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Mirror Confusion in Reading and Writing and Its Related Principles

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Abstract: Mirror confusion in writing and reading is a common phenomenon. This paper further put forward the concept of mirror recognition which differs from mirror reading. In addition, this paper also lists the statistical learning hypothesis, implicit right writing Rule hypothesis and neuron re-use hypothesis of mirror confusion, as well as three factors related to mirror confusion: gene, handedness and intelligence.

1. Mirror confusion

Mirror confusion refers to the visual recognition of the original stimulus and its corresponding mirror stimulus (for example, p and q). Even though the two stimuli are imaged in different directions, individuals may ignore their orientation and assume that the two stimuli are the same.

In fact, mirror confusion is an adaptive mechanism and a feature of the visual system. It helps us quickly recognize objects, faces and locations from different angles. In nature, the left and right directions of most objects are not important. For instance, whether you look at a tree from left or right, you will see the same scene [1].

In studies on adults in the 20th century, mirror confusion was often regarded as a diagnostic criterion for some dyslexia and used to predict the performance of adult reading ability [2, 3]. As research went on, scholars discovered that mirror confusion is common when children begin to learn to read and write [4, 5, 6]. At the same time, studies have shown that the incidence of mirror confusion in young children decreases gradually with age, and it almost disappears by the time the child is 8 to 10 years old.

Although the neural mechanism of mirror confusion remains controversial, the phenomenon of mirror confusion is usually attributed to the delayed development of mirror generalization adaptation mechanisms in children's learning to read and write. In the study of mirror confusion, there are two forms of mirror confusion, namely, mirror writing and mirror reading. The phenomenon of mirror writing was discovered earlier [7]. Horizontal mirroring confusion is more common than vertical mirroring confusion [8]. Then, the earliest study of mirror reading was published by Hildreth in 1934 [9].

2. Mirror recognition and mirror reading

Mirror image recognition refers to the equivalent response between the image and mirror image of the same object in the individual visual cortex. Mirror recognition is a product of biological evolution. It is found in a wide variety of organisms, including primates [10], pigeons [11], and cephalopods.

Through habitual paradigms, researchers demonstrate that children aged 3 to 4 months have mirror recognition, an adaptive visual processing pattern [12]. This visual mechanism is thought to have been active in human history for 25 million years or more [13]. Mirror reading occurs when an individual creates mirror recognition in a text. In general, mirror recognition is different from mirror reading to some extent.

Dehaene and his co-workers used fMRl and the same-different task to explore the brain activity and behavioral results of adult subjects under the condition of mirror discrimination. The same-different task is an application of the one-back task. The two target stimuli in the experiment were pictures and words (French and Japanese kanji). The task of the Japanese and French participants was to determine whether two stimuli presented before and after were the same (the mirror image also needs to be responded as “same”) [14].

The fMRI results showed that the differences in mirroring priming between words and pictures were greater in the French group than in the Japanese group. This result suggests that there is some cultural difference between mirror recognition and mirror reading. The researcher analyzed that the reason for the significant difference in mirror recognition/reading in this experiment was that the two groups of subjects had completely different ways of processing characters. The Japanese processing of kanji is based on the whole rotary processing method. However, the processing of French by the French is based on morphemes.

Experimental data on behavioral results showed that mirroring priming was stronger in the images. At the same time, mirror priming was very weak in response to literal stimuli. Even in the French group, literal stimulus was not present at all.

In fact, numerous empirical studies on different types of stimuli confirm that mirror recognition of objects does not disappear with age.The researchers looked at different types of objects and found that normal adult subjects had a degree of confusion when the images, such as pictures of houses and locations [15, 16], animal images [17], tool images [18], human face images [19], geometric or random shapes [20, 21], were mirrored and flipped.

Mirror reading means that an individual reads a text in the opposite direction from the normal reading order [22]. In other words, an individual can read mirror text in visual recognition, which is reflected in the fact that the individual cannot distinguish the mirror symmetric text (such as b and d).

The group with a higher probability of mirror reading mainly includes people with developmental dyslexia, certain brain injury patients [23], and normal preschool children who have just started to learn reading and writing [24, 25]. Normally, children's mirror reading occurs between the ages of 3 and 7. If mirror reading persists after 8 to 10 years old, it is necessary to determine whether the child has some kind of dyslexia [26, 27].

The disappearance of mirror reading is closely related to the development of children's reading and writing ability. Children of similar age will also differ in the frequency of mirror errors depending on their reading-related abilities [27, 28]. In addition, children of similar age who started reading later

also had more mirroring reading than children who started learning text recognition earlier [29].

