Counting Backwards Produces Systematic Errors

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Subjects rapidly counting backwards made two types of systematic errors. They missed repeated digits (e.g., 77) and decade numbers (e.g., 80). The percentage of repeated-digit errors increased, and the percentage of decade-number errors decreased when subjects said only the digits comprising a given number (e.g., "three-four" instead of "thirty-four"). This pattern of errors was explained in terms of the short-term memory processes involved in counting.

Most psychologists would agree that counting reflects the operation of fundamental cognitive processes. In developmental psychology, for example, counting behavior is often used to make inferences about children's conception of number and, as a consequence, their general state of cognitive development (e.g., Gelman & Gallistel, 1978). Among researchers of human memory, however, the counting task has received surprisingly little attention. Instead, it has come to be known primarily as a technique for "cleaning out" the contents of short-term memory; that is, counting is often used merely as a distractor task through which researchers can obtain an uncontaminated assessment of long-term memory (see, e.g., Glanzer & Cunitz, 1966; Peterson & Peterson, 1959). This article seeks to bring the counting operation to the attention of memory theorists by documenting a rather striking pattern of errors that occurs when subjects count backwards. This error pattern is of potential interest because it suggests that there may be a systematic breakdown in the memory processes involved in counting.

Our investigation developed as a response to a series of observations that we made during some recent incidental learning experi-

ments (Nairne, 1983). In these experiments, subjects were asked to count backwards aloud, starting from 100 and ending with 0, as quickly as possible. The purpose of the task was simply to distract the subject prior to the presentation of a surprise recognition test for some earlier presented material. We noticed, however, that during performance of the task, subjects tended to make several systematic errors in their counting. In particular, they tended to omit two types of numbers: (a) numbers for which the first and second digits are the same (i.e., repeated digits: 99, 88, 77, 66, 55, 44, 33, 22, 11) and (b) numbers that are multiples of 10 (decade numbers: 90, 80, 70, 60, 50, 40, 30, 20, 10).

To account for why subjects might tend to miss these two types of numbers, we began with the assumption that when subjects count backwards, they control their position in sequence by closely monitoring the second digit comprising a given number (e.g., thirty-four, thirty-three, thirty-two). Such a strategy might result because it is the second digit that tends to provide the relevant information. The first digit of the number (the decade prefix; e.g., ninety, eighty, seventy) is redundant for the majority of its given interval. During the course of counting, the subjects maintain their position by checking the current contents of short-term memory to determine which digit has just been said and thus what is the next second digit in the sequence. In those cases in which the decade prefix and the next second digit sound similar (e.g., seventy-seven, sixty-six, forty-four), subjects may mistakenly conclude that the next second digit in sequence has already been said because the similar sounding decade prefix is
Table 1

<table>
<thead>
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<th>Decade digit</th>
<th>9</th>
<th>8</th>
<th>7</th>
<th>6</th>
<th>5</th>
<th>4</th>
<th>3</th>
<th>2</th>
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<tbody>
<tr>
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<td>1</td>
</tr>
</tbody>
</table>

Note. The entries in the first row represent the errors made on the numbers 99, 98, 97, and so forth; the numbers 100 and 0 were not included in the analysis. N = 59.

already represented in short-term memory. Under these conditions, subjects may hesitate or omit that number and go on in the counting sequence. Similarly, in those cases in which there is no second digit to be reported next because the next correct response is the decade prefix alone (e.g., ninety, eighty, seventy), subjects may mistakenly conclude that the next number in the sequence has already been said because the decade prefix is already in short-term memory.

We devised a straightforward test of these hypotheses by comparing the standard counting-backwards task with a task in which subjects were told to say only the digits comprising a given number as they counted. For example, whereas the subjects would say “thirty-four, thirty-three, thirty-two” in the standard task, they would respond “three-four, three-three, three-two” in the new task. According to our hypotheses, the new task should be an especially good technique for producing errors of the first type because the first and second digits for the repeated-digit numbers would sound exactly the same (e.g., three-three, two-two, one-one). On the other hand, the new task should yield relatively few errors of the second type because there would be a second digit (zero) to be reported for the decade numbers in this task (e.g., nine-zero, eight-zero, seven-zero).

