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Research Report

The Beneficial Effect of Concurrent Task-Irrelevant Mental Activity on Temporal Attention

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ABSTRACT—*It is believed that the human cognitive system is fundamentally limited in deploying attention over time. This limitation is reflected in the* attentional blink, *the impaired ability to identify the second of two visual targets presented in close succession. We report the paradoxical finding that the attentional blink is significantly ameliorated when observers are concurrently engaged in distracting mental activity, such as free-associating on a task-irrelevant theme or listening to music. This finding raises questions about the fundamental nature of the attentional blink, and suggests that the temporal dynamics of attention are determined by task circumstances that induce either a more or a less distributed state of mind.*

Human attention is limited. This is apparent in everyday life, for example, when people drive while talking on the phone (McKnight & McKnight, 1993), and in the laboratory, for example, when observers fail to detect a visual stimulus while simultaneously having to discriminate a tone (Arnell & Jolicoeur, 1999; Kahneman, Beatty, & Pollack, 1967; Pashler & Johnston, 1989). Apparently, one type of mental activity interferes with, distracts from, or takes attentional capacity away from the other (Kahneman, 1973; Pashler, 1984; Welford, 1952).

Exceptions to such limitations have been reported. For example, playing the piano and typing suffer little from concurrently shadowing a list of words (Allport, Antonis, & Reynolds, 1972; Shaffer, 1975). Furthermore, after extensive practice, some individuals are able to copy spoken sentences while at the same time reading other material with only slight lapses in accuracy (Hirst, Spelke, Reaves, Caharack, & Neisser, 1980; Spelke, Hirst, & Neisser, 1976). Interestingly, professional golfers actually improve their putting performance by simultaneously performing an auditory discrimination task instead of fully concentrating on playing golf (Beilock, Carr, MacMahon, & Starkes, 2002). However, note that in these cases, the primary task generally involves highly practiced or automated procedural skills that make step-by-step attentional control unnecessary or sometimes even harmful.

Here we report the beneficial effect of task-irrelevant mental activity on performance of a task that does not involve automated procedural skills, but instead relies heavily on paying attention to visual input. In the version of the task we used (illustrated in Fig. 1; see the Method section for details), each trial consists of a series of letters presented rapidly at the center of the display. Among the letters are two target digits (referred to as T1 and T2), and the observer's task is to report these at the end of the trial. The usual result is that detection of T2 suffers considerably if it is presented within a short lag from T1 (typically 500 ms), a phenomenon referred to as the *attentional blink*. The general explanation of this phenomenon is that processing of T1 takes up limited attentional resources. As a result, either access to these resources is denied for T2 or the representation of T2 is so vulnerable that it easily suffers from interference from temporally surrounding distractor letters (Broadbent & Broadbent, 1987; Chun & Potter, 1995; Raymond, Shapiro, & Arnell, 1992; Shapiro, Arnell, & Raymond, 1997).

The present work was motivated by participants in previous experiments, who, rather counterintuitively, reported improved

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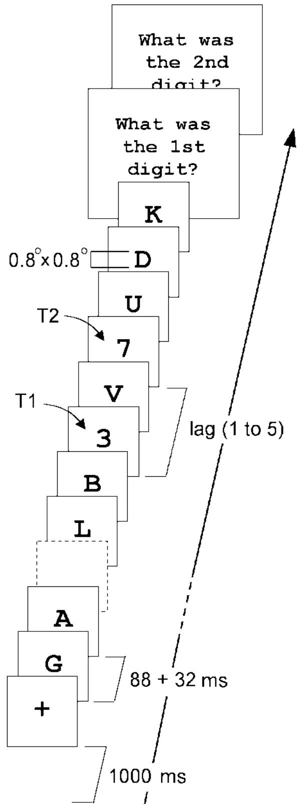

Fig. 1. Outline of the basic paradigm. On every trial, between 13 and 21 items were presented at the center of the screen, preceded by a 1,000-ms fixation cross. Most of the items were letters, presented for 88 ms each and followed by a 32-ms blank (resulting in 120 ms between different items). Among the items were two target digits (T1 and T2), which observers had to report at the end of the trial. The interval between T1 and T2, referred to as lag, varied from 1 to 5 temporal positions (i.e., from 120 ms to 600 ms).