In order to explore the relationship between mirror reading and literacy ability, Danziger and Pederson studied the mirror discrimination ability of participants with ten different mother tongues (illiterate and non-illiterate) [30]. With the exception of Tamil native speakers (illiterate and non-illiterate performed equally because there is no mirror-reverse text in this language), almost all of the people trained in reading were more sensitive to mirror differences -- that is, better at recognizing them -- than the illiterate.

Pegado and his team further studied three groups of adult subjects with different literacy skills: illiterate (they never learned writing before), pre-illiterate (they learned writing after adulthood), and non-illiterate (they learned writing in adulthood). The researchers used the same-different task to show that the lower the reading ability of the subjects, the more likely they were to mirror reading [15].

The results of this study are consistent with previous studies, and found that low literacy subjects are more difficult to distinguish between mirrored text [31]. It is also consistent with the hypothesis that improving individual reading and writing skills can promote their cognitive abilities [32].

However, we cannot ignore the exception of the Tamil native speakers mentioned above, Pederson (2003) conducted a relevant study on adult Tamil native speakers whose second language was Romani and found that these subjects had better mirror discrimination ability than those who had only learned Tamil [33].

The research shows that when orientation becomes an important recognition feature of a language, the improvement of literacy ability will promote the disappearance of mirror reading.

3. Mirror writing

Mirror writing is the process of writing in the opposite direction from normal writing, in which individual letters or entire words or even sentences are flipped over during the writing process. Therefore, the written text can be successfully read using a mirror [34].

It is generally known that mirror writing is regarded as the adaptive trend of mirror generalization in writing. The findings support the important role of visual performance in developmental mirror writing [35]. Mirror writing is most common in children between the ages of 3 and 8. This condition gradually disappears with age [36].

Research on mirror writing is comprehensive and abundant. From the research object, there are adults, children, the elderly [37], patients [38] and normal people related research; There are relevant studies in different cultures and different language backgrounds [14, 30, 39]; There are also cross-sectional [17, 40, 41, 42, 43, 44, 45] and longitudinal follow-up studies [46].

Fisher (2011) asked a total of 300 children from 18 kindergartens to write Arabic numerals and English letters from memory. The results showed that some children in each class had mirrored writing. Rates of the phenomenon ranged from 23.94% to 40.87% [47].

Li and his team observed the writing of Arabic numerals and Chinese characters in 133 right-handed children aged 5-12 years. The study found that under normal handwriting conditions, 45 percent of children aged 5 to 6 had mirror writing [48].

In the context of a large number of previous cross-sectional studies, Fischer and Koch designed and investigated the development of mirror writing during normal development in young children.The

study which included three experiments, involved 166 children. Young children are first tested between the ages of 4 and 5. Each experiment took place nearly a year apart. This longitudinal study provides evidence that mirror writing may develop at the same time as correct writing. Provides longitudinal evidence in support of the implicit right-write rule [46].

4. Explanations of mirror confusion

4.1 Statistical learning hypothesis

Treiman and his co-workers believe that to some extent, the flip of letters or numbers is related to the text shape similarity. They found that certain letters of the Latin alphabet have a vertical or semi-vertical stem, and one or more appendages attached to the right of the stem (for example, R, P, B). The letters give the impression that these characters are right-oriented [49, 50].

Then, Treiman sorted and classified the data of adult subjects. All the letters, according to the orientation of the letters, were classified as facing right, left, or neutral. In this exercise, the researchers found that only J and Z letters were classified as facing left, while most other asymmetric letters (such as D, F, etc.) were classified as facing right [50].

Based on a series of empirical studies, Treiman and his co-workers concluded that young children naturally learn the visual commonalities of these letters during the learning process, as shown statistically -- the vast majority of letters are oriented to the right.

Thus, when children remember the shape of letter but not its left-right orientation, they end up writing letters in the direction they observed the most, which is right-facing. As a result, children's mirror writing tends to flip letters which was left-facing.

4.2 Hypothesis of Implicit Right Writing Rule

The implicit right-hand writing rule hypothesis was proposed by Fischer, Tazouti and Koch, who also noted that many uppercase letters and numbers have major notches or appendages on the right (e.g. C, R, and 6). These character are also classified as right-facing. In addition, researchers began to focus on the dynamics of children's writing in the cultural environment of learning to write [44, 46, 47, 51].

Fischer put forward that under the left-right writing culture, children who remember the shape of a character but not its orientation will implicitly point this character toward the right. In short, children seem to apply the implicit right-hand writing rule, which appears to be usually flipped to the left-facing character to right.

