The cocktail party phenomenon revisited:
The importance of working memory capacity

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Wood and Cowan (1995) replicated and extended Moray's (1959) investigation of the *cocktail party phenomenon*, which refers to a situation in which one can attend to only part of a noisy environment, yet highly pertinent stimuli such as one's own name can suddenly capture attention. Both of these previous investigations have shown that approximately 33% of subjects report hearing their own name in an unattended, irrelevant message. Here we show that subjects who detect their name in the irrelevant message have relatively low working-memory capacities, suggesting that they have difficulty blocking out, or inhibiting, distracting information.

A fundamental question in cognitive science is how humans selectively attend to certain aspects of their environment, enabling detailed processing of those aspects, while of necessity ignoring other aspects. Beginning in England during World War II, psychologists developed laboratory tasks to identify individuals skilled in attending within a busy environment (Lachman, Lachman, & Butterfield, 1979). Cherry (1953) developed the dichotic listening procedure in which the task is to repeat aloud or "shadow" the message presented to one ear and ignore a different message presented to the other ear. Subjects were very successful in this task, but when asked to recall the content of an ignored message, they were able to report only physical features such as gender of the voice or whether the message was speech or tone; little or no semantic content was reported. Partly on the basis of this work, Broadbent (1958) developed a theoretical model of selective attention, according to which environmental stimulation is filtered out of awareness if it is identified as irrelevant to the subject's current concerns on the basis of its superficial physical features (e.g., voice, color, or location).

Broadbent's (1958) model has been seriously challenged, however, by demonstrations of *semantic* processing of unattended information. For example, Moray (1959) found that some subjects detect their own name when it

is presented in an unattended auditory channel. Contrary to popular belief, not all subjects demonstrate this "cocktail party effect." In fact, Moray found that only 33% of subjects reported hearing their own name when it is inserted into the irrelevant message. Using more sophisticated technology, Wood and Cowan (1995) replicated Moray's experiment and found 34.6% of subjects reported hearing their own name presented in the irrelevant message.

The purpose of the present experiment is to explain why some, but not all, subjects demonstrate the cocktail party effect. An examination of individual differences in the cocktail party effect raises some interesting possibilities. On the one hand, it is possible that the most capable subjects notice their names because they are able to monitor the irrelevant message with no damage to shadowing performance. On the other hand, it is possible that only the least capable subjects notice their names because they are poor at maintaining attention on the relevant message in the presence of distraction.

We measured subjects' capability using the construct of working memory, which is considered to be a cognitive system consisting of storage buffers as well as a central executive control mechanism. The function of working memory is to actively maintain goal-relevant information in the service of complex cognition (Baddeley & Hitch, 1974; Miyake & Shah, 1999). The limited capacity of working memory presumably constrains cognitive performance. We measured this capacity with the *operation span* task (Turner & Engle, 1989), in which series of displays were presented, each containing a simple mathematical problem and an unrelated word. The span was based on the length of the series that could be processed

with the subject still able to recall all of the words. Various investigations have demonstrated that individuals with high working-memory capacity out-perform individuals with low working-memory capacity on a range of tasks (Daneman & Carpenter, 1980; Daneman & Merikle, 1996; Engle, Tuholski, Laughlin, & Conway, 1999; Gilhooly, Logie, Wetherick, & Wynn, 1993; Toms, Morris, & Ward, 1993) and that individuals who score high on tests of working-memory capacity are better at blocking out, or inhibiting, distracting information (Conway & Engle, 1994; Conway, Tuholski, Shisler, & Engle, 1999; Gernsbacher, 1993; Hasher & Zacks, 1988; Rosen & Engle, 1997). We used the operation span task to identify high and low working-memory capacity individuals and had subjects perform a dichotic listening task in which their own name was presented in the irrelevant message, following as closely as possible the procedure reported by Wood and Cowan (1995).

METHOD

Subject Selection

The sample comprised 40 (17 male, 23 female) native English speaking undergraduates from the University of Illinois at Chicago with normal hearing, who received course credit for participation. Informed consent, approved by the local internal review board, was obtained from all subjects. Half were categorized as having a high working-memory span and half a low working-memory span on the basis of scores that fell in the upper or lower quartile of a larger sample of subjects who carried out the operation span task. All subjects repeated the same relevant message, but half of each span group was randomly assigned to an experimental condition in which the subject's first name occurred after 4 min of shadowing and the other half, after 5 min of shadowing. Any subject who received his or her name at 4 (or 5) min also received a yoked subject's name at 5 (or 4) min.

