0.001$). Post hoc

multiple comparisons revealed that the rates of looking at the location of the engine were smaller in the second to fourth trials than in the first trial. The data from the entire search duration (Fig. 3, left) confirmed that the rate of looking at the location of the engine was decreasing when observers experienced the change at different locations. The slope of linear regression of the rate of looking at the location of the engine as a function of the number of trials was significantly less than zero (mean = -2.6% per trial, $t(8) = 2.34$, $p < 0.05$, one-tailed), suggesting the decreasing trends of the effects of prior experience. Thus, the six-times repetition of detection was insufficient to produce the persistent bias on the change detection task.

EXPERIMENT 2

METHODS

Eleven undergraduate students with normal or corrected normal vision participated in Experiment 2. They were naive to the aim of this study and had never seen the airplane picture. With a few exceptions, the stimuli, apparatus, and task were the same as those in Experiment 1, as described below. The experience session was modified from Experiment 1 (Fig. 1b). The observers were shown the airplane picture where the change occurred at the location of the engine only once. In addition, in the case where the observers could not detect the change within 20 s, the experimenter pointed out the location of the engine to the observers and informed them that the picture of the airplane was shown with and without its engine. The stimulus display lasted until the observers identified the change in the location of the engine. We also instructed the participants that the experience session was only a practice session. Through these instructions, we aimed to emulate the experiences that vision scientists might have during demonstrations of change blindness in conference presentations. The subsequent test session was exactly the same as that in Experiment 1. Thus, observers performed one experience trial and twelve test trials.

RESULT AND DISCUSSION

Two observers succeeded in detecting the change in the location of the engine within 20 s in the experience session, and were excluded from the following analyses. In the experience session, the mean presentation duration for the observers who failed to detect the change within 20 s was 39.7 s. In the test session, the saccade frequency (mean = 2.3 times/s, $F(1, 8) = 3.24$, $p = 0.11$), saccade amplitude (3.5° , $F(1, 8) = 0.33$, $p = 0.58$), fixation duration (396 ms, $F(1, 8) = 1.79$, $p = 0.22$), and detection time (26 s, $F(1, 8) = 0.72$, $p = 0.42$) did not significantly differ between the airplane stimuli and new stimuli. Unlike Experiment 1, the detection time and fixation duration were not shorter for the experienced stimuli. These results indicate that the enhancement of the search performance occurs only after repeated exposure to the same stimuli.

The results of the fixated location for the airplane stimuli showed similar trends as in Experiment 1 (Fig. 4). In the test session, although the eye movements were biased toward the location of the engine in the first airplane trial, the rate of looking at the location of the engine decayed immediately after the observers experienced the airplane trial in which the change occurred at a location other than that of the engine. This decay

Fig. 4. Mean rate of looking at the location of the engine for the airplane stimuli in the test session in Experiment 2. Left: the duration summed for the entire trial. Right: the duration summed for the initial 5 seconds. The error bars represent the standard errors of the means.

was prominently observed in the initial periods of visual search. A one-way repeated measures ANOVA showed a significant main effect of the number of trials ($F(3, 24) = 14.32, p < 0.001$). Post hoc multiple comparisons revealed that the rates of looking at the engine were smaller in the second to fourth trials than in the first trial. As in Experiment 1, the slope of the decay function of the gaze bias for the entire search duration was significantly less than zero (mean = -3.3% per trial, $t(8) = 1.95, p < 0.05$, one-tailed).

The slopes and intercepts of the decay function during the test session did not differ between Experiments 1 and 2 (the slopes: $t(16) = 0.35, p = 0.73$; the intercepts: $t(16) = 0.12, p = 0.91$). Thus, the prior experiences formed in the six repetitions (Experiment 1) and in the one failure (Experiment 2) in detections had closely similar effects on subsequent visual searches: the bias of the eye movements toward the experienced target and its immediate decay.

GENERAL DISCUSSION

In the present study, we investigated the effects of prior experience on eye movements during visual search in a change blindness task. The observers' prior experiences were formed in two different ways: repetitive detection (Experiment 1) and surprise upon failure in detection (Experiment 2). Both experiences immediately modulated the search strategy in the subsequent visual searches for the same pictures that the observers had experienced, resulting in the gaze bias toward the location of the experienced change (i.e., the engine of the airplane). It appears to be certain that the top-down processes, if they are valid and available, dominate in visual search (Triesch,

Fig. 5. Comparison between the experienced naive observers in this study and the vision scientists in Takahashi and Watanabe (2008). a. Mean slopes of decay function of the rate of looking at the location of the engine as a function of the number of trials of the airplane stimuli. b. Mean rate of looking at the location of the engine for the airplane stimuli within and after 2.5 seconds from the onset of image presentation. The error bars represent the standard errors of the means.

Ballard, Hayhoe, & Sullivan, 2003; Stirk & Underwood, 2007).

