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ABSTRACT

Children from kindergarten through grade 2 were asked to copy, then print from memory, each of the 41 reversible letters and numbers administered individually on slides presented in random order. The main findings of an experiment with 179 children drawn from two elementary schools show that mirror-image reversals and other errors (1) take place largely when children print from memory, (2) occur far less often than misalignments, substitutions, and correct reproduction, (3) happen mostly during the final stages of letter/number construction, and (4) occur for the most part at random and primarily among the younger and more distractible children. Focusing children's attention by having them name the letter or number out loud before and during printing reduced reversals and other errors even though the name itself was not important in producing this effect. Together these findings challenge the prevailing accounts given to explain reversals in printing and suggest an alternative proposal. (Author/RH)

Mirror-Image Reversals in Children's Printing: Preliminary Findings[1]

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Abstract

Children from kindergarten through grade 2 were asked to copy then print from memory each of the 41 reversible letters and numbers administered individually on slides presented in random order. The main findings showed that mirror-image reversals took place less often than correct reproductions as well as errors involving either a relocation or substitution of parts. Also, when reversals and other errors did happen, for the most part the error itself occurred randomly among the reversible letters and numbers, took place largely at the terminating stage of construction for any given letter or number, occurred most frequently in kindergarten and grade 1 among children having high teacher ratings of distractibility, and primarily when these children printed from memory. Finally, focusing children's attention by having them name the letter or number outloud before and during printing reduced reversals and other errors even though the name itself was not important in producing this effect. Together these findings challenge the prevailing accounts given to explain reversals in printing and led to an alternative proposal.

Mirror-Image Reversals in Children's Printing:

Preliminary Findings

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It is estimated that as many as 75-95% of all children in the primary grades produce mirror-image reversals of letters and numbers when learning to print (Hildreth 1932). Some hold that this behavior can be explained by the child's lack of attention to, memory for, or confusion over left-right spatial orientation (Chapman & Wedell 1972, Fellows 1968, Frostig 1963, Kephart 1971, Vogel 1977). Others have argued with equal conviction that reversals stem from faulty application of strongly ingrained fine motor movements, inappropriate placement of the writing hand relative to body midline, a bias toward making letters and numbers face a given direction, interference from the reversible letter's mirror-image counterpart, lack of hemispheric dominance, insufficient writing practice, maturational lag, or emotional imbalance (Bannatyne 1972, Gilkey & Pair 1944, Hildreth 1934, Enstrom & Enstrom 1969, Firth 1971, Goodnow 1977, Huttenlocher 1967, Nelson & Peoples 1975, Orton 1925, Wilson & Flemming 1938, Zaslow 1966). In general these views result largely from work in which only mirror-image reversals were scored and/or generated by subsets of the reversible letters and numbers, novel geometric figures having reversible features, visual inspection of trends in the distribution of reversals generated by letters and numbers printed in alphnumeric order, or case studies of children with learning or other problems (Asso & Wyke 1971, Chapman & Wedell 1972, Feldes & Myers 1921, Firth 1971, Goodnow & Levine 1973, Lewis & Lewis 1965, Wilson & Flemming 1938). The 1st experiment in which I compared the probability

of forming reversals and other errors along with obtaining a detailed analysis of the stroke patterns children use when these errors occur, led me to question these accounts and to propose an alternative explanation.

One hundred and seventy-nine children (93 male, 86 female) were drawn from two elementary schools reflecting middle and lower socio-economic levels. 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 = 36 ($\bar{M}$ age = 5-4 years); K-spring, N = 43 ($\bar{M}$ age = 5-9 years); 1-spring, N = 49 ($\bar{M}$ age = 6-9 years); 2-spring, N = 51 ($\bar{M}$ age = 7-10 years). As part of a larger study each child was tested individually and asked to copy then approximately 30 days later, print from memory each of the 26 upper and lower case letters and numbers 1-9 shown one at a time on slides. Two different random presentation orders were employed. 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^{o} (a chart showing these letter-shapes can be obtained by writing the author). Under the memory condition the children were asked to print after seeing the slide for 2.5 sec. The stroke patterns used in forming the letters and numbers were recorded by an observer standing behind the child as the child printed. Observer reliability obtained on a subsample of 12 children showed agreement in the overall stroke patterns (i.e., starting point, stroke sequence, stroke direction, and terminating point) in 94.5% of the reproductions generated by each child.

