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HOW LITERACY AFFECTS VISION: FURTHER DATA ON THE PROCESSING OF MIRROR IMAGES BY ILLITERATE ADULTS

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ABSTRACT
In our former work (Kolinsky, Verhaeghe, Fernandes, Mengarda, Grimm-Cabral, & Morais, 2011), we showed that adults who remained illiterate for socio-economic reasons have difficulties at processing lateral mirror images. This probably reflects the fact that the Latin alphabet requires taking mirrorimage contrasts into account, in order to distinguish e.g., "b" from "d", and hence that its acquisition pushes the beginning reader to "unlearn" the mirror symmetry invariance that characterizes our visual system. In addition, our results suggested that the illiterate's difficulties with orientation were not general: they had stronger difficulties with mirror images than with other orientation contrasts like rotations in the plane.

In the present study, we aimed at extending the latter result by using other materials and another task. In Experiment 1, we compared two groups of illiterates, both being required to sort circles on the basis of either their size or their orientation. Orientation contrasts involved mirror images in one group and a vertical vs. horizontal difference in the other group, angular separation being the same in both cases. Illiterates were indeed slower at sorting on orientation than on size. Yet, as labeling could have been easier with the vertical-horizontal contrast than with mirror images, in Experiment 2 we used a part-verification task in which we compared mirror images to images rotated in the plane. The illiterates' performance was worse with mirror images than with plane rotations. Thus, illiterates do not have general difficulties with orientation contrasts, but rather specific difficulties for discriminating lateral mirror images.

KEY WORDS: enantiomorphy, mirror-symmetry invariance, literacy effects, orientation processing

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Learning to read involves adapting the existing cognitive architecture to solve this new task. We now begin to understand that this learning process not only creates a specific circuitry for processing written material, leading to the development of a strong response to letter strings in the left fusiform gyrus (e.g., Dehaene & Cohen, 2011), but also deeply impacts on the organization of phylogenetically and ontogenetically older processing systems, including at the brain level (Dehaene, Pegado et al., 2010).

As already discussed by Morais and Kolinsky (2001, 2002, 2005), at the behavioral level, the impact of literacy has first been demonstrated as regards spoken language. In a seminal study, Morais, Cary, Alegria and Bertelson (1979) showed that awareness of phonemes does not develop spontaneously but in relation to reading acquisition. Rather than comparing preliterate to literate children, who do not only differ by their literacy level but also by age and hence neural maturation, Morais et al. compared two groups of adults who never attended school for socio-economic reasons. One of these groups included people who remained illiterate, while the other included ex-illiterates who were from the same socio-economic background as the illiterates but learned to read at adult age, in special alphabetization classes. This comparison is crucial. Indeed, comparing illiterate, unschooled adults to schooled literates would be problematic, since the latter differ from illiterates on many other variables: they attended school for many years, are educated, belong to middle or upper classes in terms of income, and may be on better health conditions (see Kolinsky, 1999, and Morais & Kolinsky, 2001, for discussions on this point). Therefore, it is only by comparing illiterates to ex-illiterates that the specific effects of literacy acquisition can be isolated. In the study by Morais et al., these two groups were examined on the ability to manipulate phonemes intentionally. Contrary to exilliterates, illiterates were unable to either delete the initial consonant of a verbal item or add one at the onset, showing that learning to read, at least in an alphabet (Read, Zhang, Nie, & Ding, 1986), modifies the way we conceptualize spoken language.

More recently, the impact of literacy has been examined through the occurrence, in literate participants, of effects of orthography. For example, the orthographic consistency effect refers to the fact that knowledge of word spelling influences speech recognition performance: making for example lexical decision on spoken words whose rimes can have different spellings in different words of the language (e.g., in Portuguese, “dez” or “pés”) takes longer than making lexical decision on words whose rimes can have only one spelling in the written system of the language (e.g., in Portuguese, “lume”). First reported in French (Ziegler & Ferrand, 1998), this effect has been since then replicated in several other languages, including in Portuguese (e.g., Ventura, Morais, Pattamadilok, & Kolinsky, 2004). These results are impressive, as they show that literacy impacts not only the way we conceptualize language but also the very on-line processes of spoken recognition. This conclusion was further supported by the observation of event-related potentials time-locked to the occurrence of the orthographic information in auditory lexical or semantic decision tasks (e.g., Pattamadilok, Perre, Dufau, & Ziegler, 2009; Perre, Pattamadilok, Montant, & Ziegler, 2009).

