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ABSTRACT

One hundred and seventy right-handed children from kindergarten through grade 2 were asked to copy 26 upper and 26 lower case letters and the numbers 1-9 shown at one time on slide projections. The resulting stroke patterns which were observed, supported predictions derived from the starting, progression, and horizontal rules expressed in the Grammar of Action. However, other predictions based on the way these children are said to resolve conflicts among these rules were not supported. Similarly, predictions regarding the occurrence of reversals when kindergarten children print and the influence of formal printing instruction in school on the subsequent printing stroke patterns used by 1st and 2nd grade children were not confirmed. An alternative to the Grammar of Action is proposed to explain these various findings along with the general uniformity children show when they print letters and numbers as well as copy geometric figures. (Author/SS)

The Grammar of Action, Printing, and Reversals in Children's Printing[1]

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Abstract

Children from kindergarten through grade 2 were asked to reproduce the 26 upper and 26 lower case letters and the numbers 1-9. The resulting stroke patterns supported predictions derived from the starting, progression, and horizontal rules expressed in the Grammar of Action. However, other predictions based on the way these children are said to resolve conflicts among these rules were not supported. Similarly, predictions regarding the occurrence of reversals when kindergarten children print and the influence of formal printing instruction in school on the subsequent printing stroke patterns used by 1st and 2nd grade children were not confirmed. An alternative to the Grammar of Action is proposed to explain these various findings along with the general uniformity children show when they print letters and numbers as well as copy geometric figures.

The Grammar of Action, Printing, and Reversals

in Children's Printing

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When children copy geometric figures they typically begin construction at certain points and proceed in certain directions. Because of the orderly nature of this behavior Goodnow (1972, 1977, Goodnow, Friedman, Bernbaum & Lehman 1973, Goodnow & Levine 1973) has suggested that copying involves the use of a series of rules referred to as a Grammar of Action. The starting and progression rules, for example, hold that right-hand kindergarten children should begin construction at the topmost and/or leftmost point on the vertical or oblique member of the geometric figure then proceed downward. The horizontal rule states that all horizontals should be drawn after the vertical or oblique member and should proceed from left-to-right. Where conflicts between these rules take place, beginning at the topmost-leftmost point takes precedent.

Conflicts producing further exceptions to these starting, progression, and horizontal rules will occur when the figure contains an apex, as in a diamond. Here children should start at the top and come down the left oblique. Similarly, other conflicts will take place in figures where a continuous or "threading" stroke is possible. That is, a stroke in which the pencil either remains in contact with the paper throughout construction or if lifted momentarily, no jump occurs in the path of construction (Goodnow, Friedman, Bernbaum, & Lehman

1973). This can be seen in figures resembling an inverted square-shaped U, (Goodnow, 1977, pg. 76) where kindergarten children start at the lower left corner and proceed upward using a continuous stroke ( ). Alternatively, they begin at the upper left corner and proceed downward using a continuous stroke in the case of figures resembling a square ( ).

Of major importance, both the rules expressed in the Grammar of Action and the way children resolve conflicts among these rules are said to generalize across geometric figures. To illustrate how this generalization takes place Goodnow has stated on a number of occasions that this rule system influences and is influenced by printing. Since formal printing instruction does not begin until 1st grade, one test of this hypothesis would involve predicting stroke patterns from these rules and then compare them against the stroke patterns actually obtained when kindergarten children are asked to print the alphanumeric characters. For example, the stroke pattern that can be expected when children print the letter b (or D ( ) should resemble that used when they construct a square since these letters involve no apparent conflicts with any of the rules stated above. The solid lines in Figure 1 show the various strokes associated with 47 letters and numbers where clear predictions were possible. The small numbers indicate the order in which the strokes should occur while the arrows indicate both the direction and terminating points of the predicted strokes. The dashed lines refer to strokes where predictions could not be made from the rules expressed in the Grammar of Action.

The Grammar of Action is also said to influence printing through the misapplication of certain rules leading to errors (Goodnow & Levine 1973, pg.92). Here Goodnow makes the interesting claim that reversals of the letter d stem from the inappropriate use of the strongly established left-to-right motor pattern and that because of this more reversals should occur when children print d than b. Unfortunately, the work of Lewis & Lewis (1965) often cited by Goodnow in support of this claim contains a serious methodological fault since children were asked to print in alphabetical order. This means that b was printed before its left-facing counterpart d which suggests that carryover from b by itself could have increased the frequency of reversals produced by d which they report. Hence, in order to substantiate Goodnow's argument we need to know if d is reversed more than b when these are presented in random order.

