Serial Pattern Learning by Event Observation: Effects of Varying Amounts of Pattern Experience

Roger Stubblefield
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SERIAL PATTERN LEARNING BY EVENT OBSERVATION:
EFFECTS OF VARYING AMOUNTS OF PATTERN EXPERIENCE

A Thesis
Presented to
the Faculty of the Department of Psychology
Western Kentucky University

In Partial Fulfillment
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Master of Arts

by
Roger Allen Stubblefield
August, 1995
SERIAL PATTERN LEARNING BY EVENT OBSERVATION:
EFFECTS OF VARYING AMOUNTS OF PATTERN EXPERIENCE

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Director of Thesis

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This paper is dedicated in memory of Robert "Bob" Wurster.
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SERIAL PATTERN LEARNING BY EVENT OBSERVATION:
EFFECTS OF VARYING AMOUNTS OF PATTERN EXPERIENCE

R. Allen Stubblefield
August, 1995
42 pages

Directed by: S. Mutter, D. Roenker, J. Bilotta

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The present study was designed to replicate the findings by Howard, Mutter & Howard (1992) that (1) overt behavioral responding is not prerequisite to serial pattern learning and (2) that observation produces a qualitatively different form of representation than an overt motor response. We also sought to extend these findings by determining how much exposure to the pattern is necessary to replicate these effects and by examining the role of stimulus-to-response mapping by adding an additional response group (unmapped-response). A version of the serial learning task used by Howard et al. (1992) was used. The task consisted of two phases. During the *acquisition phase*, an asterisk appeared in one of four locations on a video monitor. Three groups received either 1, 2, or 3 blocks of trials in which the position of the asterisk followed a 10-trial pattern (pattern block). Subjects in each group either (1) manually responded to the asterisk location (mapped-response group), (2) simply observed the asterisk locations (observation group), or (3) made a manual response that was unrelated to the pattern (unmapped-response group). During the remaining three blocks of the acquisition phase all groups responded to the asterisk location. Of the three remaining acquisition blocks, the first and third blocks were pattern blocks, while the location of the asterisk on the second block was determined randomly (random block). The difference in response times between the random block and the preceding pattern block provided an indirect measure of pattern learning. During the *prediction phase*, subjects predicted the locations of the asterisk. Prediction accuracy provided a direct measure of pattern learning.

Results of our indirect measure of pattern learning supported the findings by Howard
et al. (1992) that overt behavioral responding is not prerequisite to serial pattern learning. In addition, the amount of training strongly influenced both procedural and declarative learning. However, we were unable to find conclusive evidence to support the proposal by Howard et al. that observation produces an advantage over response on the direct measure of pattern learning. One possible reason for this could have been low statistical power to detect group differences. Because effect sizes for group differences were small to moderate (group, $\eta^2 = .04$; group by training, $\eta^2 = .06$), and power analyses for these effects indicated that power was very low (group, power = .40; group by training, power = .45), we could not rule out this possibility. A second possible reason could have been a slight difference in methodology. While Howard et al. included only one awareness probe (following prediction), our design included two awareness probes (one following acquisition and one following prediction). It is possible that the addition of the early awareness probe obscured group differences by sensitizing subjects to the possibility of a pattern. Further research employing greater power and different methodology will be needed to resolve this issue.
Chapter I

Introduction

In recent years, there has been considerable interest in the question of how serial pattern knowledge is acquired. Two major theoretical positions have been proposed (e.g., Fendrich, Healey, & Bourne, 1991; Howard, Mutter, & Howard, 1992; Stadler, 1989; Willingham, Nissen, & Bullemer, 1989). The perceptual learning hypothesis holds that serial pattern knowledge may develop through the independent acquisition of either perceptual or motor knowledge. Perceptually-based knowledge could facilitate response to serially ordered stimulus events by allowing the subject to anticipate and/or shift attention toward the subsequent item in the series. Motor response-based knowledge could similarly manifest itself by allowing the subject to prepare in advance for each response. In contrast, the response learning hypothesis is based upon the premise that both a perceptual and motor response are necessary for the acquisition of serial pattern knowledge. Within this framework, serial pattern knowledge is encoded as a series of condition-action rules, whereby the condition (e.g., serial position) is directly mapped to the action (e.g., response to subsequent serial position) rather than to a more general perceptual representation of the stimulus condition as it relates to external space. Thus, according to this hypothesis, any disruption of the connection between the stimulus condition and its corresponding motor response would forestall serial pattern learning.

The present study addresses two main issues: (a) how serial pattern knowledge is acquired, i.e., perceptually or motorically and (b) the effect of varying levels of pattern experience on procedural and declarative acquisition of a serial pattern. First, we addressed the issue of how serial pattern knowledge is acquired. To do this we divided volunteers into three groups. The groups were defined by the type of response that was required during the acquisition phase. In the observation group, subjects were instructed to merely watch the presentation of each stimulus item. Since no motor response was required under
this condition, pattern knowledge must emerge from a perceptually-based source. The perceptual learning hypothesis predicts that perceptually-based knowledge is sufficient for the acquisition of serial pattern information. If this is the case, then learning should take place under conditions of mere observation. According to the response learning hypothesis, however, both a perceptual and motor response are necessary for serial pattern learning to occur and, thus, no pattern knowledge should emerge under the observation condition. In the mapped-response group, subjects made a motor response which was directly mapped to the stimulus location. Under these conditions, serial pattern knowledge may develop through either perceptual or motor characteristics of the task, or both. Both the perceptual learning hypothesis and the response learning hypotheses predict that learning would take place under this condition. In the unmapped-response group, subjects were instructed to respond to the presentation of each stimulus item. However, unlike the mapped-response group, their responses were not based on the location of the stimulus items. According the response learning hypothesis, the incongruity between the stimulus location and its corresponding motor response would prevent the formation of condition-action rules that map each stimulus item to its corresponding motor response. The response learning hypothesis would, therefore, predict that the breakdown of direct stimulus-to-response mapping for the unmapped response group would prohibit the development of serial pattern knowledge. On the other hand, the perceptual learning hypothesis predicts that, under these conditions, perceptually-based knowledge would be sufficient for serial pattern learning to occur. From this perspective, the inclusion of a motor response that is not mapped to the location of the stimulus item would be viewed at best as irrelevant to learning and, at worst, as a source of distraction from encoding of perceptually-based information.