Even more impressively, recent data show that the impact of literacy extends far beyond the language domain. In particular, literacy has been shown to affect visual non-linguistic processes both at the brain level (leading e.g. to neural competition between written words and other objects categories – in particular faces– in the left fusiform gyrus, Dehaene, Pegado et al., 2010), and in behavior.

At the behavioral level, we examined in particular the impact of literacy on the ability to discriminate lateral mirror images, or enantiomorphy. Most natural categories are indeed invariant for left-right inversion. Accordingly, the visual system readily performs mirror-image generalization, as

shown through both single inferotemporal neurons recordings in monkeys (Baylis & Driver, 2001; Logothetis & Pauls, 1995; Logothetis, Pauls, & Poggio, 1995; Rollenhagen & Olson, 2000) and brain imaging in humans (Dehaene, Nakamura et al., 2010; Pegado, Nakamura, Cohen, & Dehaene, 2011). However, mastering the Latin alphabet requires taking mirror-image contrasts into account, in order to distinguish "p" from "q" and "b" from "d". Hence, learning to read may push the beginning reader to "unlearn" mirror symmetry invariance, and this effect, also strongest for written materials, may generalize to non-linguistic stimuli (e.g., Dehaene, Nakamura et al., 2010; Pegado et al., 2011).

Recently, we carefully evaluated this hypothesis in behavioral studies conducted both in Brazil and in Portugal. Comparing the performance of illiterate, ex-illiterate and literate adults in various tasks (Kolinsky, Verhaeghe, Fernandes, Mengarda, Grimm-Cabral, & Morais, 2011), we showed that illiterates performed far worse than all other subjects when the task required paying attention to enantiomorphic differences.

More specifically, we used two different kinds of task. One was the sorting of geometrical figures according to a prespecified, target dimension. For stimuli similar to those presented in Figure 1a, the target dimension was either the orientation of the diagonal line, or the size of the circles. We used the sorting conditions designed by Garner (1974). The task, which remains formally the same for the participant throughout the various conditions, allows one to distinguish difficulties in paying attention to the target dimension in the presence of variations on another, irrelevant, dimension from more basic perceptual difficulties with the target dimension. Indeed, potential basic perceptual difficulties could be observed in the baseline, so-called standard condition, in which, for example if orientation is the target dimension, only small circles are presented and only line orientation varies. In the other conditions, the target dimension remains the same, but size varies in an irrelevant way. Size can be either redundant (e.g., when in the sorting set all stimuli with / diagonals are small and all with \ diagonals are large), or orthogonal (when both large and small circles appear with either / or \) to the variations of orientation. Comparing performance between the orthogonal and the standard condition allows one to evaluate the participants' attentional filtering capacities. Indeed, if the intentional processing of the target dimension – orientation – entailed also some processing of the non-target dimension – size, participants would be unable to filter out, at least completely, the irrelevant variations and would display poorer performance in the orthogonal condition than in the standard one. This effect, referred to as Garner interference (Pomerantz, 1983), reflects difficulties of selective attention to the underlying dimensions (e.g., Thibaut & Gelaes, 2002). In other words, when figures vary according to more than one dimension, selective attention is needed to guide the sorting decision.

The other task used by Kolinsky et al. (2011) was a comparison of two geometrical (or blob-like, depending on experiment) figures as being the same or different, the only difference between the two figures, when there was any, being their orientation (e.g., if participants were presented with the first line of Figure 1a and had to answer "different"). Here, on "different" trials, stimuli varied only according to orientation, but their identities varied across trials.

Coherent with former data (Kolinsky, Morais & Verhaeghe, 1994), we observed that the illiterates were not totally insensitive to mirror-image contrasts. As a matter of fact, in our study (Kolinsky et al., 2011) even illiterates obtained reasonable performance (always higher than 85% correct) when nothing else than orientation was varying in the stimulus set, as was the case in the standard condition of the sorting task. However, when other aspects of the stimuli varied in an irrelevant way, illiterates had strong difficulties at paying attention to the mirror-image contrasts. This was observed both when

the stimuli were varying on another dimension in the stimulus set, i.e., in the orthogonal condition of the sorting task, and when the stimuli were varying by identity across trials, as was the case in the same-different judgment task. In these situations, illiterates performed frequently at or near chance level, and, crucially, much poorly than both ex-illiterates and schooled literates. This demonstrates a specific effect of acquiring literacy in a writing system that incorporates mirrored letters like "b" and "d": the beginning reader unlearns the default invariance for mirror symmetry, and generalizes this process to nonlinguistic stimuli.