The resulting data from the 41 reversible letters and numbers were scored for the presence of three error types. Mirror-image reversals were said to have

occurred when all of the parts in the original letter or number were reproduced and rotated about a vertical axis (i.e., d → b, S → Ƨ). Misalignment errors took place when all of the parts were reproduced but relocated forming something other than a mirror-image reversal (i.e., d → p, S → Ɛ). Substitution errors resulted when parts were added to and/or deleted from the original letter or number leading to a totally different figure (i.e., d → k, S → C).

Table 1 contains the mean number of reversal, misalignment, and substitution errors per child generated by the 41 reversible letters and numbers according to error type, task (memory vs copy), sex, school, and grade. The major findings relevant to the aim of this investigation showed a highly reliable error main effect ($F = 50.71$ (2/326), $p < .001$), error x task ($F = 5.67$ (2/326), $p < .004$), error x sex ($F = 7.82$ (2/326), $p < .001$), error x grade ($F = 19.56$ (6/326), $p < .001$), and error x task x sex x grade interaction ($F = 2.45$ (6/326), $p < .03$). With the Newman-Keuls test these results indicate that misalignment and substitution errors occur far more often than reversals, that these differences are most pronounced among males in the early grades independent of school, and that reversals along with other errors take place largely when children print from memory. Closely related to this the Wilcoxon test showed that reversals happen far less frequently than correct reproductions (shown in Table 1) of the reversible letters and numbers at each grade independent of sex, school, or task ($T = 0$, $N = 6$ to 16, two-tail $p < .01$). In fact, approximately 97% of all reproductions generated for example, during the memory task by the kindergarten males were correct. Together these additional findings mean that mirror-image reversals are relatively rare occurrances and do not represent a major form of error when children print.

Next, inspection of the stroke patterns used in forming the reversals indicated that the error itself took place in a highly systematic fashion. That

is, if in reversing a lower case "b" or "d", the reversible feature (i.e., the curve) was drawn last, the error was said to have taken place at the end of construction. If drawn first, the error was judged to have occurred at the onset of construction. Employing this criterion with each of the reproductions generated by the 32 letters and numbers where such judgments could be made the Wilcoxon test showed that the reversal itself occurred at the end of the 1st or during the 2nd or 3rd stroke with reliably greater frequency than at the beginning of the 1st stroke ($z = 3.47$, two-tail, $p < .001$). The same finding was obtained when this analysis was applied to the misalignment ($z = 3.69$, two-tail $p < .001$) and substitution errors ($z = 5.29$, two-tail $p < .001$). Of closely related interest, the 1st strokes used by the same children when forming a correct rendition of these same letters and numbers matched the 1st strokes used when reversal, misalignment, or substitution errors were made. In other words, focusing on those letters and numbers in which the error took place at the terminating stage of construction, I compared the number having 1st strokes that agreed or disagreed with those used when the same letter or number was printed correctly by the same child. The results showed that agreement occurred with reliably greater frequency than disagreement ($z = 3.24$, two-tail $p < .001$). Similar findings were obtained from the data produced by the 1st and 2nd grade samples. Considered together this shows that the stroke initiating construction is typically the same regardless of whether a correct or incorrect reproduction of the letter or number eventually resulted or of the type of error that actually occurred.

Also, as described in detail elsewhere (Simner 1979), I did not find that the mirror-image letters b, d, p, and q were particularly troublesome as often claimed. Instead, using the error term from an analysis of variance conducted

according to procedures described by Murdock & Ogilvie (1964) the Newman-Keuls test showed that 4, 9, N, S, and Z, generated reliably more reversals ($p < .05$ to $p < .01$) in the kindergarten sample under the memory condition than 31 of the remaining reversible letters and numbers. Similar findings were obtained from the copy task data and for the copy and memory task data generated in Grade 1. It is worth noting that for the most part others (e.g., Hildreth 1934, Lewis & Lewis 1965, Wilson & Flemming 1938, Zaslow 1966) have also reported more reversals among 9, N, S, and Z although 4 is rarely mentioned suggesting that the latter might not be a stable effect. While the reason for this is not clear it may be important that the lettershapes used for 9, N, S, and Z contain an oblique member and it is well known that children often have trouble correctly reproducing obliques, specially from memory (Bryant 1974). In addition, recent work with preschool children (Berman, Cunningham & Harkulich 1973) has shown that this difficulty is more pronounced when the oblique is presented within a rectangular as opposed to a circular frame and children are asked to copy on rectangular instead of circular paper (as was the case in this and all previous investigations dealing with this issue). Similar findings emphasizing the importance of surrounding horizontal and vertical cues have also been obtained with older children (Abranavel & Gingold 1977). Therefore in keeping with previous suggestions, it could be that conflicting directional information possibly associated with the horizontal and/or vertical elements of the projection screen, paper, or the figures themselves might have been responsible for this result.