The second main issue was to determine the effect of varying levels of pattern experience on procedural and declarative acquisition of a serial pattern. To address this issue, we varied the amount of pattern exposure for each of the three groups. For each
group, training varied from one block (1-block training), to two blocks (2-block training), to three blocks of training trials (3-block training). We expected additional training to enhance performance for all groups. However, we were less certain about the relative effects of practice on each of the groups -- that is, would training enhance the performance of all groups to the same degree? We predicted that training would have similar effects on all groups for the indirect measure of pattern learning. We also predicted that any differences which may exist between observation and the mapped-response groups on the direct measure would be maintained at all levels of training.
Chapter II  
Review of the Literature

Five studies have provided evidence in support of either the perceptual learning or response learning hypothesis. The first of these studies (Willingham, Nissen, & Bullemer, 1989) provided evidence in favor of the response learning hypothesis. The remaining four studies (Cohen, Ivry, & Keele, 1990; Fendrich, Healey, & Bourne, 1991; Howard, Mutter, & Howard, 1992; Stadler, 1989) provided evidence supporting the perceptual learning hypothesis.

Willingham, Nissen & Bullemer (1989, Exp. 3) found evidence in support of the response learning hypothesis. In this task, four keys were positioned relative to four possible stimulus locations on a computer monitor. During acquisition, however, each subject's response was based not on the relative position of the stimulus, but rather on the color of the stimulus item. The order of presentation of the colors resulted in three possible conditions, and each subject was assigned to only one of these conditions. In the perceptual sequence condition, the presentation of colors (along with corresponding motor responses) followed a random pattern, but the location in which the stimulus appeared followed a 10-trial pattern. In the motor sequence condition, the sequence of color presentations followed a 10-trial pattern, but the stimulus location was random. Thus, the perceptual characteristics were random, but the motor responses followed a pattern. In the control condition, both the stimulus color and location were random. Results showed that, compared to controls, the perceptual sequence group failed to display a drop in response latency during the acquisition blocks, while the subjects in the motor sequence group showed a significant relative decline in response latency. Following the acquisition blocks, all groups were given a transfer task in which they responded to the relative position of a color stimulus. In each block, the location of the stimulus followed 10 repetitions of a 10-trial pattern. Results showed that, during transfer, both the perceptual and motor sequence groups failed to show a greater reduction in response latency than controls. These results
were interpreted by Willingham et al. (1989) to suggest that subjects had acquired their knowledge of the task as a result of an overt response (i.e., a button press), rather than by a perceptual response to the stimulus location. Willingham et al. also concluded that the failure of both the motor and perceptual sequence groups to display a reduction in response latency during the transfer task was evidence that the representation of the motor sequence was not independent of the perceptual characteristics of the task. Rather, it was argued that subjects had learned a series of condition-action statements which map each stimulus condition (i.e., color) onto its appropriate response.

Cohen, Ivry, & Keele (1990, Exp. 2) examined the role of motor response in serial learning by manipulating the effector systems used during overt motor response. In this task, subjects were instructed to use three fingers to press each of three keys which corresponded to the location of a stimulus which could appear in one of three positions on a video monitor. Following training, subjects were separated into two transfer groups. The first group (structured group) responded to 10 blocks of the same 10-trial pattern, while the second group (random group) responded to 10 blocks of a 100-trial sequence in which the location of the stimulus was determined randomly, the only constraint being that the same position was not repeated on successive trials. The critical change for both groups, however, was a change in response effector systems -- that is, each group was now required to respond with only one finger rather than with three. According to Cohen et al. (1990), the manipulation of response modality changed the primary effector system from the individual fingers to that of the arm. The difference in response time for the structured group versus the random group was used as an index of pattern learning. Following transfer, response times for the random group greatly increased, while the response times for the structured group showed no such increase. Cohen et al. (1990) concluded that serial pattern knowledge exists independently of the specific effector system used during acquisition. These findings fail to support the response learning hypothesis because a disruption in the connection between the stimulus condition and its corresponding
response, via a change in effector system, should have prevented the transference of serial pattern knowledge.

Using a different task, Stadler (1989) also found evidence in support of the perceptual learning hypothesis. In this task, subjects responded by pressing a button which corresponded to one of four quadrants in which the target stimulus appeared. The first six trials were "simple" trials in which only the target item appeared in one of the four quadrants. The seventh trial was a "complex" trial in which the target item was embedded within an array of 35 distracter items. The first six trials described complex rules which predicted both the quadrant and the location within the quadrant in which the target item appeared during the seventh trial. Following extensive training with the seven trial sequences, subjects were switched to a position transfer task in which, on the seventh trial, the location of the target item within the quadrant was switched to the diametrically opposite corner. Therefore, the rules governing which quadrant would contain the distracter digit, and the response made to that position, remained the same but the perceptual characteristics of the target within the quadrant were changed. After retraining with the original 7-trial sequence, subjects switched to a response transfer condition in which the quadrant, and location within the quadrant, remained unchanged but the fingers required to make the response were different. According to Stadler (1989), the position transfer condition would only affect subjects if the information were encoded by perceptual rather than response characteristics; whereas the response transfer condition would affect subjects only if the information were encoded as a sequence of motor responses. Larger negative transfer effects were found for the perceptual transfer condition than for the response transfer condition. Stadler (1989) concluded that acquisition of the rules was based primarily on the perceptual characteristics of the task.

Similar results were obtained by Fendrich, Healey, & Bourne (1991, Exp. 2). In this task, subjects entered lists of 4 digit sequences on a keypad layout similar to that of a calculator. Following a one week retention interval, subjects entered four digit sequences
in which the keypad layout had been changed to the format of a touch-tone telephone. Some of the digit sequences were the same as earlier sequences but, because of the change in the keypad layout, required different responses (old digit). Other digit sequences were not presented during acquisition, but required the same sequence of motor responses as the previous sequences (old motor). Still other sequences were novel with respect to both the response pattern, and the sequence of digits (new lists). Both the old digit and old motor lists showed an advantage in entry speed over the new lists. Fendrich et al. (1991) concluded that perceptual and motor information were encoded separately during acquisition.

