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Mirror writing in typically developing children: A first longitudinal study

Jean-Paul Fischer*, Anne-Marie Koch

University Lorraine, InterPsy Laboratory, EA 4432, France

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ABSTRACT

The present study examined the development of mirror writing in typically developing children using a longitudinal design involving 166 children initially aged 4–5 years. The children were tested three times, with approximately one year between tests. The main predictions were that: (i) mirror copying of characters at T1 (4- to 5-years old) will be less frequent than mirror writing from memory at T2 (5- to 6-years old), (ii) an implicit right-writing rule—which holds that children orient single characters toward the right and hence most frequently reverse the left-oriented characters (e.g., 3, J)—explains well both character reversal at T2 and T3 and changes between T2 and T3 (6- to 7-years old), and (iii) name-mirror writing is possible as soon as children start learning to write.

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1. Introduction

Mirror writing refers to writing of letters or digits that can be successfully read using a mirror.

Complete mirror writing may be defined as writing which runs in the opposite direction to the normal and in which each individual letter is reversed (Critchley, 1926). Partial mirror writing occurs when only single letters or digits are reversed.

The earliest research into mirror writing in the neuropsychological literature dates back to Buchwald (1878) but, to the best of our knowledge, no one has ever carried out a longitudinal statistical study of the phenomenon in typically developing children. Although there are a number of reasons for the lack of such studies, the most important explanation is the long-standing and deeply rooted belief that mirror writing is limited to specific children, notably those who are left-handed (e.g., Gordon, 1921; Lebrun, Devreux & Leleux, 1989; Schiller, 1932). However, this belief has been shown to be unfounded, both by recent advances in the neuropsychological understanding of mirror perceptions of symbolic materials (letters, digits, words) in adults (Dehaene, 2010; Dehaene, Nakamura et al., 2010; Dilks et al., 2011; Nakamura, Makuuchi & Nakajima, 2014; Pegado, Nakamura, Cohen, & Dehaene, 2011) and by numerous older (Cornell, 1985; Frith, 1971; Hildreth, 1934, 1936; Legrün, 1931; Lewis & Lewis, 1965; Simner, 1984; Zaslow, 1966) and more recent (Brennan, 2012; Cubelli & Della Sala, 2009; Della Sala & Cubelli, 2007; Fischer, 2011, 2013; Fischer & Koch, 2016; Fischer & Tazouti, 2012; Johansson, 2005; Mather, 2012) non-longitudinal empirical studies of mirror writing in 4- to 7-year-old children.

Single letter or digit reversal has often been studied on its own, without reference to complete mirror writing. Recently, two theories have emerged to try and account for the results of these studies. Treiman and Kessler (2011) and Treiman et al. (2014) proposed a possible link between reversals of letters (and, secondarily, of digits) and their shape. They noted that a number of letters of the Latin alphabet have a vertical or semi-vertical stem and one or more appendages attached

* Corresponding author at: 23 Bd Albert Ier, BP 3397 54015 Nancy Cedex, France. Fax: +33 3 54 50 51 71.
E-mail address: jean-paul.fischer@univ-lorraine.fr (J.-P. Fischer).

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to the right (e.g., b, P, R), which gives the impression these letters face right. More recently, Treiman et al. (2014) used data from adult participants to classify all the letters, including those without a vertical or semi-vertical stem (e.g., C), according to whether they are perceived as right-facing, left-facing or neutral. Among the uppercase letters (the script examined in the present study), only two letters were classified as left-facing (J and Z), whereas the majority of the other asymmetrical letters were classified as right-facing (B, C, D, E, F, G, K, L, P, Q, R, and S). According to Treiman and co-workers, statistical learning leads children to pick up visual commonalities among the shapes of letters, most notably the fact that most letters are right-facing. Hence, when children remember the shape of a letter but not its left–right orientation, they tend to produce the orientation they have observed to be most common. This leads them to reverse mainly the left-facing letters.