Method

We tested 59 subjects counting backwards in our two related tasks. The subjects were all undergraduate students at the University of Colorado participating for course credit. In the standard condition, subjects were told simply to count backwards from 100 to 0 as fast as possible. Speed was emphasized to the extent that subjects were told not to be overcautious about making errors at the expense of reducing their counting rate. Similar instructions were given in the digit condition except that subjects were told to say only the digits comprising each number when counting. All subjects participated in both of these counting tasks, and task order was counterbalanced across subjects. The responses of all 59 subjects were recorded on tape and scored later by two independent raters.

Results and Discussion

The results are summarized in Tables 1 and 2, which display errors for the standard and digit conditions, respectively. An error was defined as an omission of a number in its proper sequence. These errors actually took two forms: (a) subjects would omit a number entirely (e.g., 79, 78, 76) or (b) omit a number but return and correct themselves (79, 78, 76, 77, 75). In this latter case, only the number 77 was counted as an error because it was passed by in the sequence. In addition, sometimes subjects would repeat a number in sequence (79, 78, 77, 77, 76), but this mistake was not counted as an error.3

Examination of Table 1, which shows errors for the standard condition, reveals the kind of systematic pattern anticipated. Out

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1 We assume that the representation of the numbers in short-term memory is acoustic or articulatory (see Conrad, 1964; Hintzman, 1967), although we do not deny that short-term memory may involve semantic or visual coding under some circumstances (see, e.g., Healy, 1977; Shulman, 1971).  
2 We use the term short-term memory with some hesitation because we are not yet able to determine whether the relevant memory store has the properties of short-term memory, as described, for example, by Lee and Estes (1981), or, rather, of the less durable precategorical acoustic store, described by Crowder and Morton (1969).  
3 In a study in which subjects generated two intercollated series including the successive letters of the alphabet and a descending number sequence, Crowitz (Note 1) found that repetition errors were as frequent as omission errors. However, such repetition errors were not common in our experiment, perhaps because responses were oral, rather than written as in the Crowitz study, or because there was no additional alphabetic memory load in our experiment.
of a total of 72 errors, 42% occurred on the repeated digits, and 36% occurred on the decade numbers; thus, overall, 78% of all errors occurred on these two number types. Table 2, which shows errors for the digit condition, also shows a systematic, although somewhat different, error pattern. Out of a total of 190 errors, 66% occurred on the repeated digits, but only 9% occurred with the decade numbers. To assess the statistical reliability of these effects, a repeated measures analysis of variance was conducted with two levels of task type (digit and standard) and three levels of error type (repeated digit, decade number, and remainder). This analysis was performed on the percentages of possible errors for each subject in an effort to equate the different error potentials across the error types. The analysis revealed highly significant effects ($p < .001$) of task type, $F(1, 58) = 29.4$, $MS_e = 94$, error type, $F(2, 116) = 52.2$, $MS_e = 115$, and the interaction of task with error type, $F(2, 116) = 33.7$, $MS_e = 96$.

Summary and Conclusions

Several results are clear. First, subjects, regardless of task, committed an unusually large number of errors on the repeated digits. In the digit condition, for example, over 50% of the subjects missed the number 77. Although it is not certain exactly why these numbers were missed so frequently, we suggest that similarities in sound between the decade prefix and the second digit may play an important role. This conclusion is supported by the predicted increase in repeated digit errors in the digit condition. In addition, the errors in this condition tended to occur more consistently across the different repeated-digit examples (e.g., 55, 44, 33) than in the standard condition. This consistency is not surprising given that the first and second digits sound exactly the same for all repeated-digit numbers in this task but often sound somewhat different in the standard task (e.g., thirty-three, twenty-two, eleven). Second, as predicted, the relative incidence of decade-number errors is reduced in the digit task. Decade-number errors accounted for 36% of the total errors in the standard condition compared with only 9% in the digit condition. Although some evidence is present that subjects have a tendency to omit the decade numbers even in the digit condition, the general pattern is consistent with the hypotheses we outlined earlier.

These results therefore provide striking evidence for systematic failures in counting-backwards performance. There is little question that the breakdowns observed here were enhanced by the strains induced by our emphasis on counting speed. Nevertheless, the error pattern we found should provide insight into the cognitive processes invoked in counting both inside and outside the laboratory. In particular, these patterns may help to elucidate the important role of short-term memory processes in the counting task.

Reference Note


References

Glanzer, M., & Cunitz, A. R. Two storage mechanisms


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