Using a variation of the serial reaction time task developed by Nissen and Bullemer (1987), Howard, Mutter, and Howard, (1992, Exp. 2) also found evidence in favor of an independent perceptual mechanism involved in serial pattern learning. Subjects were assigned to one of two groups. The first group completed three blocks of trials in which they were to press one of four keys in response to the location of an asterisk which could appear in one of four possible locations on a video monitor (response group). Subjects in group two observed the presentation of the asterisks without making a manual response during the first 3 blocks (observation group). Following the third block, both groups responded for three additional blocks. Blocks 1-4 and block 6, were pattern blocks in which the location of the asterisk followed 10 repetitions of a 10-trial pattern. The fifth block was a random block in which the location of the asterisk was determined on a random basis. The difference in response times for the fourth (pattern block) and fifth (random block) blocks was used as an indirect measure of pattern learning. The measure was "indirect" in the sense that learning was inferred from changes in motor performance, rather than requiring the subject to deliberately remember the pattern (Richardson-Klavehn & Bjork, 1988). The seventh block was a generation block in which the subject responded by pressing the key which corresponded to the location of the next asterisk. The accuracy of both groups on the seventh block was used as a direct measure of pattern knowledge.
The measure was "direct" because the instructions required the subject to deliberately make use of information obtained during the acquisition phase (Richardson-Klaven et al., 1988). Results yielded equivalent performance for the observation versus response groups on the indirect measure. Howard et al. (1992) concluded that mere observation produced coding of spatiotemporal properties of the pattern similar to that of response (cf. Bandura, 1986; cf. Lashley, 1951). However, during the first two cycles of the generation block (direct measure of learning), the observation group performed better than the response group. According to Howard et al. (1992), these findings extend those of the previous work by suggesting not only that overt motor response is not necessary for serial pattern learning to occur, but also that observation produces a representation which is more amenable to deliberate recollection. This dissociation provided support for the position that observation produces a qualitatively different representation than response.

**Procedural/Declarative distinction.**

It has been suggested that there are two qualitatively different types of representations in memory. A number of researchers interested in serial pattern learning recognize a distinction between procedural versus declarative memory (e.g., Squire & Cohen, 1984; Nissen, & Bullemer, 1989; for alternate distinctions see also Richardson-Klavehn, & Bjork, 1988). Procedural memory reflects knowledge and retention of skilled motor performance resulting from prior experience (Cohen, 1984). An example of this form of learning is expressed in tasks such as skilled typing (Rumelhart & Norman, 1982). The indirect measure of pattern learning in the serial learning task most likely reflects procedural knowledge because learning is inferred from changes in motor performance without referring to the prior learning episode (Cohen, 1984). By contrast, declarative memory supports the acquisition and retention of factual knowledge and the deliberate recollection of prior events (Cohen, 1984). The generation portion of the serial learning task most likely reflects declarative knowledge of the pattern because subjects deliberately use prior information to generate the pattern.
Using the serial reaction task, Nissen and Bullemer (1987) found that procedural knowledge of a pattern was evident within the first block of 100 trials, despite the fact that some subjects did not report awareness of the pattern following as many as four blocks. This finding raised the issue of the temporal relationship between procedural and declarative learning -- that is, does one form of learning precede the other, or are the two forms acquired independently? Willingham et al. (1989, Exp. 2) found evidence that the two forms of knowledge are acquired independently. Using the serial reaction task, subjects were given from zero to six blocks in which a manual response was made to a repeating pattern sequence. Subjects' awareness of the pattern was then assessed via verbal report, which in turn was followed by the generation task. This method allowed Willingham et al. (1989) to track the amount of procedural versus declarative knowledge, as a function of the amount of exposure to the pattern. Results showed that practice strengthened both procedural and declarative learning. However, the relative effect of practice on declarative versus procedural learning was not the same for all subjects -- that is, practice led some subjects to acquire procedural knowledge prior to declarative knowledge, while practice led other subjects to develop declarative knowledge before procedural knowledge. Willingham et al. (1998) concluded that, in the serial reaction task, one form of knowledge is not prerequisite to the development of the other form.

Howard et al. (1992) demonstrated that overt behavioral responding is not prerequisite to serial pattern learning. This evidence was based on the fact that there were no differences between the observation versus mapped-response groups on the indirect measure of pattern learning. However, on the direct measure of pattern learning, a group by pattern cycle interaction was found. This interaction was the result of superior performance of the observation group during the first two pattern cycles of the prediction block, followed by no group differences during the remaining pattern cycles. This finding led Howard et al. to conclude that observation produces a more declarative representation in memory than does response. The present study was designed to replicate the findings by
Howard et al. (1992) that (a) overt behavioral responding is not prerequisite to serial pattern learning and (b) that observation produces a qualitatively different form of representation than response. We sought to extend these findings by determining how much exposure to the pattern is necessary to replicate these effects, and by examining the role of stimulus-to-response mapping by adding an additional response group (unmapped-response). The following specific hypotheses were tested.

a) Observation and mapped-responding will lead to equivalent performance on the indirect measure of pattern learning, while unmapped responding will lead to poorer performance than either observation or mapped responding.

b) Training will produce similar effects on indirect test performance for the observation and both response groups. Specifically, greater training will lead to better performance.

c) The observation groups will show greater accuracy during prediction than the mapped-response group, which in turn will show better performance than the unmapped-response group on the direct measure of pattern learning (i.e. prediction).

d) Training will produce similar effects on direct test performance (i.e., prediction) for the observation and both response groups. Specifically, greater training will lead to greater prediction accuracy.