In any event, it needs to be emphasized that these four troublesome figures produced on average 7.25 reversals apiece in the kindergarten sample under the memory condition meaning that although they are more difficult

relative to the remaining letters and numbers when considered individually, as a group they generated only 33% of the total number of reversals obtained. Similar results were found in the 1st grade sample. Hence, in combination with the foregoing evidence, it would seem that the majority of reversals are produced at random by each of the remaining letters and numbers. In line with this point, 24 kindergarten children (14 male, 10 female) were readministered the memory task approximately 30 days later. The results showed stability among children in the total number of reversals generated on both occasions ($r_{xy} = +.49$, $df = 22$, $p < .05$). Nor was there any evidence that change had occurred in the mean number of reversals between the 1st ($\bar{M} = 1.23$ reversals per child) and 2nd session ($\bar{M} = 1.33$ reversals per child). Despite this consistency though, the Wilcoxon test revealed that a different letter/number was far more likely to be reversed than the same letter/number during the 2nd session independent of whether 9, N, S, or Z was involved the 1st time ($T = 6.0$, $N = 15$, two-tail $p < .01$). In other words, the reversals themselves were not tied to specific letters or numbers. Similar evidence favoring individual differences in the production of misalignment ($r_{xy} = +.83$, $df = 22$, $p < .01$) and substitution errors ($r_{xy} = +.75$, $df = 22$, $p < .01$) also was obtained along with results showing that in these as well the actual letters and numbers producing the errors changed between the 1st and 2nd session (misalignment: $T = 4.5$, $N = 11$, two-tail $p < .01$; substitution: $T = 22.5$, $N = 15$, two-tail $p < .05$). It would seem therefore that neither reversals, misalignments, nor substitutions stem from properties intrinsic to any given letter or number even though certain letters/numbers are somewhat more troublesome and certain children are more likely than others to make these errors.

Finally the total number of reversals, misalignments, and substitutions

generated during the memory task correlated positively with teacher ratings of the child's distractibility in both kindergarten and grade 1. That is, based on inferences made while observing the children during the course of testing, I asked the teachers to rate each child using a ten point scale with 10 indicating good general attention span in class (low distractibility) and 1 reflecting poor attention span in class (high distractibility). The product -moment correlation between these ratings and the overall number of errors per child was -.58 ($df = 34$, $p < .01$) in the K-fall sample, -.54 ($df = 40$, $p < .01$) in the K-spring sample, and -.32 ($df = 47$, $p < .05$) in grade 1. Basically the same results were obtained when separate correlations were generated between the distractibility ratings and number of reversal (K-fall: -.30, K-spring: -.39, 1-spring: -.19), misalignment (K-fall: -.38, K-spring: -.49, 1-spring: -.32), and substitution errors (K-fall: -.55, K-spring: -.39, 1-spring: -.25).

In sum the main findings from the 1st experiment show that reversals (1) take place largely when children print from memory (2) occur far less often than misalignments, substitutions, and correct reproductions, (3) happen mostly during the final stages of letter/number construction, and (4) occur for the most part at random and primarily among the younger and more distractible children. On the whole, when considered with recent evidence that children typically print by constructing the distinctive features of letters and numbers last (Simner 1979), this suggests that reversals might not stem from problems with left-right orientation, lack of hemispheric dominance, inappropriate motor skills, etc. Instead, due possibly to the younger child's distractibility, periodic lapses in attention could lead to a poorly formed, unstable, or incomplete memory trace of the letter or number. When asked to print entirely from memory

the child is denied an opportunity to strengthen this trace. Therefore, if the distinctive feature that remains to be drawn has faded from memory by the time the child reaches the end of the 1st stroke, substitution errors result. Alternatively, if the form of the distinctive feature is remembered but its location is not, misalignment errors take place. Considered in this way, a reversal is merely a subcategory of misalignment error in which the relocated part appears opposite instead of say, above, below or at random relative to its original position. In line with this possibility, it is important to note the results obtained when the misalignment errors were subdivided into inversions (b → p, n → u) and random relocations (b → [illegible], n → [illegible]). Using the data obtained from the kindergarten children under the memory task condition and based on the 28 reversible letters and numbers where such comparisons were possible, the Wilcoxon test showed no difference in frequency per letter/number of inversions ($\bar{M}$ = 0.40) and reversals ($\bar{M}$ = 0.64) and that both together occurred as often as random relocations ($\bar{M}$ = 1.09). Similar findings were obtained from the copy task data provided by these children as well as the memory and copy task data generated by the 1st grade sample.