T2 performance when being somewhat unfocused on the task. For what it was worth, our own introspection also suggested that the task was best done in a "slightly distracted state of mind." To test this idea, we recruited four groups of participants, whose primary task was to detect the two digits in the stream of letters. An explanation of the task was provided to all participants. In addition, in the *standard* control group, participants received the type of instruction that is standard for this and related kinds of experiments, namely, to concentrate and report as many targets correctly as possible. In the first experimental group—the *free-association* group—participants were instructed that while doing the task, they should think about either their most recent holiday or their shopping requirements for an imaginary dinner with friends. No mention was made of the need to concentrate or to report as many digits correctly as possible. If T2 detection indeed improves under distracting conditions, we would expect an increase in performance in this condition. To further test the idea that a moderate amount of distraction may improve performance on the attentional blink task, we asked observers in the *listen-to-music* group to perform the task while listening to a rhythmic tune. In one block, they were asked to just listen. In another block, they were given the additional task of detecting an occasional yell that was part of the tune.

An alternative explanation for an improvement in performance in the experimental conditions would be that the somewhat funny instructions or the presence of music might contribute to a higher appreciation of what would otherwise be a boring experiment, resulting in more motivation for the task overall. We tested for this possibility by including a *reward* condition, in which participants were paid according to their performance (Bahrick, Fitts, & Rankin, 1952; Lewis & Linder, 1997).

METHOD

Participants

Sixty-six randomly assigned healthy subjects with normal or corrected-to-normal vision participated: 17 in the standard condition (10 male; average age = 22 years), 17 in the free-association condition (9 male; average age = 21 years), 16 in the listen-to-music condition (5 male; average age = 20 years), and 16 in the reward condition (6 male; average age = 21 years). None of the participants were aware of conditions other than the one they were placed in. There were no significant effects involving sex (all Fs < 1.5).

Stimuli

Stimuli were generated and responses recorded using E-Prime (Psychology Software Tools, Inc., Pittsburgh, PA). The stimuli and task were the same in all conditions, unless stated otherwise. On each trial, a $0.5° \times 0.5°$ (visual angle) fixation cross was presented for 1,000 ms in the center of the display and subsequently replaced by a rapid serial presentation of 13 to 21 letters, each measuring approximately $0.8° \times 0.8°$. Each letter was randomly drawn (without replacement) from the alphabet and presented for 88 ms, followed by a 32-ms blank. The letters *I*, *O*, *Q*, and *S* were left out because of their resemblance to digits. Two of the letters in the stream were replaced with digits, randomly drawn (without replacement) from the set 2 to 9. The second digit (T2) was presented three to six temporal positions from the end of the stream. The temporal distance between the first digit (T1) and the second was systematically varied from 1 to 5 items, corresponding to lags of 120, 240, 360, 480, and 600 ms. All stimuli were presented in black on a gray (40 cd/m^2) background.

Procedure

The participant's task was to identify both T1 and T2. An unspeeded response was made at the end of each trial by typing the digits in order on a standard keyboard. Each erroneous response was immediately followed by negative feedback stating, in red, "No, it was _," with the correct digit indicated. Participants were instructed to guess whenever they failed to identify a digit. A new trial began 500 ms after response. The experiment started with 10 practice trials, followed by two blocks of 100

trials, resulting in a total of 40 trials per lag, which were randomly mixed. The experiment lasted approximately 25 min, and participants were paid €4 (except in the reward condition, as explained later).

In the standard condition, each block was preceded by the usual instruction to concentrate on the task and report as many digits as possible. In the free-association condition, participants were invited to think about their holidays (in one block) or about their shopping plans for a dinner with friends (in the other block, with block order counterbalanced across participants) while doing the task. It was mentioned that they could freely associate from these themes and return to the themes if they could no longer think of something else.

In the listen-to-music condition, participants were presented (through a set of headphones) with a continuous rhythmic tune running at 120 beats per minute. In this condition, the start of the visual stimulus (i.e., the fixation cross) was synchronized with the start of the musical measure. The presentation of the letters and digits was not synchronized with the beat. In one block, participants were asked to just listen to the beat while doing the task. In the other block (again block order was counterbalanced), they were asked to detect an occasional yell that was part of the music (there were no other verbal elements in the music). If a yell occurred during a trial, as was the case on 15% of trials, the task was to type in two capital *X*s instead of the digits. These trials were included to make sure that participants indeed listened to the music but were excluded from any analysis. Note, however, that because participants received 15% more trials in this condition, any improvements in their performance may have been due to their longer experience with the task. We therefore conducted the same statistical analyses with the last 15% of the trials removed. Excluding these trials made no difference whatsoever in the results (even numerically there was hardly a difference).