Finally, Goodnow also argued that the rules expressed in the Grammar of Action are themselves influenced by the formal instruction in printing children receive in school (Goodnow, Friedman, Bernbaum, & Lehman 1973). Although she provides cross-cultural evidence showing differences in the stroke patterns children use to construct geometric forms that correlate with the instructional sequences taught in school, as she herself pointed out, other differences between these cultures might also explain these findings. With this in mind, unless we have evidence that children do employ the instructed patterns when they form letters and numbers, there would be little reason to expect transfer from these instructed patterns to other copy tasks. In other words, if the motor rules taught during formal printing instruction have no immediate influence on the way children actually print, it would seem unlikely that children would subsequently use these taught motor rules when they copy other geometric figures. Therefore, we must demonstrate first that following formal instruction in printing in grade 1 and grade 2 children do in fact use the instructed stroke patterns in favor of alternative stroke patterns when printing.

Method

Subjects: One hundred and seventy right-hand caucasian children (88 male, 82 female) from two elementary schools reflecting middle and lower socio-economic levels, participated in this study. Based on returned parental permission forms and absenteeism at the time of testing, this number represents 77% of all children in age appropriate grades available for testing at these schools. The children were distributed as follows: K-fall, N = 39 (M age = 5-4 years); K-spring, N = 43 (M age = 5-10 years), 1-spring, N = 47 (M age = 6-9 years); 2-spring, N = 41 (M age = 7-1 years).

Procedure

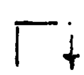
Each child, tested individually, was asked to copy the 26 upper and 26 lower case letters and the numbers 1-9 shown one at a time on slides. Two different random orders were used. The 1st and 2nd grade children were told to print as they normally do in class. The slides appeared on a 16.5 x 21.6 cm rear-view projection screen located .9 m in front of the child. The specific letter-shapes (projected as black against a white background) were those used in the school system and subtended a visual angle of approximately 3°. Because mirror-image reversals are known to occur more often when children print from memory (Asso & Wyke 1971), to obtain a sufficient sample of reversal errors the same task was readministered approximately 30 days later to the kindergarten children with the children being asked to print from memory immediately after seeing each slide for 2.5 sec. Under both copy and memory conditions, each letter and number was printed on a separate 7.5 x 12.5 cm sheet of white paper. The sheets were removed before the next slide appeared.

The stroke patterns employed in forming the letters and numbers were recorded by an observer standing behind the child as the child printed. Observer reliability was obtained on a subsample of 12 children. Agreement was judged to have occurred for any given letter or number if the overall stroke pattern (starting point, stroke sequence, stroke direction, and terminating point) was identical for both observers. Using this criterion, on the average, agreement was obtained in 94.5% (SD = 4.4%) of the reproductions generated by each child.

Results

First, X^2 tests were employed to determine if certain overall stroke patterns were used more frequently than others by the kindergarten children in producing accurate reproductions of the letters and numbers during the copy task. That is, following the procedures used by Goodnow & Levine, reproductions with added, missing, or misaligned parts were eliminated. The results from the combined kindergarten sample (N = 82) showed that a single overall stroke pattern occurred significantly more often than any other in 50 of the 61 letters and numbers (X^2 (1) = 4.5, $p < .05$ to 54.5, $p < .001$). In the 11 remaining cases either two or three patterns appeared with equal frequency and with few exceptions, here too, each of these patterns occurred reliably more often than any of the other patterns used to construct these letters and numbers (X^2 (1) = 6.5, $p < .02$ to 19.5, $p < .001$). It is worth noting that when these data were subdivided and reanalyzed, for the most part, independent of test order, the same modal patterns appeared in both schools, among male as well as female children, and in both spring and fall semesters. These overall obtained stroke patterns are shown in Figure 1. As inspection of this figure indicates, of the obtained stroke patterns, agreement with the predicted starting and progression rules (begin at the topmost/leftmost point and proceed downward) occurred in 85% of the cases. Similarly, the predicted order of occurrence of the horizontal stroke and its left-to-right direction was obtained in all but one case.

Of considerable interest however, are the 19 cases where the predicted stroke(s) either was not obtained or did not occur with reliably greater frequency than another alternative stroke(s) (A, B, D, E, F, N, P, R, T, Y, b, f, m, p, q, r, u, y, 5). In 14 of these, the predicted pattern called for amending the starting, progression, and/or horizontal rules because the form of the letter or number itself generated a conflict by requiring the child to employ either more than one rule simultaneously or to engage in threading. In fact, of the seven letters where a bottom-to-top starting stroke followed by threading should have been evident (F, M, N, P, R, f, and p), only M conformed to prediction. Similarly, for those where a top-to-bottom starting stroke followed by threading should have taken place (B, D, E, L, U, b, and 4) only L, U, and 4 showed evidence that the predicted pattern occurred more often than any other.

