Through the Looking Glass:
Literacy, Writing Systems and Mirror-Image Discrimination

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Abstract
A part/whole judgment task was administered to adults in ten different language communities around the world. Participants were instructed to treat two-dimensional abstract line figures differently from the left/right mirror-image reflections of the same figures. The data support the proposal that sensitivity to this kind of mirror-image contrast is acquired: Literate individuals generally were better able to operate in terms of this distinction than were non-literate participants in the study. Contrary to this general pattern, however, Tamil literates as well as non-literates often treated the left/right mirror-image reflections as non-reflected figures, despite the training to treat them differently. The difference between the Tamil literates and the literate individuals in the other language communities sampled may reflect the fact that mirror-image contrasts are used to different degrees in their respective scripts.

1. Introduction

The functional asymmetry between the human right and left hands is an
anomaly in nature. There are a few rather mysterious cases of left/right asymmetry in the non-human world, but almost none of them seem to have consequences. Two natural objects which are mirror-image counterparts of one another may in general be treated without difficulty as examples of "the same thing" (Gibson 1969:415–16, Corballis & Beale 1976:190–97, Gardner 1991). This is quite clear when one imagines watching a nature film that is accidentally playing left/right reversed. Most of the audience will not even notice the reversal. In the cultural realm, however, such differences may become extremely important. If a baseball film plays left-right reversed, there will be many complaints.

Cultures differ in the degree to which they exploit mirror-image reflection for functional purposes (Levinson & Brown 1994). For example, the Roman alphabet uses mirror-image reflection to make graphemic contrasts of the type instantiated in the difference between the letters b and d. Likewise, the intuition that abstract left/right mirror-image counterparts should count as perceptually different from one another is not a universal one. It has long been noted (Davidson 1935, Ilg & Ames 1950) that European and American pre-school children often have difficulty with tasks that rely on this intuition. Certain psychologists (Corballis & Beale 1976:414–59, Casey 1964) have wondered whether maturational factors are at stake. Others (notably Gibson et al. 1962, Gibson 1969:416) have proposed instead that this intuition is a learned one, arising from exposure to reading and writing in the first years of school. Verhaeghe & Kolinsky 1991 have shown that exposure to cultural experiences in which the left/right mirror image distinction is functionally salient — and not spontaneous physiological development alone — indeed lies behind the intuition that left/right mirror-images should count as different from one another. In their study, literate Portuguese adults rejected abstract left/right mirror-image reflections as not the same, after they had been trained to do so. But non-literate of similar age and social background often accepted mirror-image reflections as "the same" despite training to the contrary. For these Portuguese subjects, literacy was clearly one major experiential variable affecting judgments about the similarity or difference of simple abstract figures that differed only in their spatial orientation. However, Verhaeghe & Kolinsky also found that, among Portuguese non-literate, women who made lace in their spare time were considerably better at the mirror-image discrimination task than those who did not. They conclude from this that literacy/schooling is only one member, albeit an important one, of an unspecified and open-ended set of culturally motivated experiences that can lead to a person's acquiring the otherwise unnecessary attentional skill of treating two-dimensional left/right reversals of the same image as different from one another.\footnote{Kolinsky et al. 1994 show that, when left/right orientation is critical to a below-awareness optical illusion, the illusion still occurs in unschooled subjects. That is, even among those who would consciously judge a line that is oriented diagonally up and to the right to be "the same" as one oriented diagonally up and to the left, subjects do respond at a level out of awareness to the difference between the two lines. What is learned in judging mirror-image figures as "different" is not strictly perceptual (see also Robinson & Higgins 1979).}

In this study, we ask how cross-culturally widespread is the judgment that mirror-image counterparts are the same. Is literacy always a reliable predictor of sensitivity to this distinction? In data from speakers of ten distinct languages, we find that sensitivity to the mirror-image distinction among adults is far from universal. We also find in several of our samples that literacy is a predictor of this kind of discrimination. However, we note that literacy does not correlate with mirror-image discrimination in all our samples; most notably, the correlation falls in the single sample drawn from a population in which individuals are often literate only in a non-Roman script.

To approach these questions, a standardized task requiring the intuition that left/right mirror images should count as different from one another was taken to ten different language communities around the world. The ten languages are distributed across six different language families. In six of the ten communities, our samples include non-literate as well as literate individuals. In two of the ten communities (Tamil and Japanese), literacy is primarily in a non-Roman script.