To compare the effect of prior experience on visual search between the vision scientists and the experienced naive observers, we conducted two additional cross-experiment analyses using data from the present experiments and our previous work where the vision scientists were measured (Takahashi & Watanabe, 2008). First, we compared the decay of the gaze bias toward the location of the engine in order to test the persistence of the modulation of prior experience. The decay was defined as the slope of linear regression of the rate of the gaze toward the location of the engine for the entire search duration as a function of the number of trials (Fig. 5a). As a result, the slope of the naive observers in this study was significantly less than that of the vision scientists ($t(24) = 2.49, p < 0.01$), suggesting that unlike the case of the vision scientists, the effects of the prior experiences of the naive observers did not persist but decreased after they realized their futility. Accordingly, the repetition of detection and surprise upon failure in detection were sufficient to modulate the visual searches, which were performed immediately after the experience. However, these were insufficient to produce the persistent gaze bias observed in the vision scientists. In other words, the naive observers in this study could flexibly adopt the search strategy (Wolfe, Horowitz, Kenner, Hyle, & Vasan, 2004).

One may expect that the lack of the persistent gaze bias toward the location of the engine in the experienced naive observers is due to the lack of knowledge about the general procedures of psychological experiments. Although we did not present any instructions, the vision scientists in the previous study may consider that both the experienced (i.e., the location of the engine) and unexperienced (i.e., the objects other than the engine) changes would be presented and that the experience of the change would be the factor in experimental design. In this case, it was rational for the observers to persist in searching for the engine even after they met the display in which the change did not occur at the location of the engine. If only the vision scientists expected the location of the

engine to change prior to performing a visual search, they would direct their eyes to the location of the engine first and then scan the other locations (Eckstein, Drescher, & Shimozaki, 2006; Torralba et al., 2006).

To test these possibilities, we conducted the analysis of the time course of the gaze bias in each trial (Fig. 5b). We divided the data on the eye movements into two bins in each trial: within and after 2.5 s (i.e., within and after the presentation of the first and second images) from the onset of each trial. The results showed that the rate of looking at the location of the engine did not differ between the vision scientists and the experienced naive observers within 2.5 s ($t(24) = 0.77, p = 0.46$), while the vision scientists looked at the location of the engine for a longer duration after 2.5 s ($t(24) = 2.52, p < 0.05$). This implied that both the vision scientists and experienced naive observers initially attempted to detect the engine in each visual search; however, only the vision scientists keep directing their eye to the engine although they have searched it in the trial. In other words, the vision scientists had a gaze bias toward the location of the engine even after they had confirmed that the location of the engine did not change in each trial. The expectation prior to performing the search that both the experienced and unexperienced changes would be presented, which was derived from the knowledge about the procedures of psychological experiments, could not explain the difference in the gaze bias between vision scientists and naive observers after they had confirmed that the location of the engine did not change. This was because the modulation of such expectation usually appears in the initial period of visual search (Eckstein, Drescher, & Shimozaki, 2006).

On observing the fruitless gaze bias after the initial search periods and its persistence, we have to carefully consider the function of each gaze in visual search. One may consider that the memory limit was inadequate for the long search duration for natural and complex scenes (McCarley, Wang, Kramer, Irwin, & Peterson, 2003), due to which the observers forgot the searched location and reexamined the location of the engine. However, this appears to be unlikely because the location of the engine is prominent for the experienced observers. Another more likely possibility is that each gaze may not always reflect the behavior of detection itself or attentional orientation, particularly in the case of a difficult visual search such as a change blindness task. Since it takes a considerable amount of time to detect the target, some breaks should be included instead of the continuous search for the target throughout the trial. Perhaps, the most prominent object in the contextual information, which is the airplane engine for the vision scientists, may tend to serve as a resting place during the long visual search process. Note that this does not mean that the observer tends to take a rest by fixating at the center of the display because such gaze pattern was not observed for the novel pictures in our previous work (Takahashi & Watanabe, 2008). The interesting question whether the futile gaze reflects memory limits or some other peculiar function during complex visual searches still remains open.

The final question concerns why repetitive detection or surprise upon failure in detection was insufficient to produce the persistent gaze bias, although the observers indeed learned the location of the change. Although we could not propose clear explanations, we speculate one account based on the difference of the meta-knowledge

about the airplane picture and change blindness task. After undergoing the experience session, the naive observers in this study would have thoughts such as *the airplane has lost its engine*. On the other hand, most vision scientists would know that *the airplane has lost its engine is a typical demonstration of change blindness* prior to participating in the experience. In the test session, wherein the observers encounter changes other than the location of the engine, the experienced naive observers have to update their thoughts: *the changes occur at various locations*, resulting in that the airplane engine is no longer the special object. On the other hand, vision scientists would newly acquire the knowledge that *the changes occur at various locations in this experiment*, maintaining the meta-knowledge about the location of the engine in the change blindness task. Thus, the engine can still be the special object and probably persist in modulating the visual search during the experiment, because the vision scientists knew that they were performing the change blindness task (Navalpakkam & Itti, 2005; Rothkopf, Ballard, & Hayhoe, 2007). These observations imply that our behavior is modulated by the contextual information derived not only from the searched stimuli (i.e., the change occurs at the location of the engine) but also from what the observers were doing (i.e., they are performing the change blindness task). Investigating the modulation of the location of the engine in the airplane picture on the other psychological tasks (e.g., a priming task) will help to reveal the interaction between stimulus-driven and task-driven contextual information.