We were also interested in whether group and/or training would be related to pattern awareness. Given that previous research (Howard et al., 1992) has shown that observation leads to a more declarative representation than does a mapped-motor response, we predicted that the observation groups would be more likely to report pattern awareness than the mapped-response or unmapped-response groups. We also predicted that additional training would lead to higher rates of reported pattern awareness. Finally, we sought to determine whether any of our subtests were related to performance on the indirect or direct measures. Previous research (Reber, Walkenfeld, & Hernstadt, 1991) has shown that performance on direct memory tasks correlated strongly with traditional measures of IQ (i.e., WAIS-R), while performance on indirect tasks showed no relationship to these
measures. We, therefore, expected to find a relationship between the WAIS-R subtests used in the present study (i.e., Vocabulary, Digit-Symbol, and Digits Backward) and our direct measure of pattern learning (prediction), but we expected to find no relationship between these measures and our indirect measure of pattern learning. We predicted that our remaining tests (i.e., Location Span and Hidden Figures) would also be related to our direct measure, but not with our indirect measure. These propositions led to us to the following hypotheses:

a) The observation group will show higher rates of reported pattern awareness than either the mapped-response or unmapped-response groups.

b) Training will be positively related to reported pattern awareness.

c) The WAIS-R subtests Vocabulary, Digit-Symbol, and Digits Backward will be related to the direct, but not indirect, measures of pattern learning.

d) The Location-Span and Hidden Figures tests will be related to performance on the direct, but not indirect, measure of pattern learning.
Chapter III

Method

Subjects and Design

A 3 X 3 mixed factorial design with group (observation vs mapped-response vs unmapped-response) and number of initial acquisition blocks (1 vs 2 vs 3) as between subjects factors was used. One hundred and eight subjects (12 Ss per group) were selected from introductory psychology classes at Western Kentucky University, and all received course credit for their participation. Subjects were randomly assigned to one of the nine experimental conditions.

Stimuli and Apparatus

Stimuli were presented on the monitor of a Macintosh computer. Four squares were equally-spaced horizontally across the bottom of the screen. The stimulus was a high contrast asterisk (*) which alternately appeared in each of the four boxes. Manual responses were made by either pressing one of four keys on a keyboard located below and in front of the computer monitor (mapped-response), or by pressing the spacebar of the keyboard (unmapped-response). The response keys ("Z," "X," ",," and "/") were clearly marked with green tape and corresponded to the position of the four boxes on the screen. The 10-trial stimulus pattern used for each group was identical to that used by Nissen and Bullemer (1987). Specifically, designating positions from left to right as A, B, C, and D, the pattern was as follows: D-B-C-A-C-B-D-C-B-A.

In the mapped-response condition, the asterisk appeared in the center of the first box in the series until the key which corresponded to the location of the asterisk was pressed. Following a 500 msec delay, the asterisk reappeared in the subsequent position in the series. In the observation condition, the asterisk appeared in the boxes in the same pattern as the response condition. However, since no response was required during the observation phase, a 350 msec stimulus duration was used to match the typical viewing time of the response group. As in the mapped-response condition, a 500 msec delay
separated the presentation of each asterisk. The unmapped response group made a manual response; however, unlike the mapped-response group their responses were not based on the location of the asterisk and, therefore, were not mapped to its location. As was the case for the observation group, the unmapped-response group's viewing time for each asterisk was not determined by their responses, but rather by a fixed interval of 350 msec stimulus duration followed by a 500 msec delay.

Procedure

After filling out informed consent and biographical questionnaire forms, subjects were seated in front of the video monitor and keyboard in a moderately lit, sound attenuated booth or in a quiet room. Subjects in the mapped-response condition were instructed to place the middle and index finger of each hand on the response keys and to press the key which corresponded to the location of the asterisk as quickly as possible without making errors. Subjects in the observation condition were instructed to merely "watch" the presentation of the asterisks. Subjects in the unmapped-response condition were told to respond to the presentation of each asterisk by pressing the spacebar as quickly as possible using the thumb of their preferred hand.

The task consisted of two general phases, i.e., acquisition, and prediction. A summary of procedures for each group by training condition is presented in Table 1. During the acquisition blocks, an asterisk appeared in one of four locations on a video monitor. Depending upon the amount of training received, the total number of acquisition blocks varied from 4 to 6 for the observation, mapped-response, and unmapped-response groups. The training 1, observation group observed for one block, then responded for the remaining 3-blocks in the acquisition phase, the training 2, observation group observed for two blocks, then responded for the three remaining acquisition blocks, and the training 3, observation group observed for three blocks, then responded for the three remaining acquisition blocks. The training 1-3, mapped-response groups received the same sequence of events, but responded throughout. The training 1-3, unmapped-response groups also
responded throughout; however, their responses to the first 1-3 acquisition blocks were made by pressing the spacebar, while subsequent responses were made using the four response keys. For all groups, the first 1-3 acquisition blocks constituted pattern blocks in which the 10-trial pattern was repeated 10 times for a total of 100 trials. Each block was separated by approximately 2 minutes. At no time were subjects informed of the presence or absence of a pattern.
Table 1

Summary of Procedures for Each Experimental Condition

<table>
<thead>
<tr>
<th>Block</th>
<th>Observation</th>
<th>Mapped-Response</th>
<th>Unmapped-Response</th>
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<tbody>
<tr>
<td>1 (pattern)</td>
<td>obs</td>
<td>mr</td>
<td>mr</td>
</tr>
<tr>
<td>2 (pattern)</td>
<td>obs</td>
<td>obs</td>
<td>mr</td>
</tr>
<tr>
<td>3 (pattern)</td>
<td>obs</td>
<td>obs</td>
<td>obs</td>
</tr>
<tr>
<td>Acquisition Blocks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4 (pattern)</td>
<td>mr</td>
<td>mr</td>
<td>mr</td>
</tr>
<tr>
<td>5 (random)</td>
<td>mr</td>
<td>mr</td>
<td>mr</td>
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<tr>
<td>30-minute Retention Interval</td>
<td></td>
<td></td>
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<tr>
<td>6 (pattern)</td>
<td>mr</td>
<td>mr</td>
<td>mr</td>
</tr>
<tr>
<td>Prediction Block</td>
<td></td>
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<tr>
<td>7 (pattern)</td>
<td></td>
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<tr>
<td>Awareness Questionnaire</td>
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<tr>
<td>Hidden Figures and Location Span Tests</td>
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</table>

Note. "obs," "mr," and "umr" indicate observation, mapped-response, and unmapped response respectively.
Following the first 1-3 acquisition block(s), all subjects were asked to respond to either one or two awareness probes. The initial probe consisted of the following question: "What do you think about this task?". If the subject spontaneously mentioned the pattern, the response was noted by the experimenter, and the subject continued to the next block. If, however, the subject did not mention the pattern, the experimenter asked the question, "any other observations?". Again, the subject's exact response was recorded. Regardless of the nature of the subject's response, the experimenter at no time asked additional questions, altered or resubmitted prior questions, or gave any form of confirmatory feedback.