Operation Span Task Procedure

The procedure was adapted from a previous study (Turner & Engle, 1989) to measure working memory capacity. The subject was presented with a series of displays on a computer screen. Each display contained a mathematical operation and an unrelated word (e.g., IS $(6+4)/2 = 5$? DOG). The subject's task for each display was to say the equation aloud, answer "yes" or "no" as to whether the equation was true, and then say each word. When the series of displays ended, the task was to write all of the words on a response sheet. The number of displays in a series varied from 2 to 6. Three series of each length were presented for a total of 15 series, with series length randomized and not predictable by the subject. The subject's span score was the cumulative number of words recalled from series that was perfectly recalled in the correct serial order, with no points awarded for imperfect recall of a series. The average score was 24.85 (range of 17–44) for high-span subjects and 8.22 (range of 6–12) for low-span subjects. Subjects in the middle two quartiles of the range of span scores were omitted from the study. Performance levels on various versions of verbal working-memory tasks like this one are highly correlated with one another (Daneman & Merikle, 1996; Engle et al., 1999).

Selective Listening Procedure

Subjects were tested individually in a well illuminated, sound-insulated room. The auditory stimuli, obtained from Wood and Cowan (1995), were recorded onto a normal-bias audio cassette and then digitized onto a computer at a sampling rate of 22 kHz and dynamic range of 16 bits. They were presented through stereo headphones at a constant volume for all subjects. The relevant message contained 330 monosyllabic words recorded in a monotone female voice at the rate of 60 words per minute and lasted 5.5 min. The irrelevant message contained 300 monosyllabic words recorded in a monotone male voice. The onset of the irrelevant message began 30 sec after the attended message, allowing for a brief practice period without distraction. The onsets of the words were synchronized across messages. The order of the words was identical across subjects except for the names, which were digitally inserted into the irrelevant message in place of a word after 4 and 5 min of shadowing. Each subject's first name was inserted into the irrelevant message. The experimenter was aware of each subject's name because each had previously been in the lab to perform the operation span task.

Subjects were instructed to listen to the message presented to the right ear and to repeat (shadow) each word as soon as it was presented, making as few errors as possible and to ignore the distractions coming to the left ear. Subjects shadowed until all sounds in the attended message stopped. During shadowing, the experimenter was seated at a separate table in the same room and recorded shadowing errors. After shadowing, the subject completed a questionnaire regarding the irrelevant message, identical to one used by Wood and Cowan (1995). Subjects stating that they detected something unusual in the irrelevant message when queried went on to specify that it was their own name.

RESULTS AND DISCUSSION

Using retrospective report immediately after the shadowing task, we found that 20% of high-span subjects and 65% of low-span subjects reported hearing their name in the irrelevant message (see Figure 1). Fisher's exact test indicated that the probability of obtaining these proportions by chance alone (under the assumption that high- and low-span subjects actually are equally prone to detecting their name in the irrelevant message) is only $p = .005$. No subject reported hearing a yoked control subject's name that also was presented. Clearly, the low-span subjects detected their own names more often.
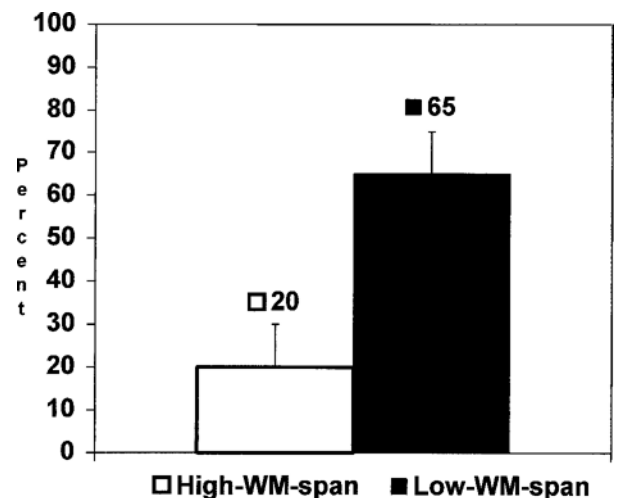