Obviously, there are many other possibilities that may cause the different gaze bias between the vision scientists and naive observers (e.g., the duration between the experience and the experiment, experience of psychological experiments, personalities, or motivations). Prior experiences are mandatorily involved in most instances of visual search in our daily life. What constitutes the strong and persistent effects of prior experience warrants further investigation by controlling several of the abovementioned factors. This would be helpful in order to understand visual search in a broader and more naturalistic framework.

REFERENCES

- Chun, M. M., & Jiang, Y. 1998. Contextual cueing: implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology*, **36**, 28–71.
- Eckstein, M. P., Drescher, B. A., & Shimozaki, S. S. 2006. Attentional cues in real scenes, saccadic targeting, and Bayesian priors. *Psychological Science*, **17**, 973–980.
- Itti, L., & Baldi, P. 2006. Bayesian surprise attracts human attention. *Advances in Neural Information Processing Systems*, **19**, 1–8.
- Koch, C., & Ullman, S. 1985. Shifts in selective visual attention: towards the underlying neural circuitry. *Human Neurobiology*, **4**, 219–227.
- McCarley, J. S., Wang, R. F., Kramer, A. F., Irwin, D. E., & Peterson, M. S. 2003. How much memory does oculomotor search have? *Psychological Science*, **14**, 422–426.
- Navalpakkam, V., & Itti, L. 2005. Modeling the influence of task on attention. *Vision Research*, **45**, 205–231.
- Peterson, M. S., & Kramer, A. F. 2001. Attentional guidance of the eyes by contextual information and abrupt onsets. *Perception & Psychophysics*, **63**, 1239–1249.
- Rensink, R. A. 2002. Change detection. *Annual Review of Psychology*, **53**, 245–277.
- Rensink, R. A., O'Regan, J. K., & Clark, J. J. 1997. To see or not to see: The need for attention to perceive

- changes in scenes. *Psychological Science*, **8**, 368–373.
- Rothkopf, C. A., Ballard, D. H., & Hayhoe, M. M. 2007. Task and context determine where you look. *Journal of Vision*, **7**, 16.1–20.
- Ryan, J. D., Althoff, R. R., Whitlow, S., & Cohen, N. J. 2000. Amnesia is a deficit in relational memory. *Psychological Science*, **11**, 454–461.
- Scarborough, D. L., Cortese, C., & Scarborough, H. S. 1977. Frequency and repetition effects in lexical memory. *Journal of Experimental Psychology: Human Perception and Performance*, **3**, 1–17.
- Simons, D. J. 2000. Current approaches to change blindness. *Visual Cognition*, **7**, 1–15.
- Simons, D. J., & Levin, D. T. 1997. Change Blindness. *Trends in Cognitive Sciences*, **1**, 261–267.
- Simons, D. J., & Rensink, R. A. 2005. Change blindness: past, present, and future. *Trends in Cognitive Sciences*, **9**, 16–20.
- Smith, C. N., Hopkins, R. O., & Squire, L. R. 2006. Experience dependent eye movements, awareness, and hippocampus-dependent memory. *Journal of Neuroscience*, **26**, 11304–11312.
- Stirk, J. A., & Underwood, G. 2007. Low-level visual saliency does not predict change detection in natural scenes. *Journal of Vision*, **7**(10), 1–10.
- Takahashi, K., & Watanabe, K. 2008. Persisting effect of prior experience on change blindness. *Perception*, **37**, 324–327.
- Torralba, A., Oliva, A., Castelhano, M. S., & Henderson, J. M. 2006. Contextual guidance of eye movements and attention in real-world scenes: the role of global features in object search. *Psychological Review*, **113**, 766–786.
- Triesch, J., Ballard, D. H., Hayhoe, M. M., & Sullivan, B. T. 2003. What you see is what you need. *Journal of Vision*, **3**, 86–94.
- Wolfe, J. M., Horowitz, T. S., Kenner, N., Hyle, M., & Vasan, N. 2004. How fast can you change your mind? The speed of top-down guidance in visual search. *Vision Research*, **44**, 1411–1426.
- Yarbus, A. L. 1967. *Eye Movements and Vision*. New York: Plenum.

(Manuscript received December 31, 2007; Revision accepted April 21, 2008)