Immediately following the awareness probe(s), subjects completed the three remaining acquisition blocks, i.e., blocks 4, 5, and 6. The mapped-response group received no additional instructions since there was no change in procedure. The observation group and unmapped-response groups, however, received instructions identical to those previously given to the response group and thus were required to respond to the position of each asterisk. The 4th acquisition block consisted of 10 repetitions of the 10-trial pattern (pattern block). The 5th block consisted of a 100-trial sequence in which the location of the asterisks was determined randomly (random block), with the constraint that no position could immediately follow itself. The difference in response times between these two blocks was used as an indirect measure of pattern learning. The 6th acquisition block (pattern block) returned to 10 repetitions of the 10-trial pattern. The 5th and 6th blocks were separated by a 30 minute retention interval. During the retention interval, subjects were given the following WAIS-R subtests: Digit Symbol, Digits Backward, and Vocabulary. All WAIS-R subtests were administered and scored according to the standardized methods outlined in the WAIS-R manual.

A prediction block immediately followed block 6. In the prediction task, subjects were told that they would see four empty boxes and that their task was to press the key that corresponded to the location where they thought the first asterisk would appear. Subjects
were told that if their prediction was correct, the asterisk would appear; if their prediction was incorrect, the boxes would remain empty and they should try again. Subjects were instructed that following a correct prediction of the location of the first asterisk, they should predict the location of the next asterisk, and so on, until the end of the task was signaled. Thus, this task the "correct" key was the key that corresponded to the position of the asterisk that would appear next in the pattern. Subjects were not informed of the presence of the pattern, and they were instructed that response accuracy was more important in this task than the speed of their responses.

Following completion of the prediction block, subjects were asked a series of questions regarding their awareness of the pattern, and the exact response of each subject was recorded. The questions began with the general inquiry: "What did you think about this task?". If the subject failed to mention the pattern, they were asked a series of increasingly specific questions. If the subject exhausted the questions and still did not mention the pattern, or if at any time the subject acknowledged awareness of the pattern, they were asked how they were able to accomplish the task. Subjects were then asked to verbally describe the order in which the asterisks appeared in the boxes. Finally, subjects completed a generation task in which they described the order of presentation using a 10 X 4 matrix in which the trial number appeared on the rows and the position of the asterisk appeared on the columns (see Appendix A). Subjects were asked to place an asterisk in one of the four boxes on row 1 where the asterisk occurred first, and to place an asterisk in row 2 where it occurred next, and so on until they completed all ten rows.

Following completion of the generation task, subjects were given the Hidden Figures and Location-Span tests. The Hidden Figures test consisted of a series of problems in which the subject was required to find a simple geometric design that was embedded in a more complicated design. The task was to identify the location of as many simple figures as possible in a 10-minute period. We developed the Location-Span test to combine the characteristics of a direct memory test (e.g., the WAIS-R subtest Digit-Span) with the
characteristics of a more spatially driven task (e.g., Hidden Figures). Subjects were shown 5" X 8" index cards which displayed an asterisk in one of four boxes that were equally spaced across the bottom of the cards (see Appendix B). The position of the asterisks on each card was determined randomly, with the only constraint that no position could immediately follow itself. The cards were presented at a rate of one card per second. The task was to recall the location of the asterisk on each of the cards in the correct order. The pattern length began with 3 cards and increased by 1 card for each correct answer for a maximum pattern length of 9 cards. Subjects were allowed two attempts at each pattern length. However, the pattern on a second attempt was always a new pattern. Each subject's score was determined by the length of the longest pattern they were able to successfully recall. For example, a pattern length of 7 equaled 7 points.

Finally, all subjects were debriefed regarding the significance of their participation in the project.
Chapter IV

Results

Data Reduction

The mean of the median RTs were calculated for each of the 10-trial cycles within each response block. An indirect measure of pattern learning was obtained by calculating the RT score for the random block (block 5) and subtracting the RT score of the pattern block (block 4). The larger this number, the greater the amount of procedural knowledge of the pattern. RTs for all incorrect responses were excluded from these data. Preliminary analysis of response error rates showed high levels of performance (all group means exceeded 94% correct). RT scores for the response group were obtained for each of the 4-6 acquisition blocks. For both the unmapped-response and observation groups, however, RT scores could only be obtained for the 3 acquisition blocks in which a mapped-response was made.

Three direct measures of pattern learning were used. The first was obtained from the prediction task, the second from the generation task, and the third from the awareness probes. The first direct measure of pattern learning was obtained by calculating the proportion of correct predictions for each of the 10-trial cycles within the prediction block. The greater this number, the greater the amount of declarative knowledge of the pattern. The generation task provided our second direct measure of pattern learning. Because from the subjects perspective there was no "first" position inherent in the pattern, performance was evaluated in terms of chunks of correct pattern generation. Each correctly generated chunk of the pattern was assigned a value of 1 point. The possible size of the chunks ranged from 2 to 10, with 2 representing the smallest possible subsequence of the pattern and 10 being the largest chunk of the pattern. We began looking for the smaller chunks and worked our way to the larger chunk sizes. A chunk of 2 correct positions in the pattern could be present at any of 9 positions in a subject's 10-trial generation of the pattern, thus producing 9 possible points. Similarly, a chunk size of 3 could be present in 8 locations in
the subjects generated pattern producing 8 possible points, and so on. We continued this process until we were looking for the largest possible chunk of 10. Points generated for each of the 9 subsequences were summed, yielding a maximum score of 45 points for correctly generating the entire pattern. If the subject was unable to generate the entire pattern, we simply summed the points obtained for correctly reproduced subsequences of the pattern. This method allowed us to identify any correct subsequences of the pattern that were present in any position of the subjects' generated pattern, thereby giving a measure of partial acquisition of the pattern. Our third direct measure of pattern learning was obtained from the two awareness probes. The first awareness probe followed the acquisition phase, while the second awareness probe followed the prediction phase. For each of the awareness probes, frequency data were obtained by tallying the number of subjects within each group who acknowledged awareness of the pattern. Unless otherwise noted, all analyses reported as significant achieved $p < .05$ and all analyses reported as marginally significant achieved $0.05 < p < 0.10$. All $\eta^2$ reported were partial $\eta^2$.