In addition, our results (Kolinsky et al., 2011) suggested that the illiterate's inattention to orientation was not general: they had stronger difficulties to make same-different judgments when "different" pairs included lateral mirror images than when they were presented with other orientation contrasts like rotations in the plane.

In the present study, we aimed at extending the latter result by using other materials (Experiment 1) and another task (Experiment 2). In Experiment 1, we compared two groups of illiterates, both being required to sort circles on the basis of either their size or the orientation of their diagonal. Orientation contrasts involved mirror images in one group and a vertical vs. horizontal difference in the other group, angular separation being the same in both cases. Since labeling could have been easier with the vertical-horizontal contrast than with mirror images, in Experiment 2 we used a part-verification task (described in more detail below) in which we compared mirror images to images rotated in the plane by either 90° or 180°. In both tasks, if illiterates had general difficulties with orientation contrasts, they would perform as poorly with whatever kind of orientation contrast. If, on the contrary, their difficulties were specific to lateral mirror images, their performance would be better with nonenantiomorphic contrasts than with enantiomorphic ones.

Some characteristics of the illiterates we examined in the present study applied to all samples and hence are indicated here once for all. They had never attended school in childhood, with the exception of a few participants (always less than 20% of the sample), who did attend school in childhood but just for some months and in an irregular way. No participant was able to read even simple words; most were even unable to sign their own name. They were working as farm workers (both genders), shoemakers, masons, workmen (for men), servants, housewives (for women), or were retired or unemployed.

EXPERIMENT 1: SORTING OF LATERAL MIRROR IMAGES, HORIZONTAL-VERTICAL, OR SIZE CONTRASTS

Two groups of illiterate adults were required to sort circles on the basis of either size or orientation of printed diameter, with orientation contrasts being, for one group, mirror images (henceforth, 45° left/right material), and, for the other group, a vertical vs. horizontal difference, angular separation being the same in both cases (see Figures 1a and b). If illiterates had specific difficulties for lateral mirror images, they should perform better with the latter material than with the 45° left/right contrast.

Method

Participants

On the whole, 24 illiterate women were tested, being randomly selected to be presented with either the 45° left/right material or the vertical/horizontal material. Care was taken to match the two groups in age. Half of the participants were presented with the 45° left/right material; they were aged from 33 to 64 yrs (average: 53 yrs) and came either from Beira Baixa or from the region of Lisbon. The others were presented with the vertical/horizontal material; they were aged from 29 to 63 yrs (average: 50 yrs) and came from the region of Lisbon.

Material and procedure

The stimuli were circles appearing with their printed diameter (see Figure 4). They varied by their size (2.6 vs. 2.2 cm diameter for large vs. small circles) and by the orientation of the tilted diameter. Two different materials were used, one in which the diameter of the circle was tilted 45° left or right from the vertical, the other in which it was either horizontal or vertical (see Figures 1a and b). Thus, angular separation was 90° in both cases. Each stimulus was drawn in black ink and centered on a white plastic card 6.2 cm wide on 10 cm height.

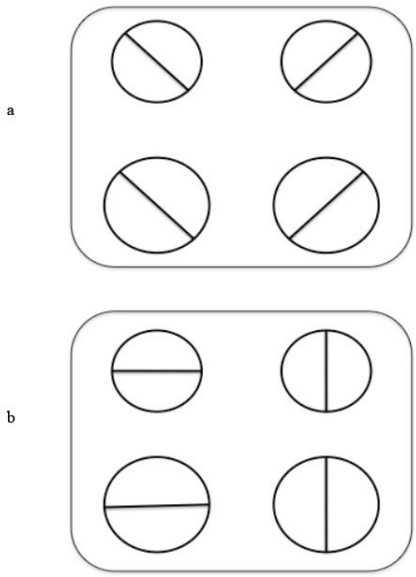

Figure 1: Geometrical figures used in Experiment 1 (a: 45° left/right material; b: vertical/horizontal material).

There were three conditions: standard, redundant, and orthogonal. For all conditions, the task was presented as a card game. Being given a pile of 32 cards in hands, the participant had to sort it into two piles on the table, one on the left and one on the right, according to a preset criterion.