The second theory to account for character reversal was developed by Fischer (2011, 2013), Fischer and Tazouti (2012) and Fischer and Koch (2016) who noted that many capital letters and digits have either their main concavity on the right (e.g., C and 6) or a vertical stem and an appendage on the right (e.g., P and R). Consequently, they qualified these characters as right-oriented. However, perhaps because Fischer and co-workers also studied the digits, they were led to focus on the dynamics of writing in the cultural environment in which children learn to write. For example, Fischer (2013) argued that it is a combination of the structure of the digit 4 and the dynamics of how it is written that determines its orientation. This approach allows all the asymmetrical characters to be classified as either left-oriented (1, 2, 3, 7, 9, J, and Z) or right-oriented (all the others). Fischer and co-workers went on to suggest that, in a left–right writing culture, children who know the form of a character but not its orientation implicitly direct this character toward the right. Thus children appear to apply an implicit right-writing rule which leads them to reverse the left-oriented characters. With the negligible exception of N,[1] the uppercase letters classified as left-oriented and right-oriented by Fischer and co-workers are the same as those classified as left-facing and right-facing by Treiman et al. (2014).

Drawing on neuropsychological and empirical data, Fischer (2013) and Fischer and Tazouti (2012) put forward a simple theory of left–right character (capital letters and digits) reversal based on the process of mirror-image generalization via the symmetrization of memory traces (Corballis & Beale, 1976). Although symmetrization is adaptive for many purposes, mirror-image generalization is detrimental for learning to read and write. In reading, it may lead children to confound the letters b and d, and p and q, and in writing it may lead them to produce mirror-images of the digits (e.g., ε) and letters (e.g., ∪), rather than writing them correctly (e.g., 3 and J, respectively). Thus, as Kolinsky et al. (2011, p. 235) noted for readers, a longitudinal assessment of the way beginning writers unlearn mirror generalization would be highly informative. According to Fischer and co-workers' theory, the spontaneous reversal of single characters by 5- to 6-year-old children takes place during the period of "unlearning" mirror-image generalization, which eventually allows them to disentangle the image of a character and its mirror.

Both Treiman and co-workers' statistical learning hypothesis and Fischer and co-workers' implicit right-writing rule account very well for children's frequent reversals of the left-facing capital letters J and Z, but neither theory explains why children often completely mirror write words, notably their name. However, when a child completely mirror writes, he or she writes from right to left, thereby the influence of the implicit right-writing rule, postulated by Fischer and coworkers, will be weakened. In fact, the rule may disappear or the child may even transform it into an implicit left-writing rule. Hence, this rule could account for the orientation of the letters toward the left.

The aim of the present research was not to choose between the two preceding theoretical accounts of character reversal—statistical learning versus application of an implicit right-writing rule (see Fischer, 2013; for some convergences and divergences between the two proposals). Rather, because both accounts concur on the fact that children reverse mainly the left-oriented characters, we decided to include a study of character reversal by children in a longitudinal study of mirror writing. Of the two theories, only Fischer and co-workers' implicit right-writing rule systematically addresses digit reversal and allows predictions to be made about complete mirror writing; therefore, our hypotheses were formulated mainly with reference to this theory.

By carrying out a longitudinal study, we were able to statistically test several specific predictions arising from the implicit right-writing rule theory. Because symmetrization occurs during transfer to memory, a developmentally non-trivial prediction of the theory is that children should be able to correctly copy a character when they are 4- to 5-years old, but then have a tendency to reverse the same character when writing it from memory when they are 5- to 6-years old (Prediction 1).

Secondly, we expected children to resort to the implicit right-writing rule less frequently as they gain experience in writing and reading (particularly in first grade). This leads to a decline in the strength of the rule between the ages of 5 and 7 years (Prediction 2a). However, because of the variability of its use (both between children and between the items to be written), the latter prediction does not mean the rule disappears completely in 6- to 7-year-old children. In addition, reversal is determined by the left-orientation of the characters, which does not change with time; therefore, according to

[1] Treiman et al.'s (2014) adult American participants categorized N as neither right-facing, nor left-facing. However, in France, where we conducted the present research, children learn to write N by producing an upward vertical stroke, followed by a right trending downward stroke, and then another vertical upward stroke. Given this writing dynamic, N clearly appears right-oriented.

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