**Response times by block.**

The initial examination of RT performance compared all three groups at each level of training across the final three blocks of the acquisition phase (blocks 4, 5, and 6). Mean RT scores by block for each group and each level of training are shown in Figure 1. A 3 (Group) X 3 (Training) X 3 (Block) mixed design factorial ANOVA with repeated measures on block produced no main effect of group, $F (2, 99) = .02, MSE = 249.59, \eta^2 = .00$, and no Group X Block, $F (4, 198) = 1.56, MSE = 2,655.15, \eta^2 = .03$, Group X Training, $F (4, 99) = .59, MSE = 6,149.84, \eta^2 = .02$, or Group X Training X Block interactions were significant, $F (8, 198) = 1.41, MSE = 2,410.72, \eta^2 = .05$. The lack of an effect of group indicated that RT performance was equivalent for the three groups. There was a main effect of block, $F (2, 198) = 321.72, MSE = 549,226.26, \eta^2 = .77$, which was due to the increase in RTs for all groups during the random block. There was also a marginal effect of training, $F (2, 99) = 2.66, MSE = 27,683.11, p < .075, \eta^2 = .05$, as
well as a Training X Block interaction, $F(4, 198) = 4.11$, $MSe = 7,008.74$, $\eta^2 = .01$.

Inspection of Figure 1 revealed that, following block 4, RTs for all groups sharply increased during the random block (block 5). This increase was followed by an equally sharp decrease in RTs when the pattern was reinstated in block 6. The increase in RT during the random block, followed by a reduction in response latency when the pattern was reinstated, suggested that all groups were using pattern knowledge to enhance RT performance.
Figure 1. Mean of the median reaction time scores in milliseconds as a function of block for each group at each level of training.
The Training x Block interaction indicated that the effect of training was not consistent across blocks. Simple effects analysis for the effect of training within each block revealed that there were differences in training in block 4 (pattern block), $F (2, 99) = 5.45$, $MSe = 31,327.57$, $\eta^2 = .10$, but no differences in block 5 (random) and block 6 (pattern) [$block 5, F (2, 99) = .26$, $MSe = 887.51$, $\eta^2 = .01$; $block 6, F (2, 99) = 2.04$, $MSe = 9,485.5$, $\eta^2 = .04$]. The failure to obtain an effect of training during block 5 was expected given that no amount of exposure to the previous pattern blocks could help subjects produce a random sequence. Inspection of Figure 1 shows that the lack of an effect of training during block 6 was likely due to the restriction on the range of RT scores as all groups continued to gain pattern knowledge across blocks. A post hoc pairwise comparison of the means for the three levels of training within block 4 (Tukey, a) shows that the effect of training was due to the difference between the 1-block training and 3-block training levels. RTs for neither the 3-block training level nor the 1-block training level were different from the 2-block training level.

Indirect measure of pattern learning.

Mean difference scores for the indirect measure of pattern learning are shown in Figure 2. A 3 (Group) X 3 (Training) mixed design factorial ANOVA yielded no main effect of group on the indirect measure, $F (2, 99) = 1.32$, $MSe = 4,672.60$, $\eta^2 = .03$. There was, however, a main effect of training, $F (2, 99) = 7.73$, $MSe = 27,256.5$, $\eta^2 = .14$. A post hoc pairwise comparison (Tukey, a) of the mean difference scores of the 3 levels of training collapsed across group revealed that 3-block training resulted in greater learning than the 1-block or 2-block levels. There was also a marginal Group X Training interaction, $F (4, 99) = 2.04$, $MSe = 7,196.05$, $p < .09$, $\eta^2 = .08$. Although the interaction only reached marginal significance, the effect size was moderate (Cohen, 1988). Inspection of Figure 2 suggested that only the observation and mapped response groups benefited from training. This, and the moderate effect size, prompted an examination of the marginal Group X Training interaction. Simple effects analyses for the effect of training
within each group showed an effect of training for the observation group, $F(2, 33) = 7.27$, $MSe = 32,464.94$, $\eta^2 = .31$, and for the mapped-response group, $F(2, 33) = 5.77$, $MSe = 9,068.43$, $\eta^2 = .26$, but no effect of training for the unmapped-response group, $F(2, 33) = .03$, $MSe = 115.24$, $\eta^2 = .00$. Thus, it appeared that the unmapped-response group did not benefit from additional training. Simple effects analyses for the effect of group at each level of training produced a main effect of group at the 3-block level of training $F(2, 33) = 3.86$, $MSe = 16,245.14$, $\eta^2 = .19$), but not at the 1-block or 2-block levels of training [1-block training, $F(2, 33) = .51$, $MSe = 2,061.81$, $\eta^2 = .03$; 2-block training, $F(2, 33) = .33$, $MSe = 757.75$, $\eta^2 = .02$]. A post hoc pairwise comparison (Tukey a) of mean difference scores for the 3 groups at the 3-block level of training revealed that the observation group performed significantly better than the unmapped-response group. Together these findings indicate that, while there are no overall group differences on the indirect measure, the unmapped response group did not perform as well as the other two groups at the 3-block training level.
Figure 2. Mean reaction time difference scores as a function of block for each level of training.
Direct measures of pattern learning.