In the standard condition, there were only two types of cards in the original pile. When participants had to sort according to size, the orientation of the diagonal was kept constant within a pile (tilted 45° right in the vertical/horizontal material; vertical in the 45° left/right material). For both materials, when they had to sort according to the orientation of the diagonal, the size of the figure was kept constant, with an intermediary size, namely 2.4 cm diameter. In the redundant condition, for both orientation and size sorting, the diameter of the large circle was tilted 45° right (or was horizontal, in the other material) while the diameter of the small circle was tilted 45° left (or was vertical, in the

other material). In the orthogonal condition, for each material the four figures were used within a pile, and it was only the sorting criterion (orientation or size) that varied according to instructions.
Thus, for each dimension of each material, each participant was presented with two standard conditions, one redundant condition and one orthogonal condition. For each of these conditions, there were three piles of cards of 32 cards each, presented in random order. For each material, the 12 piles corresponding to sorting according to one specific dimension were blocked, with half of the participants starting with orientation sorting, the others with size sorting. The order of the standard, redundant and orthogonal conditions was also counterbalanced between participants. There were thus 12 different testing orders by group.

Instructions were given before the participant was presented with the first sorting pile. They emphasized both speed and accuracy and were illustrated by examples that remained in front of the participant (on the top of the left/right positions where the response cards were to be placed) all the time he/she had to perform the same sort. For each material, when sorting for the first time on a specific dimension, the participant could choose the side where he/she preferred to set the two specific figures that were required as response (e.g., for form, arrows on the left and triangles on the right, or the reverse). This attribution of response to side was then maintained for that dimension throughout all conditions.

Instructions were repeated before each pile. The participants were presented with each pile of card upside down. They were instructed to turn it and begin sorting only when told by the experimenter, who at the same time started the chronometer, which was stopped when the participant had put the last card of the pile on the table. This allowed registering sorting times with an accuracy of roughly 0.1 sec. The experimenter also noted each error. For each material, the whole session lasted about one hour.

Results

We performed an overall ANOVA with material (45° left/right vs. horizontal/vertical) as between-subjects factor, and condition and dimension as within-subject factors. Contrary to what we expected, neither the material effect, $F(1,22) = 1.10$, $p > .10$, nor the interaction between material and dimension, $F(1,22) = 2.34$, $p > .10$, was significant in the ANOVA on error rates. This revealed only a significant main effect of dimension, $F(1,22) = 5.29$, $p < .05$, showing size to be better processed than orientation, with average error scores of 0.6 and 4.9%, respectively. Even orientation sorting of the 45° left/right material was well succeeded (4.08 and 6.86% errors in the standard and orthogonal conditions, respectively).

However, inspection of the sorting times revealed that this absence of effect had a strong cost for illiterates in terms of processing speed. As a matter of fact, the ANOVA on sorting times showed a significant dimension by material interaction, $F(1,22) = 5.45$, $p < .05$. As illustrated in Figure 2, when sorting on size, there was no difference in sorting times between the two materials, $F < 1$. However, when sorting on orientation, illiterates were slower with the 45° left/right than with the vertical/horizontal material, $F(1,22) = 4.72$, $p < .05$. Indeed, although for both materials illiterates were slower to sort orientation than size, $F(1,11) = 8.96$ for the 45° left/right and $= 8.01$ for the vertical/horizontal material, both $p < .025$, they took almost 15 s more per pile of 32 cards (i.e., about 455 ms more per card) to sort orientation for the 45° left/right material (on average, 49 s) than for the vertical/horizontal material (on average, 34 s).