2. The Experiment

The experimental task was designed by Stephen Levinson and Bernadette Schmitt, inspired by the work of Palmer 1977 and Verhaeghe 1998. In this task, subjects are asked to judge whether or not one figure can be found as part of ("inside") another. Five "Whole" figure cards are presented, and each Whole figure card has three candidate "Part" cards; see Figure 1. In one of the candidate Part cards, the figure displayed is actually to be found inside the Whole figure; this is the Genuine match. In the second candidate Part card, the figure displayed cannot be found inside the Whole figure; this is the
The instruction sessions were accompanied by a demonstration using three transparent overlay cards which reproduced the Genuine, the Control, and the Mirror match for the Whole figure of the training set. The transparency was first placed over the particular candidate Part card, to show that the figure it displayed was identical to the candidate Part. Then the transparency was lifted and placed (without rotation or “flipping”) over the Whole figure card, so that consultants could judge whether the part displayed on the transparency appeared anywhere in the Whole figure. Attention was called to the fact that the transparency is neither horizontally rotated nor vertically flipped when it is lifted. Under these circumstances, the Genuine match will readily be found on the Whole figure card, but neither the Control nor the Mirror image part will be found. All individuals whose data appear in Figure 2 successfully managed the training trials. The training trials were followed by a practice session before experimental trials began.

2.1. Task administration

The task was administered to adult native speakers of ten different languages, representing six different language families and a wide variety of cultural conditions. In all cases, the task was taken to the part of the world in which the speakers live, by a field researcher who had previously spent time in the community and who had a good grasp of the native language. Native speaker consultants were involved in the translation of the task instructions into each language, and the task was administered by the investigator in the native

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Figure 1. Sample drawings used in the mirror-image part experiment

Control match. The final candidate Part card displays the left-right mirror image of the Genuine match; this is the Mirror match. In all cases, the candidate parts were “Good” parts in the sense of Palmer 1977.2

Each Whole figure is presented three times (in counterbalanced sequences), always side by side with one of its candidate Part cards. The consultant is asked to say whether what is shown in the Part card also appears in the Whole Figure. Since there are five different Whole cards, this yields 15 trials in total, of which five involve Mirror matches. Before the 15 trials were begun, the investigators used training materials similar to the task materials; and subjects were instructed that they should accept the Genuine match and reject the Control match. They were also explicitly instructed to reject the Mirror match. The set of task and training materials are presented in Appendix A.

2. Palmer 1977 sought a metric that would correspond to the ease with which subjects could find various parts within a complex line figure. His metric combines values along various Gestalt dimensions such as continuity of the segment (discontinuous segments are less easy to find than continuous ones) and orientation of the segment with respect to the whole. In tasks unrelated to the mirror-image issue, unschooled and non-literate adults have been found to have difficulty detecting less-good parts, as defined by Palmer's metric; however, these adults are readily able to detect parts defined by Palmer’s metric as “good” parts (Kolinsky et al. 1987, 1990).
Figure 2. Mean acceptance of mirror-image parts across all language samples

language of each community (in the case of Dutch and Japanese, the task was administered by a native speaker). Data were collected in Belize [Mopan [Mayan]], Mexico [Tzeltal [Mayan], Yucatec [Mayan], and Totonac [Totonac]], India [Tamil [Dravidian]], Papua New Guinea [Kilivila [Austronesian]], Japan [Japanese [Altai?]], the Netherlands [Dutch [Indo-European]], and Oceania [Longgu [Austronesian] and Pohnpeian [Austronesian]]. We are grateful to all of the researchers who collaborated on this project, and who supplied data for it; their names are listed on the bottom of Figure 2.

Information was recorded and analyzed for each consultant as to age, sex, years of schooling, bilingualism, and literacy. Literacy was coded as a simple yes or no, based on consultants' answers to the question whether they were able to read and write. Of course, more detailed information about the degree and nature of the literacy would be desirable, but it was often socially difficult to code beyond self-report of literacy. 4 A In almost all cases, literate status corresponded to exposure to several years of childhood schooling, although the reverse was not necessarily so.5

Literacy in the Tamil, Japanese, Longgu, Dutch, and Pohnpeian communities is primarily in the native language of the speakers. Literacy in the Mopan, Tzeltal, Yucatec, Totonac, and Kilivila communities is primarily or entirely in non-native languages. Whether literacy was in L1 or L2 does not appear to be a factor in our results.