Figure 3 shows mean accuracy scores across pattern cycles for each condition on the direct measure of pattern learning. A 3 (Group) X 3 (Training) X 10 (Pattern Cycle) mixed design factorial ANOVA produced no main effect of group, $F (2, 99) = 1.94$, $MSe = .52$, $\eta^2 = .04$, and no Group X Training, $F (4, 99) = 1.51$, $MSe = .41$, $\eta^2 = .06$, Group X Cycle, $F (18, 891) = 1.54$, $MSe = .02$, $\eta^2 = .03$, Training X Cycle $F (18, 891) = 1.24$, $MSe = .02$, $\eta^2 = .02$, or Group X Training X Cycle interactions, $F (36, 891) = .90$, $MSe = .36$, $\eta^2 = .04$. Although the Group X Training interaction was of moderate size, this effect fell short of statistical significance. The failure to obtain group differences suggests that the groups performed equally well on the direct measure of pattern learning. This finding was contrary to our predictions and will be discussed in more detail elsewhere.

There was a main effect of pattern cycle, $F (9, 891) = 10.81$, $MSe = .15$, $\eta^2 = .10$. This effect was due to the increase in accuracy across the 10 cycles of the pattern. There was also a main effect of training, $F (2, 99) = 3.69$, $MSe = .99$, $\eta^2 = .07$. A post hoc pairwise comparison (Tukey, $a$) of the mean accuracy rates at each level of training collapsed across group and pattern cycle revealed that 1-block training resulted in poorer accuracy than 3-trial training. Neither 1-block training nor 3-block training differed from 2-block training.

Inspection of Figure 3 indicates that there is a continuous improvement in prediction accuracy across levels of training. Suggesting that increasing amounts of training benefited all groups on the direct measure of pattern learning.
Figure 3. Proportion of correct predictions as a function of pattern cycle for each group at each level of training.
Awareness of pattern.

Our second direct measure of serial pattern knowledge was obtained from the first awareness probe. Analyses could not be done for the second awareness probe because 106 of 108 subjects reported pattern awareness by that time. A hierarchical log linear analysis of group, training, and awareness produced a significant relationship between training and awareness, $\chi^2 (2) = 10.11$, and a marginal relationship between group and awareness, $\chi^2 (2) = 5.3$, $p < .07$. An analysis of the standardized residuals for the association between group and awareness revealed that the observation group was more likely than chance to report awareness of the pattern at this time. While 67% of the subjects in the observation group reported pattern awareness, only 44% of the subjects in either the mapped-response and unmapped-response groups reported awareness. Analysis of the standardized residuals for the association between training and awareness showed that reported awareness was positively related to the amount of training. While subjects with 1 block of training reported awareness only 34% of the time, subjects with 2 and 3 blocks of training reported awareness 69% and 53% of the time, respectively.

Correlation of subtests with indirect and direct measures of learning.

Correlation coefficients of the 6 subtests with the indirect measure of pattern learning are contained in Table 2. None of the 6 subtests were significantly correlated with the indirect measure. However, correlation coefficients of the same subtests with the direct measure of pattern yielded a small positive relationship for each variable.
Table 2
Correlations of the 6 Subtests With Indirect and Direct Measures

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<tr>
<td>2 Digit Symbol</td>
<td>-.02</td>
<td>.21*</td>
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<tr>
<td>3 Digits Backward</td>
<td>.15</td>
<td>.29**</td>
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<tr>
<td>4 Location Span</td>
<td>.17</td>
<td>.24*</td>
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<tr>
<td>5 Vocabulary</td>
<td>.09</td>
<td>.23*</td>
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<tr>
<td>6 Generation Accuracy</td>
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Note. 2-tailed Significant: * .01 ** .001
Chapter V

Discussion

The present study was designed with the following objectives in mind. The first was to replicate the findings by Howard et al. (1992) that an overt motor response is not necessary for the development of pattern knowledge. The second objective was to find evidence to support the findings by Howard et al. that observation produces a qualitatively different form of representation than response -- that is, while observation leads to procedural learning as readily as responding, observation has a slight advantage over motor-response learning on a more declarative measure of pattern acquisition (i.e., prediction task). Our third goal was to extend these findings by determining the relative effect of pattern experience (training) on procedural and declarative acquisition of a serial pattern. Our fourth objective was to establish that the WAIS-R subtests, Hidden Figures task, and Location-Span task, would all be related acquisition of declarative but not procedural knowledge.

Regarding the first objective, we found support for the proposition that an overt motor response is not necessary for the development serial learning. The results of our indirect measure of pattern learning showed no group differences in the amount of procedural learning acquired by the three groups. The failure to observe group differences on the indirect measure supports the perceptual learning hypothesis by demonstrating that observation alone is sufficient to facilitate the acquisition of pattern learning. Such a finding is consistent with Howard et al. (1992), who found that pattern exposure under conditions of observation facilitates procedural learning to the same degree as an overt motor response.

Our second major objective was to find evidence in support of the proposition by Howard et al. (1992) that observation leads to a qualitatively different form of learning than response. Howard et al. found that while the 3-block observation group performed as well as the 3-block mapped-response group on the indirect measure, the observation group
showed a slight advantage over the response group on the direct measure of pattern learning. Specifically, a group by pattern cycle interaction was found which showed that the performance of the observation group was better during the first two pattern cycles of the prediction block. Contrary to our predictions, and to this earlier study, we found no effect of group, no group by cycle interaction, and no group by training by cycle interaction. The group by training interaction was of moderate size ($\eta^2 = .06$) but did not reach significance. This finding suggests that one reason why we failed to replicate the effects found by Howard et al. was that the statistical methods employed did not have sufficient power to detect small to moderate group differences. Power analysis for the group by training interaction indicated that power to detect group differences was low (power = .451). Under conditions of low power, combined with small to moderate effect sizes, our chances of a type II error were greatly increased. The increased chance of a type II error leaves us with the difficult question of whether our failure to reject the null hypothesis was due to a lack of group differences, or merely due to insufficient power to detect true group differences.

The administration of the first awareness probe provides another possible reason for why we failed to replicate the differences found by Howard et al. (1992). Howard et al. (1992) included only one awareness probe following prediction while our design included two awareness probes, one during acquisition, and one following prediction. Although the awareness probes were carefully worded to avoid leading the subjects' response, it is possible that the addition of the first awareness probe sensitized the subjects to the possibility of a pattern. Indeed, a number of subjects' responses to the first probe indicated that they thought their job was to figure out the pattern. For example one subject said, "I don't know what you want me to say. There must be a pattern or something, I just don't see it yet." Although it is not entirely clear that the probe was the cause of such responses, it was quite possible that stating such ideas aloud increased the subjects sensitivity to the
likelihood of a pattern. If this was in fact the case, then the early awareness probe may have been enough to obscure small differences between the groups.