These exceptions to both threading rules are even more striking when considered with some additional evidence gathered after these findings became known. Specifically, 37 of the children from the K-fall sample were retested and asked to copy both the square and inverted square-shaped U along with the letters B, D, E, F, N, P, R, b, and f presented on slides in random order. The results showed that threading as obtained by Goodnow was used with reliably greater frequency than any other stroke pattern when the children were asked to copy the geometric forms from which the two threading paths were derived ( : X^2 (1) = 5.8, p < .02;  : X^2 (1) = 9.0, p < .01). However, of the 17 children using , on the average 59% did not construct F, N, P, R, and f by starting at the bottom and proceeding upward. Similarly, of the 14 using , on the average 80% did not use this threading sequence to form B, D, E, or b. Therefore, it seems clear that the rules describing the child's behavior when constructing these geometric forms do not necessarily transfer when children print letters to which these rules should apply. In essence then, despite the considerable uniformity which does exist when children print, it would appear that only the starting and progression rules (topmost/leftmost starting point and 1st stroke direction) as well as the horizontal rules (stroke sequence and left-to-right stroke direction) pertain to both the construction of geometric forms and the printing of the alphanumeric characters.

Next we asked if the number of reversal errors produced by d exceeded the number produced by b. A reversal error was defined as an error in which all of the parts in the original letter or number were correctly reproduced and rotated about a vertical axis. Following the recommendations of Murdock and Ogilvie (1968) for dealing with non-continuous data, the resulting sample of 79 kindergarten children that completed the memory task was subdivided randomly into 13 groups of 6 children each (one child was selected at random and eliminated to achieve equal numbers in each group). Using a repeated measures analysis of variance the results showed that the 88 reversal errors obtained during the memory task were distributed differentially (F (40/480) = 2.68, $p < .005$) among the 41 reversible letters and numbers. Employing the error term from this analysis, the Newman-Keuls procedure revealed that 4, 9, N, S, s, and Z generated reliably more reversals than 31 of the remaining letters and numbers ($p < .05$ to $p < .01$)[2]. None of the other comparisons reached significance. Hence we found no evidence that d produced more reversals than b or for that matter that these letters were particularly troublesome relative to the other reversible letters and numbers as often claimed (Enstrom & Enstrom 1969). Similar findings were obtained using the reversal errors produced during the copy task (N = 55).

Finally, we asked if formal printing instruction received in school which lasts 10-15 minutes each day from September through December in Grade 1 and from September through November in Grade 2 using the alternative or taught stroke patterns shown in Figure 1 had any affect on the children's printing. That is, did drill involving countless repetitions by each child of the taught stroke sequences shown in Figure 1, produce statistically reliable new stroke patterns that conformed to the taught patterns. This question was examined by analyzing the reproductions generated in the case of the nine figures where threading appeared as a unique and statistically reliable pattern in kindergarten, but where threading was discouraged through formal instruction (G, M, U, V, W, u, v, w, and 5). Once more contrary to prediction, inspection of the data showed that with few exceptions, for each of the three grade 1 and three grade 2 samples, threading remained the modal pattern and for the combined sample occurred reliably more often for each letter and number than the taught pattern (X^2 (1) = 5.8, $p < .05$ to 39.5, $p < .001$). Similar results were obtained with the seven other alphanumeric characters where the taught pattern again clearly differed from the single statistically reliable pattern appearing in kindergarten (K, T, a, g, k, y, and 9). That is, again with few exceptions, the modal pattern shown in Figure 1 under the column labelled "Obtained" remained in use by the children in each of the classes and for the combined sample exceeded the frequency with which the taught pattern occurred (X^2 (1) = 4.6, $p < .05$ to 80.3, $p < .001$). Therefore, since none of the five teachers instructing these children was able to discourage the use of threading or other pre-existing stroke patterns through formal printing instruction it would seem unlikely that such instruction by itself produces new motor rules that in turn would generalize from printing to other copy tasks as Goodnow claimed.