2.2. Results

Data were taken only from consultants who, during the 15 actual trials of the task, accepted at least 4 of the 5 Genuine matches presented, and who rejected at least 4 of the 5 Control matches. Each consultant who met this criterion was coded as accepting 0, 1, 2, 3, 4 or 5 of the Mirror matches presented.

There was considerable variation across the populations in the degree of acceptance of Mirror candidates as parts of the Whole figure (see Fig. 2). In some samples the mean acceptance rate for the Mirror parts was below 0.5 over 5 trials. In others, it was above 3.0. We did not concern ourselves here with differences in absolute rate of mirror image rejection across populations (many different cultural factors can play a role in absolute rates achieved on standardized tasks; cf. Cole & Scribner 1974:171–200). Rather we asked whether, within each sample, literacy emerges as a significant variable in accounting for the rejection of candidate mirror-image parts.6

The four samples in which all consultants reported themselves as literate (Japanese, Longgu, Dutch, and Pohnpeian) showed a very low acceptance rate for mirror-image parts, despite the considerable cultural and linguistic differences across these communities. In these cases, literacy indeed co-occurs

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4. Although we might often expect individuals to over-report their literacy skills in response to social pressure to appear literate, it is also true that, in certain cases, cultural circumstances are such that individuals would be more likely to under-report than to over-report their abilities. Mopan women, for example, are socialized to an ethos of discretion and modesty (Gregory 1964); and this makes it unlikely that they would claim more expertise than they actually feel they have in this area. If anything, the reverse is probably true.

5. In several of the communities sampled, schooling takes place in a second language (such as English or Spanish) with which small children are not familiar. Those who have attended only a few years of school in these circumstances may never have learned even basic skills. The effect of this is that we have subjects who are (at least officially) schooled, but who are not literate.

6. There was no observable item effect within this task: Subjects were equally likely to accept a mirror image with any of the five mirror-image matches presented.
with a high rate of rejection of mirror-image-parts.\footnote{As highly educated, largely urban subjects, the Japanese in our sample are almost certainly more “fluent” in their literacy than the Austro-Melanesians represented in the Longgu and Pohnpeian samples. Our data thus suggest that, if literacy is indeed the relevant phenomenon, then the threshold of literate fluency required to defeat mirror-image acceptance is relatively low. For more detail about space and spatial language in Longgu, see Hill 1997; for Pohnpeian, see Keating 1995.}

We next asked to what extent literacy correlates with the rate of mirror-image part acceptance within the six remaining samples. In these six samples, nine individuals reported themselves as being able to read and write, and some reported themselves as unable. Across all six variable-literacy samples, literate individuals reject more mirror-image parts than do non-literate individuals (see Figure 3). In two of the samples (Totonac and Kilivila) the numbers are too small to allow for reliability testing.\footnote{For more on space and spatial language in Totonac, see Levy 1998; for Kilivila, see Senft 1997, Introduction.} However, in four of the samples, the numbers are large enough to allow for such testing.\footnote{The statistical analyses that appear here and elsewhere in the paper were performed by László Nagy.} In two of these four (Mopan and Tzeltal), literacy clearly correlates with mirror-image part rejection (although other factors may also be at work; see Levinson & Brown 1994; Danziger 1997). In the Yucatec sample, literacy is only a marginal predictor of mirror-image part rejection. However, this reflects the fact that even non-literate Yucatec speakers tend to reject mirror-image parts. An account along the lines of the “lacemaker” phenomenon — in terms of some still unidentified factor of cultural experience, common to literates and non-literates alike in the Yucatec speech community — presumably accounts for these data. Finally, in the Tamil sample, literacy also does not correlate reliably with mirror-image part rejection. But here the data are more puzzling, since Tamil has the highest rate of mirror-image part acceptance of any sample in the study! Among the Tamil speakers, even many literates accept mirror-image candidates as good parts.\footnote{It is important to clarify that there is no doubt as to the literacy of the Tamil subjects who reported themselves as literate. These Tamil subjects were drawn from the area in and around Madurai (approximately 1.3 million inhabitants), a city with a central role for millennia in the written history of Tamil culture.}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure3.png}
\caption{Figure 3. Mean acceptance of mirror-image parts, by literacy (in samples with non-literate subjects)}
\end{figure}