In contrast to the measure of declarative knowledge from the prediction task, our direct measure obtained from the first awareness probe revealed that pattern awareness was related to both the type of training and the amount of training. As predicted, we found that the amount of training is positively related to pattern awareness. This finding was consistent with the results of previous studies (Willingham et al., 1989; Nissen & Bullemer, 1987) which revealed that verbal reports of awareness are most likely at higher levels of training. We also confirmed our prediction that the observation group was more likely than the response groups to report awareness of the pattern. This finding was consistent with the proposition by Howard et al. (1992) that observation leads to a more declarative representation than response. It also suggests another possible explanation for why no group differences were obtained during the later prediction trials -- that is, while group differences were found during the very early measure of pattern awareness, i.e., the first awareness probe, such differences may have been reduced as all groups gained additional pattern knowledge during the remaining 3 blocks of exposure to the pattern, i.e., pattern blocks 4 and 6, and prediction block 7.

Given our conditions of low power, the possible influence of the first awareness probe, and the group differences observed in pattern awareness, we find that the data regarding possible differences between observation versus mapped-response on the direct measure of pattern learning (i.e., prediction) are inconclusive, and do not allow us to confidently accept or reject the null hypothesis. Further research employing greater power, and different methodology, will be needed to resolve the issue of whether there are, in fact, qualitative differences between the observation versus mapped-response groups.

Our third major objective was to determine the relative effect of pattern experience (training) for each of the three groups on procedural and declarative acquisition of a serial pattern. On our indirect measure of pattern learning we found an effect of training.
Comparisons of the levels of training revealed that both the 1-block training and 2-block training showed less evidence of procedural learning than the 3-block training condition. These findings suggest that procedural knowledge accrues over training. The moderating effects of a marginal group by training interaction showed, however, that this pattern of results was not consistent for all groups. While the observation group and the mapped-response groups showed an effect of training, the unmapped-response group did not. We are not sure why this pattern of results was obtained. One possibility is that the presence of an unmapped-motor response merely served as a source of distraction. This pattern of results is what the response learning hypothesis would predict given the breakdown of the connection between the location of the stimulus items and the corresponding motor responses. Indeed, previous research by Willingham, Nissen, and Bullemer (1989, Exp. 3) has shown that when a motor response is required, but not mapped, to the location of the stimulus item, the development of procedural knowledge is inhibited. Thus, it seems that making an irrelevant motor response is worse than making no motor response at all.

The analyses of the direct measures of pattern knowledge show that declarative acquisition of the pattern was enhanced by training. This finding is consistent with the effects of training we found on the indirect measure of pattern learning discussed above. Together these results show that, with the exception of the 3-block unmapped-response group, training enhances procedural and declarative knowledge in similar ways for all groups. These findings support those of Willingham et al. (1989) that the amount of training enhances both procedural and declarative acquisition of a serial pattern.

Our fourth objective was to establish that the WAIS-R subtests (i.e., Vocabulary, Digit-Symbol, and Digits Backwards), Hidden Figures task, and Location-Span task, would all be related acquisition of declarative, but not procedural knowledge of the pattern. As predicted, we found that all the above tests showed a small association with the declarative knowledge of the pattern, while none of the tests were associated with procedural knowledge of the pattern. These findings are consistent with previous research
by Reber et al. (1991), who found that IQ is related to declarative but not procedural knowledge. Together, these findings suggest that declarative knowledge may be supported by cognitive processes similar to those measured by standard IQ devices such as the WAIS-R, while procedural knowledge seems to operate independently of such processes. Further research will be needed to confirm the exact nature of the relationship between IQ and declarative versus procedural learning.

Finally, a note on the applied value of the present investigation to the study of observational learning. Bandura (1986) argued that many [if not most] human behaviors are acquired through observation. He further argued that observational learning can be particularly important when information regarding temporal and spatial arrangements is not readily amenable to verbal description (Bandura, 1986). Our results demonstrate that an overt motor response is not prerequisite to the development of serial pattern knowledge. Further, increasing pattern exposure under conditions of observation appears to increase pattern learning at least to the same degree as pattern exposure involving an overt motor response. These findings lead us to believe that under some conditions observational learning plays a key role in the acquisition of serially ordered behaviors. However, we know little about the specific conditions under which observational learning is likely to be involved. If Bandura's belief in the ubiquitous nature of observational learning is accurate, then it will be important for future investigations to examine the specific conditions which promote observational learning.

In summary, the results of our indirect measure of pattern learning supported the findings by Howard et al. (1992) that overt behavioral responding is not prerequisite to serial pattern learning. The amount of training strongly influenced both procedural and declarative learning. In fact, in the present study, the amount of training had a greater effect on both procedural and declarative knowledge than did the type of training. We were unable to find conclusive evidence to support the proposal by Howard et al. (1992) that observation has an advantage over response on the direct measure of pattern learning.
However, the data showed trends toward small to moderate differences between the groups which may have gone undetected due to poor power. In addition, the data from the first awareness probe suggested that the observation group showed evidence of pattern awareness earlier than the mapped-response group. Further research employing greater power, and different methodology, will be needed to resolve this issue.
References


Appendix A
Directions for Generation Task

Now try to describe this order by placing an asterisk ("*") in one of the boxes in row T1 where you think the asterisk occurred first, then place an asterisk in one of the boxes in row T2 where you think it occurred next, and so on until you complete all ten rows.

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# Appendix B

Location Span Task

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Appendix B (Cont.)

Location-Span Task Directions

In this task you will see a series of asterisks presented on index cards. As before each asterisk will correspond to one of four positions. After the series is presented, your task will be to describe this order by placing an asterisk in one of the boxes in row T1 where you think the asterisk occurred first, then place an asterisk in row T2 where you think the asterisk occurred next, and so on until you see the word "STOP". When you see the word "STOP", place your pencil on your desk.

Please note that the patterns of asterisk locations are no longer related to any previous task. Do you have any questions?