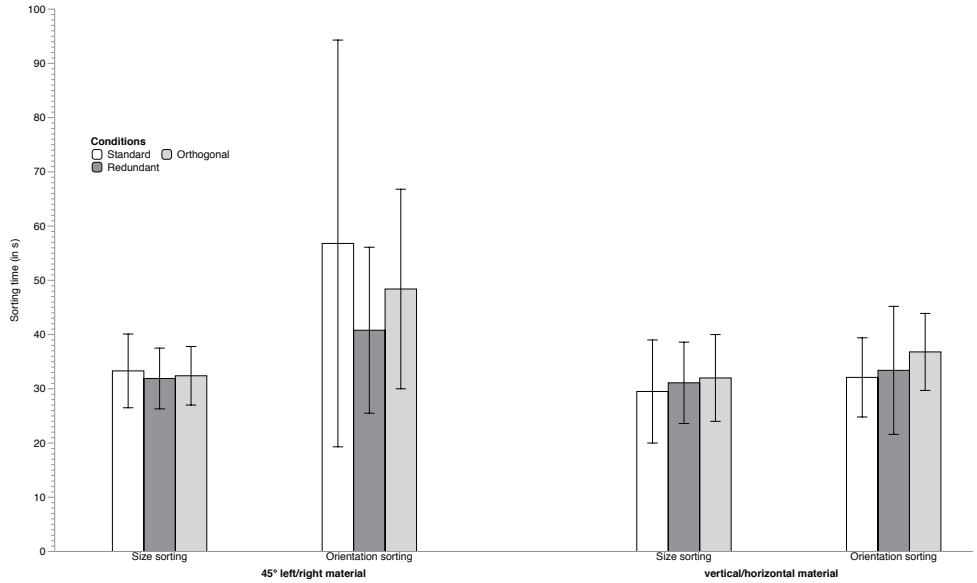

Figure 2: Average sorting times (in s) per block of 32 stimuli observed in the sorting task used in Experiment 1, separately for each material, each condition and each sorting dimension.

In the analysis on sorting times, there was also a significant condition by material interaction, $F(2,44) = 4.0$, $p = .025$. With the 45° left/right material, the illiterates were actually so slow in the standard condition (and this was mainly due to orientation, as illustrated in Figure 2) that the Garner interference effect and hence the main condition effect was cancelled out, whereas in the vertical/horizontal material the condition effect came out significantly, $F(2,22) = 4.5$, $p < .025$, reflecting a small but significant Garner interference effect in the orthogonal condition, $F(1,22) = 8.91$, $p < .01$.

Thus, the present results suggest that illiterates have special difficulties with lateral mirror-image contrasts. Although the illiterates examined here succeeded in sorting such contrasts quite correctly, they did so at the cost of sorting times, which were far longer when they had to sort on the basis of a mirror contrast than on the basis of a vertical-horizontal orientation contrast. Angular separation being the same in both materials, this factor cannot account for the observed result pattern. Nevertheless, we should acknowledge that the two different materials may have differed, at least for illiterate people, in terms of the accessibility of the linguistic labels associated to the contrast they present. Indeed, it is plausible that people who do not read and write are more familiar with the "horizontal" and "vertical" labels than with the "left" and "right" ones. This is why we designed Experiment 2, in which the labels associated to rotations in the plane are certainly not more familiar than the "left" and "right" ones.

EXPERIMENT 2: PART-VERIFICATION OF MIRROR IMAGES AND PLANE ROTATIONS

In the present experiment, we examined whether the illiterates' tendency to neglect lateral mirror-image contrasts would also manifest itself in a partverification task that required participants to discard mirror images as being the correct part of a complex drawing.

In this task, the participants' judgment was about the presence/absence of a three-segment part that was either very salient (H pairs) or embedded within a six-segment figure (M pairs, see an illustration in Figure 3), the task and the material being inspired by Palmer (1977). We know from former work (Kolinsky, Morais & Brito Mendes, 1990; Kolinsky, Morais, Content & Cary, 1987) that finding

such embedded parts is difficult for illiterate (and, more generally, for unschooled) people. However, rather than being interested here in their ability to find the more or less deeply embedded parts, we specifically checked whether illiterates would be able, on negative pairs, to reject parts that are mirror images of the one actually included in the figure.

Danziger and Pederson (1998) and Pederson (2003) have already used a similar manipulation with the part-verification task. Their participants were instructed to accept the exactly identical part and to reject both a clear non-part (for example a square instead of a triangle) and the mirrored part (of the same triangle). The authors showed that readers of a written system that does not incorporate mirror-image signs (the Tamil syllabary) were very poor in rejecting mirrored parts. Coherently, Pederson (2003) found that monoliterate Tamil participants were poorer than biliterate ones, i.e. than those who also knew the Latin alphabet.

However, Danziger and Pederson (1998) did not demonstrate the specificity of the impact of Latin literacy: the effect could be more general, making it easier to discriminate forms whatever the type of orientation transformation, or even to discriminate other visual characteristics than orientation, depending, for example, on the visual complexity of the written system. In addition, our own results (Kolinsky et al., 2011) suggest that the inclusion of trials with a clear non-part could have lowered somewhat their participants' performance by making them focus their attention on form variations rather than on the orientation of the part.

For these reasons, on negative pairs we used here only orientationdifferent parts (and never clear non-parts), but in addition to mirrored parts, illiterates were presented with parts that were rotated in the plane by either 90° or 180° from the vertical. If illiterates had general difficulties to process orientation contrasts, they would be as poor for these rotated parts as for mirrored parts. If, on the contrary, their difficulty were specific to mirror images, they should reject more easily the rotated arts.