Strikingly, not only is the Tamil sample the only one which has a high degree of acceptance of the mirror-image parts among the literate individuals, but both literate and non-literate subjects actually tend to accept mirror-image parts more than they reject them. Only one of the non-literate individuals, along with three of the literate individuals, consistently reject these parts (i.e. give a maximum of one mirror-image acceptance). Clearly, not all types of “literacy” are identical in their cognitive effect.\footnote{Full Tamil data are given in Appendix B.}

There are no significant differences among the Tamils when they are sorted according to literacy, sex, amount of schooling (literacy perfectly correlates with schooling in this sample), their general living environment (urban vs. rural), or the number of languages spoken (all but two individuals in the Tamil sample were monolingual). It is interesting, however, to consider the hypothesis that it is the nature of the Tamil script itself which corresponds to the non-significance of literacy in the Tamil sample.
3. Literacy in Non-Roman scripts: Japanese and Tamil

In 8 of the 10 populations in our study, literacy is normally in the Roman script alone. In our samples from these populations, the hypothesis that literacy is an important factor in the acquired intuition that two-dimensional left/right mirror-images should be considered distinct is supported, or at least not disconfirmed. Let us now consider the two populations (Japanese and Tamil) in which literacy in a non-Roman script is involved.

3.1. Tamil

Tamil is written with an indigenous script (see Table 1) that derives from the alphasyllabic script which also gave rise to the modern Devanagari script (used, e.g., for Hindi). Tamil is never written with the Roman script, and literate Tamils need not be familiar with Roman script.

Graphically, the Tamil and Roman scripts share many features. Both scripts are consistently written from left to right, and both consist of graphemes for which the mirror-images would be incorrect representations (e.g., in Roman script, $R$ is not a normally acceptable allograph of $R$). That is, learners of both Tamil and Roman scripts must learn to conduct their visual scan from left to right (cf. Vaid 1995), and both must learn not to produce “backwards” letters. However, the Roman script, but not the Tamil, has graphemes for which the mirror-image is actually another distinct grapheme (i.e. $b$ vs. $d$ and $p$ vs. $q$). That is, the learner of Roman script must learn to meaningfully distinguish between two acceptable mirror-image alternatives in reading. A Roman script reader attends to this distinction constantly. In this paragraph alone, the reader must attend to a mirror-image graphemic distinction 33 times! Left/right confusions are notoriously commonplace while learning to write, but with Roman script — unlike Tamil script — the

Table 1a. The principal Tamil characters: Vowels

| A: Juxtaposed vowels | a | ë | i | ë | o | u | o'<br>au 9.<br>au 9.
|---------------------|---|---|---|---|---|---|---
| B: Vowels which produce a new grapheme when combined with a consonant | a | ë | i | ë | u | u: | u: |

Table 1b. The principal Tamil characters: Consonants

<table>
<thead>
<tr>
<th>Consonant + vowel from row B above</th>
<th>a</th>
<th>ë</th>
<th>i</th>
<th>ë</th>
<th>u</th>
<th>u:</th>
</tr>
</thead>
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<td>$k + V$</td>
<td>ஞ</td>
<td>ஞ</td>
<td>ஞ</td>
<td>ஞ</td>
<td>ஞ</td>
<td>ஞ</td>
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<tr>
<td>$n + V$</td>
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<td>$c + V$</td>
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<td>$n + V$</td>
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<tr>
<td>$t + V$</td>
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<tr>
<td>$n + V$</td>
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<td>$r + V$</td>
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<td>$l + V$</td>
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<td>$v + V$</td>
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<td>$l + V$</td>
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<td>$r + V$</td>
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<td>$d + V$</td>
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<td>$f + V$</td>
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<tr>
<td>$s + V$</td>
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<tr>
<td>$h + V$</td>
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</table>
left/right confusion is also possible in learning to read. Even the passive user of Roman script must make use of the distinction between left/right mirror images.

This continuous attention to “minding one’s p’s and q’s” — a systematic discrimination between graphemes which differ essentially only in the feature of mirror-image inversion — may be one of the critical experiences of literacy which motivates mirror-image rejection in non-reading tasks. Of course, many scripts require one to recognize that there is a correct left/right orientation to each letter. However, in learning Roman script, one must learn that the left/right orientation of a figure is often (in four of 26 lower-case letters) a specifically contrastive feature in the system of writing. Other scripts may make more or less use of mirror-image contrasts. This systematic attention to mirror-image contrasts in reading may motivate a preference for attending to this distinction in other (novel) domains of shape categorization. More detailed work examining this hypothesis, and in particular the degrees and types of literacy among individual Tamils participating in mirror-image tasks, is currently underway.