Finally, in the reward condition, participants were paid according to their performance. The minimum payment was €3. For each correct identification, earnings increased by €0.01. For each incorrect identification, earnings decreased by €0.03. Thus, the maximum possible earnings were €7 (€3 plus 200 trials times 2 identifications per trial). The earnings were updated and shown after every response, together with the feedback text.

In all conditions, all instructions were automated and presented on screen. Apart from initial setup and final payments, there were no interactions with the experimenter, who was a lab assistant naive to the main purpose of the experiment.

RESULTS AND DISCUSSION

Figure 2 shows the average T1 and T2 detection accuracy for all groups, as a function of the lag between T1 and T2. Note that we report T2 accuracy averaged across all trials. However, the same pattern of results was found for T2 accuracy contingent upon correct T1 report. An omnibus analysis of variance

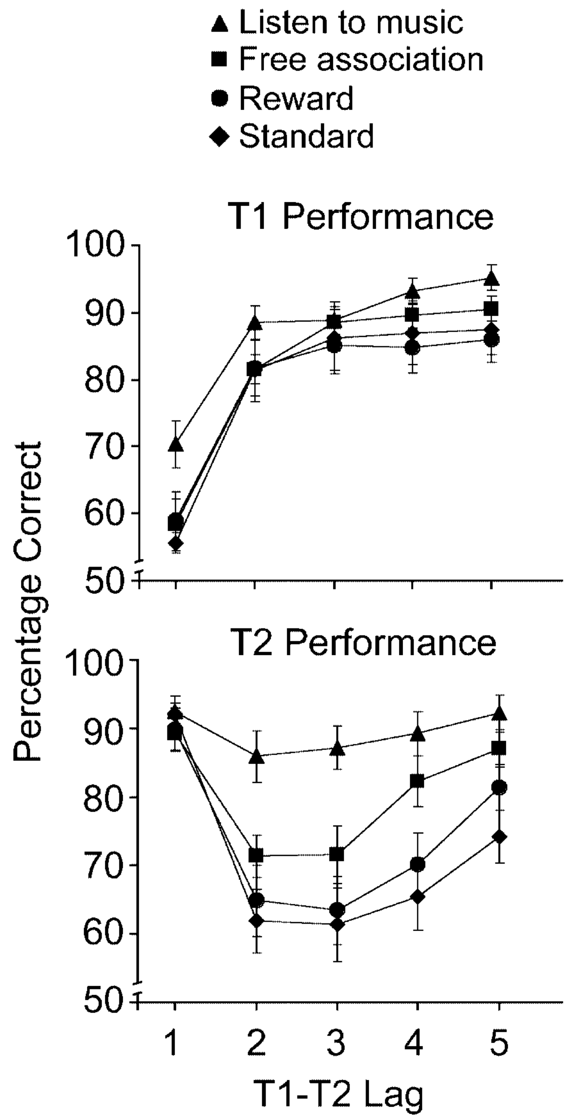

Fig. 2. Average detection accuracy for the first (T1; top panel) and second (T2; bottom panel) of two target digits in a rapid serial visual stream of letters. Results are presented separately for two control conditions (standard, reward) and experimental conditions in which participants freely associated or listened to music. Error bars denote standard errors of the means.

(ANOVA) on T1 accuracy revealed a main effect of lag, $F(4, 248) = 196.69$, $p < .001$, $\eta_p^2 = .760$; a trend toward a main effect of group, $F(3, 62) = 2.30$, $p = .087$, $\eta_p^2 = .100$; and a trend toward a Group × Lag interaction, $F(12, 248) = 1.65$, $p = .079$, $\eta_p^2 = .074$. The same ANOVA on T2 accuracy showed all main effects and interactions to be significant: lag, $F(4, 248) = 55.85$, $p < .001$, $\eta_p^2 = .474$; group, $F(3, 62) = 6.4$, $p < .001$, $\eta_p^2 = .237$; and Group × Lag, $F(12, 248) = 5.06$, $p < .001$, $\eta_p^2 = .197$.