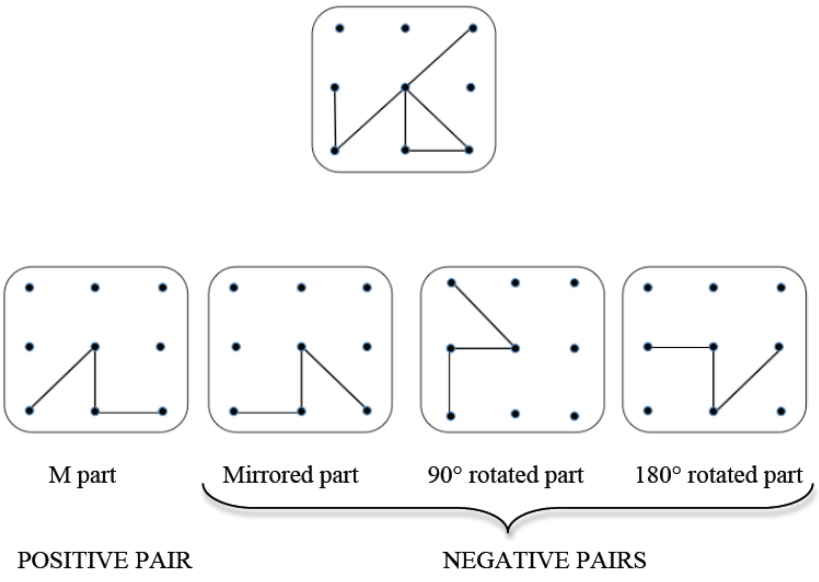

Figure 3: Illustration of the material used in Experiment 2, adapted from Palmer (1977). The figure appears at the top line, the parts at the bottom.

Method

Participants

The 36 illiterates (25 women) were aged from 34 to 84 yrs (average: 61 yrs); most of them were from Alentejo, Ribatejo or the region of Lisbon.

Material

Each target part was made out of three segments, and each figure out of six segments. All the stimuli were drawn on a computer (Harvard Graphics Program) and printed in black within a 3 x 3 dotted square matrix of 2.2 cm on side. This matrix was centered on a white plastic card. Different cards were used for the figure and for the target part.
The material was created on the basis of the figures and parts designed by Palmer (1977). There were 24 positive pairs (in which the part was present in the same orientation), half with a high (H) and half with a medium (M) goodness level. As illustrated in Figure 13, for each of the figures, three negative pairs were constructed, one with the target being a lateral mirror image (henceforth, mirrored parts), the two others with the target being a plane rotation (either 90 or 180°, henceforth rotated parts) of the part actually included in the figure. There were thus a total of 48 pairs, half positive (12 H 14 and 12 M) and half negative (8 with a part rotated by 90°, 8 with a part rotated by 180° and 8 with a mirrored part, half being H and half M targets).

The pairs used here were slightly different from the ones designed by Palmer (1977) and used by Kolinsky et al. (1987; 1990), because they had to be adaptable to mirror- or rotation-transformations, which was not the case of all the parts used in former studies. For this reason, 24 students of the University of Lisbon evaluated the (randomly mixed) positive pairs for the quality of the relationship between the part and the figure, using a scale from 1 (very bad relationship) to 10 (very good relationship). H pairs elicited higher evaluations than M pairs (9.31 vs. 6.97, on the average), the effect goodness level being significant in the ANOVA run on these scores, $F(1, 23) = 111.32$, $p < .0001$.

Six additional figures and parts were used as examples (3 positive and 3 negative pairs, the latter including one mirrored part and two rotated parts) and training pairs (half positive – 3 H and 3 M – and half negative, among which 2 mirrored parts and 4 rotated parts).

Procedure

On each trial, the experimenter showed first the figure and next the part. The two cards then remained on the table in view of the participant until a response was given. The participant's task was to find "whether the small part is within the big drawing". Instructions emphasized accuracy, not speed of response.

The session began with six pairs of examples. The 12 training pairs were then presented. For both the examples and training trials, the experimenter gave a verbal feedback as well as a visual feedback, using a transparent plastic sheet on which the target was printed. This plastic sheet was first superimposed on the target (to show that it matched it) and then on the figure, to check for the presence or absence of the target.