Figure 1. The proportion of high- and low-span subjects who reported hearing their name in the irrelevant message.
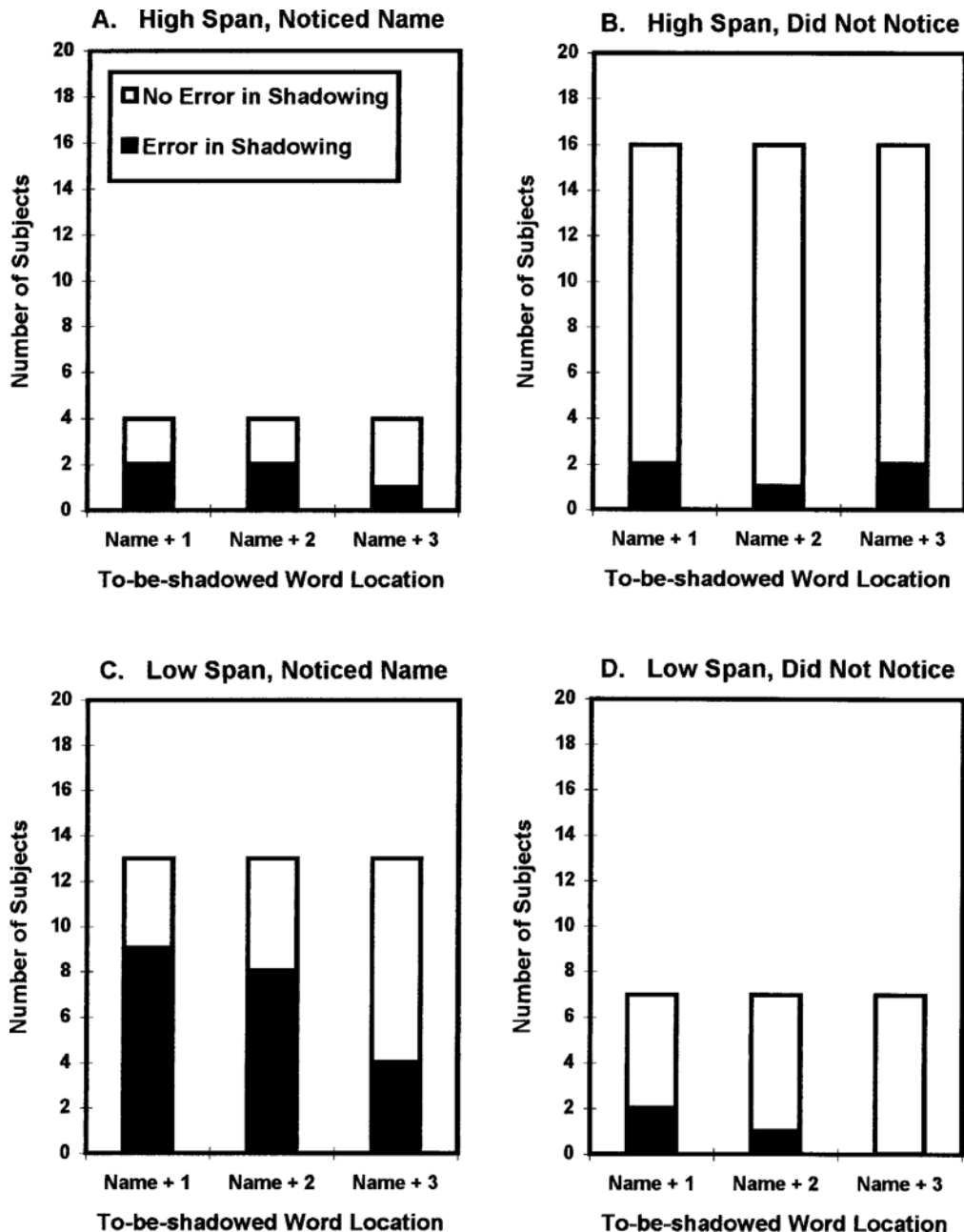
A. High Span, Noticed Name

No Error in Shadowing
Error in Shadowing

Number of Subjects

Name + 1   Name + 2   Name + 3

To-be-shadowed Word Location

B. High Span, Did Not Notice

Number of Subjects

Name + 1   Name + 2   Name + 3

To-be-shadowed Word Location

C. Low Span, Noticed Name

Number of Subjects

Name + 1   Name + 2   Name + 3

To-be-shadowed Word Location

D. Low Span, Did Not Notice

Number of Subjects

Name + 1   Name + 2   Name + 3

To-be-shadowed Word Location

Figure 2. The number of high- and low-span subjects who did and did not notice their own names in the irrelevant message in a selective listening task (heights of frequency bars), and the proportion of those subjects who made errors in shadowing words in the relevant message (dark portion of bars) that occurred 1, 2, or 3 words after the subject's name (abscissa parameter). Panel A: High-span subjects who noticed their names. Panel B: High-span subjects who did not notice their names. Panel C: Low-span subjects who noticed their names. Panel D: Low-span subjects who did not notice their names. Many more low-span subjects noticed their names, and subjects who noticed their names made proportionally many more shadowing errors in the name+1 and name+2 positions.