As can be seen clearly in Figure 2, T2 detection in the standard group suffered considerably at almost all lags. An exception was Lag 1, for which T2 detection was quite good—a phenomenon that is referred to as Lag 1 sparing (Potter, Chun, Banks, & Muckenhoupt, 1998). The results for the standard

group are typical for the attentional blink. Note further that for all groups, T1 detection was quite poor for Lag 1. The close temporal proximity of T1 and T2 may lead to both being perceived, but in the wrong order. Thus, participants may enter T2 first (leading to a T1 error), but upon receiving negative feedback, enter T2 again (now correctly as T2) as they realize they got the order wrong (Chun & Potter, 1995).

Interestingly, T2 detection was significantly better overall in the free-association group (in which participants were instructed to think about their holiday or shopping requirements) than in the standard group, $F(1, 32) = 4.60$, $p < .05$, $\eta_p^2 = .126$. There was no improvement relative to the standard group for Lag 1, leading to a Group × Lag interaction, $F(4, 128) = 4.36$, $p < .01$, $\eta_p^2 = .120$. Note that T1 detection performance did not suffer in the free-association group ($F < 1$). This is important because it means that our results cannot be explained as due to the instructions leading to a shift of attentional resources from T1 to T2. Fewer T1 detections might lead to fewer trials on which a blink occurs and hence better T2 detection (Chun & Potter, 1995). However, Figure 2 clearly shows that T1 detection did not deteriorate in the free-association group.

The listen-to-music group completed two types of blocks, one in which they just listened to the tune and another in which they had to detect a yell in the same tune. In the latter type of block, they detected 96% of the yells. However, performance did not differ between the yell and no-yell blocks, and we present their results combined here. Figure 2 shows a dramatic improvement in T2 detection in this condition compared with the standard condition, $F(1, 31) = 17.01$, $p < .001$, $\eta_p^2 = .354$. The improvement relative to the standard group occurred across all lags except Lag 1, resulting in a Group × Lag interaction, $F(4, 124) = 11.20$, $p < .001$, $\eta_p^2 = .265$. T2 detection accuracy in the listen-to-music group was so high that the attentional blink virtually disappeared. As can be seen from the top panel of Figure 2, this improvement in performance was not attributable to decreased T1 performance. On the contrary, T1 detection improved slightly, too, $F(1, 31) = 7.91$, $p < .01$, $\eta_p^2 = .203$. This result indicates that T1 performance was generally not at ceiling in the standard and free-association conditions.

The reward group did not show any notable improvement in T2 detection relative to the standard group ($F < 1$), except for a slight trend toward better performance at the longest lag, $t(31) = 1.41$, $p = .084$ (one-tailed). Thus, increased motivation does not appear to be a satisfactory account of the improved performance seen in the free-association and listen-to-music conditions. The results suggest that the duration, but not the magnitude, of the attentional blink may be reduced under conditions of higher motivation.

GENERAL DISCUSSION

The results show that performance on an attentionally demanding visual detection task may improve when the task is accompanied by task-irrelevant mental activity. This suggests that under conditions of rapid visual presentation, target detection may benefit from a diffusion of attention. There are several ways in which a more diffuse attentional state may have been induced by our experimental manipulations. First, the effects may be related to arousal. It is well known that overall arousal levels modulate attentional focusing (Aston-Jones, Rajkowski, & Cohen, 2000; Easterbrook, 1959; Kahneman, 1973; Yerkes & Dodson, 1908). Under normal circumstances, arousal levels may be set such that they allow for efficient focusing on T1, to the exclusion of T2. Decreased or increased arousal (as may have occurred in the free-association and music conditions) may make the attentional system more susceptible to other input, including T2. Second, thinking about one's holiday or listening to music may induce a positive affective state, something that has been shown to improve performance on several cognitive tasks, especially those requiring a broad, flexible operating mode (Ashby, Isen, & Turken, 1999). The same mechanism could also explain the slight overall improvement in T1 performance in the music condition. A third and more cognitive explanation is that it is actually the additional task itself that induces a more distributed state of attention. As attention widened to incorporate the extra task, it may have also widened temporally and thus included the second target in the letter stream.

In conclusion, our results show that providing some distraction (either through instruction to think about something else or through music) causes considerable improvements in detecting visual targets in a rapidly presented stream of items. These results have important implications for research on the attentional blink and related phenomena. Although researchers should continue their attempts to better understand the functional and neural mechanisms underlying the blink, an additional challenge will be to determine how this phenomenon interacts with the general mental state of the observer.

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