For the next 48 pairs, no more feedback was given; the experimenter only noted the participants' responses. For both these pairs and the training ones, order of pairs was pseudorandom, with the constraint that no more than three trials in a row led to the same expected response. The whole session lasted about 30 min.

Results and discussion

Overall, illiterates performed at 69.04% correct, better than chance level (50%), $t(35) = 9.1$, $p < .0001$. As in Palmer (1977) and in former studies on illiterates (Kolinsky et al., 1987; 1990), the analysis on correct performance for positive pairs showed a significant effect of goodness level of the part-figure relationship, $F(1, 35) = 108.492$, $p < .0001$, with, as illustrated in Figure 4, far better performance on H than on M pairs.

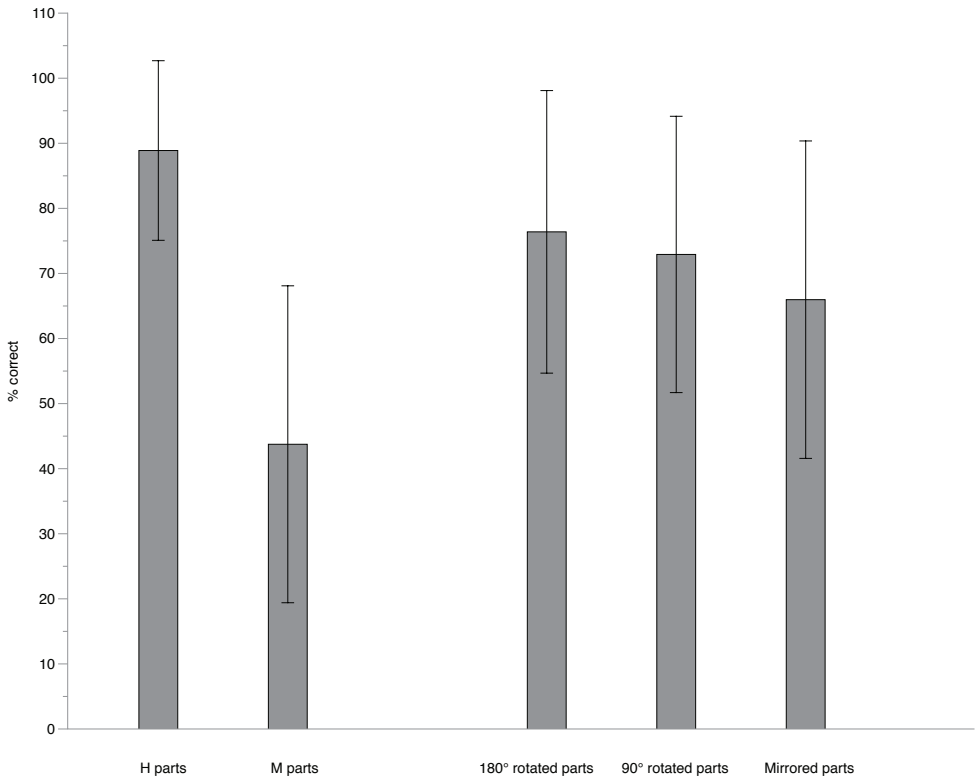

Figure 4: Average error scores (in %) observed in the part-verification task used in Experiment 2, separately for each type of part. Error bars represent one standard deviation above or below the mean.

On negative pairs, the ANOVA on correct scores included part type (mirrored vs. 90° or 180° rotated) in addition to goodness level as withinsubject variables. As for positive pairs, the effect of goodness level was significant, $F(1, 35) = 8.66$, $p < .005$, but here it reflected the fact that participants were more prone to accept (and hence to make an error on) H pairs than M pairs, which led to average correct scores of 62.3 and 81.2%, respectively. This effect of goodness level did not interact with part type, $F < 1$, which significantly affected performance, $F(2, 70) = 8.66$, $p < .0005$. As illustrated in Figure 4, although performance was better than chance for all part types (90° rotated parts: $t(35) = 6.475$, $p < .0001$; 180° rotated parts: $t(35) = 7.294$, $p < .0001$; mirrored parts: $t(35) = 3.93$, $p < .0005$), both 90° and 180° rotated parts led to significantly better performance than mirror parts, $F(1, 70) = 7.42$, $p < .01$ and $F(1, 70) = 16.71$, $p < .0001$, respectively, without differing significantly from each other, $F(1, 70) = 1.85$, $p > .10$.