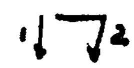
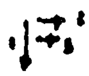
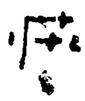
Discussion

In summary, these results show that considerable uniformity does occur in the stroke patterns children use when they print before they receive formal instruction in school. However, with the exception of the starting, progression and horizontal rules there is little reason to believe that generalizations based on how children construct geometric figures apply to printing or that formal instruction in printing is likely to produce new motor rules that in turn affect other copy tasks.

An alternative to the Grammar of Action that might explain not only a portion of the present results but also the findings reported by others using geometric figures can be seen in a proposal advanced by Ninio & Lieblich (1976). Employing both the separate and combined elements of an inverted T, they also showed that rules describing the child's performance under one set of copying conditions do not always transfer to other sets of seemingly identical copying conditions. Because of this they suggested that the overall figure itself might determine the nature of the remaining strokes and that younger children select strokes that minimize the complexity of the copying task. When applied to the present findings this could be why the 1st diagonal stroke in K, k, and Y for example is drawn from bottom-to-top whereas neither diagonal appearing in the letters X and x are drawn in this manner. That is, in the former case it might have been easier for the child to judge the location of the terminating connection between two lines thereby producing a more accurate reproduction whereas in the latter case no such judgement was required. In other words, having completed a portion of the figure and given a choice between several points to begin the remaining stroke, when necessary the child might use that starting point which, in addition to reducing ambiguity, also lowers the probability of error.

Expanding this suggestion by Ninio and Lieblich even further it could also be that children somehow gauge the amount of effort needed to complete the overall figure then select in advance those strokes which require the lowest expenditure of energy. It is well known for example, that the left-to-right sequence used in constructing horizontal lines occurs largely among right-hand children. Left-hand children draw horizontal lines from right-to-left (Goodnow 1977, pg.88). Because of the way children normally hold a pencil (Ames 1948) to do otherwise in either case very likely would require somewhat more effort since the child must push against the tip of the pencil to form a line. Also, as shown in Figure 1, the vertical stroke was drawn first and employed a top-to-bottom sequence independent of where it occurred in the letter or number (see for example F, Y, and T). While it is not clear if this top-to-bottom stroke requires less effort than a bottom-to-top stroke such a possibility gains some support from the work of Harris & Rarick (1959) showing that for adults the force exerted on the point of a writing instrument appears to be less during the top-to-bottom sequence than during the bottom-to-top sequence. If this holds for children and it can also be shown that the top-to-bottom stroke demands less effort than the left-to-right stroke, this might explain why the vertical stroke is preferred over the horizontal in most instances and why children do not adopt the taught pattern shown in Figure 1 in the case of a, g, and 9 for example. In other words, in the case of figures requiring several strokes the child might select as the first stroke, one requiring the lowest force or encountering the least resistance thereby demanding the least effort.

It is worth noting that the only exception to this top-to-bottom sequence in the present study took place in the construction of the letter M where a bottom-to-top 1st stroke occurred reliably more often than any other. Here however, if the child began at the top instead of the bottom of the left vertical line a minimum of five separate movements would have been required to complete the overall letter. Similarly, the stroke pattern taught at school demanded a total of seven separate movements. In contrast, the child's solution required only four movements, the smallest number that could have been used to construct this letter. This same distinction was evident in each case where threading persisted (G, M, V, W, u, v, w, and 5) despite two years of formal printing instruction using alternative stroke patterns. That is, the taught pattern required more overall movements than the pattern preferred by the child. Therefore, in addition to the possibility that children employ individual strokes that require less effort, it could be that children also select sequences of strokes that demand the fewest total movements.

In essence, this expanded alternative to the Grammar of Action suggests that the copying process might involve a sequence of events that take place before children begin construction of either letters, numbers or geometric figures. First, they appraise the entire figure. Next, they select in advance those strokes demanding the lowest expenditure of energy. Having done this the need to execute a correct reproduction is taken into consideration. This need in turn leads to a final choice in which strokes are selected based on their likelihood of producing the least amount of error. Clearly, if children do evaluate possible ways to save labor and reduce error in advance of copying, deciding to employ  vs  or  vs  must involve an extremely intricate processing system.

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Footnotes

[1]A preliminary report of these findings was presented at the meeting of the Canadian Psychological Association, Quebec City, 1979.

[2]Possible reasons for these findings are discussed elsewhere (Simner, 1980).

Figure 1. The most frequently used overall stroke patterns obtained from kindergarten children in constructing the 26 upper and 26 lower case letters and numbers 1 - 9. The predicted stroke patterns and those taught in grade 1 and 2 are included for comparison. The small numbers indicate the sequence of strokes while the arrows indicate both the direction and terminating points of individual strokes.