If the reasoning underlying this account is correct and reversal, misalignment, as well as substitution errors result largely because children merely forget either the form or location of the distinctive feature after completing the 1st stroke, by focusing the child's attention on the general properties of each letter and number thereby providing a more stable memory trace, it should be possible to reduce mirror-image reversals as well as these other error types. I examined this in Experiment 2 by readministering the memory task to 32 male kindergarten and 1st grade children from the original study asking those in the Experimental Group (N = 16) to name the letter or number out loud while the slide

was present and to repeat the name when printing from memory. The Control Group (N = 16) matched for mean number of reversal and other errors, was treated the same as before.

In line with prediction, the Wilcoxon test showed a significant overall decline in both mirror-image reversals ($T = 1.5$, $N = 8$, one-tail $p < .01$) as well as the combined category of substitution/misalignment errors ($T = 19.5$, $N = 13$, one-tail $p < .05$) for the Experimental Group while no change took place in the Control Group. It is worth noting in view of the previous finding concerning 9, N, S, and Z that according to the Mann-Whitney U Test the number of reversals generated by these was also reliably less following instruction in the Experimental Group ($\bar{M} = .06$) relative to the Control Group ($\bar{M} = .63$, $U = 71.5$, one-tail $p < .025$) whereas no difference occurred between these groups prior to instruction (Experimental: $\bar{M} = .31$, Control: $\bar{M} = .37$). Moreover, correct reproductions were obtained in 85 of the 88 cases where the letters and numbers were mislabeled indicating that the name itself did not trigger the correct motor pattern needed to form an accurate rendition of the letter or number. Instead, the attention needed to generate the name must have been responsible for this outcome. In conclusion, then, these results suggest that reversals in printing might not constitute a unique form of error, but along with the other error types, might stem from failure to achieve a sufficiently stable or lasting memory trace of the whole letter or number to ensure retention of the individual parts during the final stages of construction.

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Footnote

[1] An earlier version of this report was presented at the Biennial Meeting of the Society for Research in Child Development, San Francisco, 1979.

Table 1

Mean Number of Reversal, Misalignment, and Substitution Errors Generated per Child by the 41 Reversible Letters and Numbers According to Task, Sex, School, and Grade. The Mean Number of Correct Reproductions are Included for Comparison.

			MALE				FEMALE			
Task	School	Grade	Reversal	Misalignment	Substitution	Correct	Reversal	Misalignment	Substitution	Correct
Memory	Lower Ses	K-Fall	1.17	3.50	10.50	25.8	1.60	2.70	3.30	33.4
		K-Spring	1.50	2.50	3.50	33.5	1.11	2.33	4.00	33.6
		1	0.33	1.00	1.44	38.2	0.00	0.09	0.36	40.6
		2	0.00	0.18	0.73	40.1	0.00	0.00	0.25	40.8
	Upper Ses	K-Fall	1.00	2.70	7.60	29.7	0.60	1.80	2.60	36.0
		K-Spring	1.44	0.83	1.81	36.9	0.67	0.25	1.17	38.9
		1	1.11	0.16	1.16	38.6	0.30	0.20	0.60	39.9
		2	0.00	0.00	0.94	40.1	0.00	0.13	1.00	39.9
Copy	Lower Ses	K-Fall	2.00	3.83	8.67	26.5	[illegible]	2.70	4.70	32.5
		K-Spring	1.33	0.83	2.00	36.8	[illegible]	0.78	1.22	38.7
		1	0.11	0.11	0.11	40.7	0.00	0.00	0.09	40.9
		2	0.00	0.09	0.27	40.6	0.00	0.13	0.13	40.7
	Upper Ses	K-Fall	0.80	1.60	5.30	33.3	0.30	0.70	2.00	38.0
		K-Spring	0.50	0.69	0.75	39.1	0.00	0.17	0.25	40.6
		1	0.00	0.05	0.47	40.5	0.00	0.00	0.20	40.8
		2	0.06	0.00	0.25	40.7	0.00	0.00	0.13	40.9