Thus, although illiterates' performance for rotated parts was far from perfect, rotation led to better performance than mirror images. With the latter, illiterates exhibited relatively poor performance, as was the case in the samedifferent comparison task and in the orthogonal condition of the sorting task used in our previous study (Kolinsky et al., 2011).

GENERAL DISCUSSION

Based on the fact that literacy impacts on enantiomorphy, with illiterates presenting difficulties at processing lateral mirror images (Kolinsky et al., 2011), in the present study we further examined the specificity of this effect by comparing such contrasts with other orientation contrasts.

In Experiment 1, we compared two groups of illiterates, both being required to sort circles on the basis of either their size or the orientation of their diagonal. Orientation contrasts involved 45° left/right mirror-image contrasts in one group and a vertical vs. horizontal contrast in the other group, angular separation being thus the same in both cases. Although illiterates were able to sort on orientation both the 45° left/right mirror-image contrasts and the vertical/horizontal ones, they were much slower at sorting the former, showing that they experienced attentional difficulties when the target dimension was mirror orientation. Contrary to what we observed in our former study (Kolinsky et al., 2011), here, in Experiment 1, the illiterates presented difficulties to sort on left-right orientation already in the standard condition, and not only in the orthogonal condition, but these difficulties were observed only in terms of sorting times, not on accuracy. Further studies will have to assess whether this difference reflects the fact that in the present material, we used a huger leftright angular contrast (45°) than in our former study (20°), which may have turned the present material easier to sort on orientation.

In the part verification task used in Experiment 2, on negative pairs participants had to reject parts that were either mirror images or rotations of the part actually included in the figure. Illiterates were significantly poorer at rejecting mirrored parts than at rejecting rotated ones. This provides a stronger basis than Experiment 1 to demonstrate the specificity of the illiterates' difficulty with mirror images. Indeed, while in Experiment 1 the illiterates' better performance for the vertical/horizontal contrast in comparison to the mirror contrast could have been due to easier labeling of the former, this was not the case in Experiment 2.

To summarize, the present ensemble of results confirms two facts: first, that, in unschooled illiterate people, selective attention to mirror-image contrasts is much harder than selective attention to differences in other dimensions like size; second, that the illiterates' inattention to orientation is not general, as they have more difficulties with lateral mirror images than with other orientation contrasts, like a vertical-horizontal contrast (Experiment 1) or other rotations in the plane (Experiment 2). Thus, illiterates seem to experience specific difficulties with lateral mirror images, which is coherent with evidence showing that the brain areas supporting rotation and mirror reflection are largely different (Núñez-Peña & Aznar-Casanova, 2008; Weiss et al., 2009).

Future studies will have to examine what is precisely the basis of the illiterates' difficulties with mirror images. One important issue is to establish the origin of their difficulties in terms of orientation coordinates. Indeed, it has recently been shown that young preliterate children make more errors linked to extrinsic axes than beginning readers and literate adults, the latter failing mainly for reflections across the object axis (Gregory, 2010; Gregory & McCloskey, 2010). One may also wonder whether illiterates experience similar difficulties with mirror images of pictures of familiar objects like tools, clothes and furniture, or whether their difficulties are confined to less familiar geometrical (or blob-like) figures, as in our former study (Kolinsky et al., 2011) and in the present one. After all, they deal correctly with all these objects in everyday life, and do not seem to have more problems than schooled literates to put the right shoe on the right foot. We are currently exploring both issues.

COMO A ALFABETIZAÇÃO AFETA A VISÃO: MAIS INFORMAÇÕES SOBRE O PROCESSAMENTO DE IMAGENS ESPELHADAS POR ADULTOS ANALFABETOS

RESUMO
Em nosso trabalho (Kolinsky, Verhaeghe, Fernandes, Mengarda, Grimm-Cabral, & Morais, 2011), mostramos que os adultos que permaneceram analfabetos por razões sócio-econômicas têm dificuldades no processamento de imagens em espelho laterais. Isso provavelmente reflete o fato de que o alfabeto latino exige que se domine contrastes de imagens em espelho para que se possa distinguir, por exemplo, "b" de "d". Portanto, a aquisição destes contrastes empurra o leitor iniciante a "desaprender" a invariância na simetria em espelho que caracteriza o nosso sistema visual. Além disso, nossos resultados sugerem que as dificuldades com a orientação dos analfabetos não são de ordem geral: eles mostraram ter mais dificuldades com imagens de espelho do que com outros contrastes de orientações. como as rotações no plano.

PALAVRAS-CHAVE: anafabetismo, processamento em espelho, visão, adultos analfabetos

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