The implicit right writing rule and the statistical learning hypothesis mainly explain the mirror confusion from the perspectives of writing style and text structure. Both this two hypothesis explain why children often flip the left-facing letters, such as J and Z. But neither theory can explains why children write words exactly in the mirror image.

Next, we will introduce the "Neuronal recycling" hypothesis that explains mirror confusion from the perspective of brain structure.

4.3 Neuronal recycling hypothesis

Dehaene argues that reading and writing is a relatively new skill from the perspective of biological

evolution. It took a relatively short time for man to invent all kinds of symbolic systems. How did this new skill emerge in the human brain [52]?

One hypothesis is that the human brain has evolved new processors. This processor provides cognitive functions for reading and writing, allowing us to enter the realm of syntax [53]. But that possibility was quickly ruled out. Cultural acquisition activities such as reading and arithmetic are so recent that they do not put any evolutionary pressure on the brain.

So how does our brain structure adapt to the specific problems that these functions pose?

Finally, Dehaene proposed the hypothesis of "neuron recycling": the human ability to learn culture depends on the circulation of pre-existing brain circuits.

In order to recognize visual stimuli effectively, human beings evolved two visual pathways from the occipital lobe: the dorsal pathway connecting the parietal lobe and the ventral pathway connecting the temporal lobe. Among them, the dorsal pathway is responsible for processing the position and movement of visual stimuli, and the ventral pathway is responsible for processing the color, shape and recognition of visual stimuli [54, 55].

In order to recognize external stimuli more efficiently, the ventral pathway of vision has a mirror-invariant property, that is, people tend to regard objects as the same regardless of whether they are facing left or right [56]. Hence, humans use the ventral pathway of vision to quickly obtain information and identify objects. However, when the human brain began to recognize words using the plasticity of the ventral pathway when the human brain uses the plasticity of the ventral pathway to recognize characters, it encounters obstacles, leading to mirror confusion in the early years of learning to read and write.

However, with the improvement of children's literacy, the occipito-temporal cortex of the brain is further differentiated, activating the Visual Word Form Area(VWFA) for word recognition [57, 58, 59, 60], so the mirror confusion gradually disappeared. There are also related studies showing that blind people can also break this mirror-invariance by reading Braille through touch learning [61].

In addition to the three theories mentioned above, there are other theories concerning mirror confusion, as follow, the motor center hypothesis [23, 63], the visual hypothesis [63, 64, 65], the spatial-orientation hypothesis [23], and the involvement of thalamo-cortical circuitry [66].

5. Influencing factors of mirror confusion

5.1 Mirror confusion and genes

Ordinary people who want to become fluent in mirror writing can do so with a lot of practice. But for some people mirror writing is a natural gift.

Mathewson (2004) found 10 natural mirror writers through investigation and tracked them down. It turned out that 10 of the 19 children of the 10 adults had inherited the gift. According to this, the probability of mirror writing is 1:1.9. This ratio is close to the ratio of autosomal dominant trait expression, which is 1:2. Further analysis shows that there is a certain degree of gender difference in this phenomenon. Of the 45 first-degree relatives of these natural mirror writers, 11 out of 23 women were mirror writers, while only one in 22 men were mirror writers. Both the skewed sex ratio and the probability of 1:1.9 suggest that mirror writing is closely associated with a dominant gene associated with the X chromosome [67].

5.2 Mirror confusion and good hands

Mirror confusion occurs at a significantly higher rate in people who are born left-handed and whose language is written from right to left. The findings may have implications for understanding the division of labor in the brain hemispheres associated with handedness. For left-handers, there is evidence that activation in the right hemisphere or bilateral hemisphere is greater than in right-handers [68].

In fact, several studies have shown that left-handed subjects performed better on mirrored writing tasks regardless of whether they used a dominant or a non-dominant hand [69, 70]. However, the performance of MW in preschoolers has also been shown in some studies not to be related to handedness but to be related to age [45]. It may be that language centers in children at this age may not have been lateralized yet, so handedness is not associated.

Therefore, the effect of handedness on mirror-image confusion has not been determined.

5.3 Mirror Confusion and lntelligence

Some studies have suggested that mirror writing can be used as a tool to measure intelligence in older people and as a way to assess intelligence in Alzheimer's disease (AD) and vascular dementia (VAD). That is, the severity of mirror writing may indirectly reflect the severity of dementia [37].

In addition, the relationship between mirror writing and intelligence in children is not the same as that in the elderly. A number of studies have shown that mirror writing is equally likely to occur in children with normal and possible intellectual disabilities [43].

6. Conclusions and Discussion

Last but not least, this essay only partly introduce the mirror confusion, and there is still much to be explored. I hope that ecologically efficient methods can be developed to help children improve this “problem” in the future.

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