3.2. Japanese

Among the languages of our sample, Japanese is also written in a non-Roman script. In contrast to the Tamil subjects, however, Japanese literates consistently rejected the mirror image parts in our task.

At about the age of seven (second grade), Japanese schoolchildren learn the kanji characters 人 ‘to enter’ and 人 ‘person’. These two characters are initially learned as mirror-image reflections of one another in handwriting. In book (printing) fonts, these characters are no longer mirror-images: 人 has an additional stroke part, but is otherwise identical to 人. (Thanks to personal communications from Kyoko Inoue and Sotaro Kita for these observations). This is analogous to the loss of an exact mirror-image contrast between Roman b vs. d and p vs. q in the cursive handwriting taught later than the block letters and in certain printed fonts. Moreover, although Japanese is primarily written with kanji (Chinese characters) and kana (Japanese syllabary), school children — and all subjects in our Japanese sample — also learn romaji (Roman script) at age ten. So the Japanese subjects in fact share Roman script literacy with the subjects in our other samples who are literate only in Roman script. However, as we have seen, many Tamil literates are literate only in the Tamil script.

4. Conclusion

The judgment that left/right mirror-image counterparts are perceptually different from one another evidently depends to a large extent upon an individual’s exposure to cultural experiences in which this distinction has been made functionally salient. Among these experiences, literacy has been proposed (Verhaeghe & Kolinsky 1991) as especially important. The present multi-cultural and multi-linguistic study supports this claim: The intuition that two-dimensional right/left mirror-images should be distinguished from one another does not develop spontaneously. Rather, it is an acquired attentional practice which may not be learned in cultures where this distinction is not used contrastively.

The study also goes far to confirm the importance of literacy in the acquisition of the intuition that left/right mirror-image counterparts should be treated differently. In the four samples of our study in which all subjects declared themselves literate, a high rate of mirror-image part rejection was observed. In two of the four mixed-literacy samples in which numbers permit comparison (Mopan and Tzeltal), literacy was found to be a significant factor in performance. In the third of these four samples (Yucatec), literacy is not significant, but most individuals reject the Mirror matches regardless of their literacy status; this suggests that some form of cultural experience in addition to literacy is in operation. Only in the fourth mixed-literacy sample (Tamil) do both literates and non-literate accept mirror-image parts, despite instructions to the contrary.

In accounting for these observations, we suggest that specific properties of literacy in the Roman alphabet particularly favor the acquisition of the attentional practice of mirror-image discrimination. The Tamil script, unlike the Roman, does not make use of left-right orientation of lines for graphemic contrast (although it is written from left to right). Under this account, the effects of literacy on mirror-image judgments relate to the contrastive properties of the particular writing system employed, rather than to the general process of becoming literate.
Acknowledgments

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References


Appendix A: The set of cards used in the mirror-image experiment

Training Trial
Whole Figure
Genuine Part
Mirror Image
Control Non-Part

Experimental Trials
Whole Figure
Genuine Part
Mirror Image
Control Non-Part

Appendix B: The Tamil data on mirror-image acceptance

<table>
<thead>
<tr>
<th>Subject ID</th>
<th>Sex</th>
<th>Literate?</th>
<th>Signature*</th>
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<td>D2</td>
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<td>Y</td>
<td>R</td>
<td>5</td>
</tr>
<tr>
<td>D3</td>
<td>F</td>
<td>N</td>
<td>T</td>
<td>2</td>
</tr>
<tr>
<td>D4</td>
<td>M</td>
<td>Y</td>
<td>T</td>
<td>4</td>
</tr>
<tr>
<td>D5</td>
<td>F</td>
<td>Y</td>
<td>R</td>
<td>5</td>
</tr>
<tr>
<td>D6</td>
<td>M</td>
<td>N</td>
<td>S</td>
<td>5</td>
</tr>
<tr>
<td>D7</td>
<td>F</td>
<td>Y</td>
<td>T</td>
<td>3</td>
</tr>
</tbody>
</table>

NB. Subject D6 was excluded from consideration because she accepted three control parts as genuine.

*Script used in signing English-language receipt
R = signed fluently in Roman script
T = signed fluently in Tamil script
T− = signed non-fluently in Tamil script
S = unable to sign