Low-span subjects also encountered more difficulty performing the shadowing task. This is reflected in the finding that low-span subjects committed significantly more shadowing errors ($M = 20.88$) than did high-span subjects ($M = 10.00$) [$t(32) = 2.18, p = .04$]. Given this finding, we wanted to ensure that the name-detection difference between high- and low-span subjects was not simply a result of more attention shifts on the part of the low-span subjects. Therefore, we examined shadowing errors for the two words in the relevant message preceding

the name. There were no group differences in shadowing two words before the name [$t(32) = 1.0$, $p > .10$] or one word before the name [$t(32) = 1.0$, $p > .10$], ruling out the possibility that the low span subjects detected their names more often than did the high-span subjects, simply because their attention wandered to the irrelevant message at the opportune time (in fact, only one person committed a shadowing error on either word). There was a difference between high- and low-span subjects in shadowing errors committed concurrently with the presentation of the name [$t(32) = 2.59$, $p = .01$], suggesting that the presentation of the name resulted in distraction much more so for low-span subjects.

We also examined shadowing errors after the presentation of the name. Presumably, detecting one's own name in the irrelevant message would result in a decrement to performance of the shadowing task. As shown in Figure 2, a much higher proportion of subjects who noticed their name made shadowing errors on the two words following the name (marked "name+1" and "name+2"). On the two words to be shadowed immediately after presentation of their own name, high-span subjects who reported hearing their name made significantly more shadowing errors than those who did not [$t(15) = 3.04$, $p = .01$]. Similarly, on these two words, low-span subjects who reported hearing their name made more shadowing errors than those who did not [$t(15) = 2.50$, $p = .03$]. Thus, the pertinence of the subject's own name sometimes served as a distraction and resulted in a reallocation of attention to the name, significantly more frequently in low-span subjects. However, this distraction did not persist for more than two words. High-span subjects who reported hearing their own name were no more likely to commit a showing error three words after the name than were high-span subjects who did not report hearing their own name [$t(15) = 0.75$, $p > .10$]. Similarly, low-span subjects who reported hearing their own name were no more likely to commit a shadowing error three words after the name than were low-span subjects who did not report hearing their own name [$t(15) = 1.74$, $p > .10$].

The higher incidence of name detection in low-span subjects is particularly striking because the opposite result was possible. It could have been that high-span subjects, because of their greater capacity, have the ability to monitor the irrelevant message so as to hear their names. This certainly was not the case. The critical factor seems to be the ability to block information from the irrelevant message. High-span subjects are more capable of this and were therefore less likely to hear their names, and they also were less susceptible to a consequential disruption of relevant task performance.

Also striking is that the operation span task is essentially a divided attention task, whereas the dichotic listening task is clearly a selective attention task, yet subjects who performed well on one task also performed well on the other. Therefore, it is clearly not the case that some subjects habitually or spontaneously divide their attention when performing cognitive tasks. Rather, it ap-

pears that there is a general cognitive ability that allows subjects to perform well on both tasks. We argue that this ability is intimately linked to working memory capacity.

Working memory capacity is a critical cognitive characteristic, and one's capacity has a major impact on the quality of cognitive performance. Some researchers even suggest that working memory capacity is the most important factor in general fluid intelligence (Conway, Cowan, Bunting, Therriault, & Minkoff, in press; Engle et al., 1999; Kyllonen, 1996). A fundamental aspect of intelligent behavior, linked to working memory, is the ability to inhibit distracting information (Dempster, 1991). Although the present experiment does not provide direct evidence of inhibition of information presented in the irrelevant channel, the interpretation that high-span subjects are better at inhibiting distracting information than are low-span subjects is consistent with previous research. For example, in the context of memory retrieval, several experiments have demonstrated that high-span subjects are more likely to reveal retrieval inhibition effects and subsequently less proactive interference than are low-span subjects (Conway & Engle, 1994; Kane & Engle, 2000; Rosen & Engle, 1997, 1998). Also, high-span subjects reliably reveal the negative priming effect, whereas low-span subjects do not (Conway et al., 1999). Whether or not an inhibitory mechanism is necessary to account for these findings, it is clear that the ability to handle cognitive interference is a dimension on which high- and low-working memory span individuals differ.

Finally, the present result does not answer the question of whether working memory capacity drives inhibitory ability or vice versa. One interpretation is that working memory capacity is a "resource" that fuels the central executive, which is responsible for maintaining activation to relevant information and suppressing distracting information (Conway & Engle, 1994). Another interpretation is that working memory capacity refers to the "contents" of working memory, and as such, inhibitory ability regulates the contents and therefore the capacity of working memory (Hasher & Zacks, 1988). The present results are compatible with either view. Our goal here is not to resolve this issue but to demonstrate the importance of working memory for classic selective attention tasks such as dichotic listening and to possibly extend the range of tasks of working memory that will be investigated, which will ultimately lead to a better understanding of the working memory system, selective attention, and inhibition.

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