REVISTA DA **ABRALIN**

PILOT STUDY

Eye-tracking literacy effects in face and graphism recognition in a non-weird population: the Karaja of central Brazil

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ABSTRACT
This eye-tracking study investigates the Karajá, a Brazilian indigenous ethnic group, to examine how literacy may influence implicitly developed cognitive processes. We compared unschooled illiterate and literate participants regarding their eye gaze patterns across three categories: (i) faces of Karajá, other indigenous groups, and non-indigenous individuals; (ii) graphemes; and (iii) graphisms created by Karajá, other indigenous, and Western artists. Our findings reveal that literacy significantly impacts face processing. Literate participants, overcoming the natural left-right invariance, displayed a more symmetric visual inspection of faces, a pattern not observed in their inspection of graphisms. In contrast, illiterate participants primarily focused their gaze on the right side of faces, with significantly higher fixation counts and average fixation times on this side. Additionally, literacy appeared to indirectly reinforce the own-race bias: literate Karajá participants correctly identified faces from their ethnic group in 85% of trials, compared to a 65% success rate among illiterate participants. Overall, these results contribute to a less dogmatic understanding of the interplay between cognitive and cultural factors in non-WEIRD populations. By emphasizing the role of cultural and literacy-related influences, the study provides a framework in which cognitive processes can

be understood as a harmonious modulation of nature and nurture effects. Furthermore, the findings challenge prevailing assumptions in the field, particularly regarding the dichotomy between bottom-up algorithms and top-down heuristics. They highlight the potential of non-WEIRD populations as a valuable and underexplored resource for addressing foundational questions in the nature/nurture debate, offering fresh perspectives for future research.

RESUMO

Este é um estudo de rastreamento ocular de participantes de um grupo étnico indígena brasileiro, Karajá, para medir o impacto que a leitura pode representar sobre cognições implicitamente desenvolvidas anteriormente. Comparamos participantes analfabetos e alfabetizados em relação ao olhar deles para: (i) rostos de pessoas Karajá, de outros povos indígenas e não indígenas; e também (ii) grafemas e (iii) grafismos produzidos por pessoas Karajá, por outros artistas indígenas e por ocidentais. Nossas descobertas sugerem que a alfabetização afeta significativamente o processamento de rostos: ao superarem a invariância esquerda-direita, os participantes alfabetizados fazem uma inspeção visual dos rostos mais simétrica (mas não dos gráficos) do que a dos analfabetos, que não necessariamente inspecionam ambos os lados, apresentando tempos médios de fixação e contagens de fixação significativamente maiores no lado direito. Além disso, a alfabetização parece, de alguma forma, reforçar indiretamente o próprio preconceito racial: os Karajá alfabetizados identificaram corretamente os rostos do seu próprio grupo étnico em 85% dos casos, enquanto os analfabetos acertaram apenas em 65% dos ensaios. Em suma, as descobertas conduziram a um exame menos dogmático da interação entre fatores cognitivos e culturais em populações não-*WEIRD*, o que oferece ao campo um quadro analítico no qual estes fatores podem melhor harmonizados para explicar os efeitos da natureza/criação. Os resultados permitiram-nos reformular ideias consagradas na área, relativas a algoritmos *bottom-up* e a heurísticas *top-down*, que podem ter o potencial de indicar que a área relativamente nova dos estudos sobre sociedades não-*WEIRD* deve ser levada a sério como uma fonte seminal nos estudos sobre o debate natureza/sociedade.

KEYWORDS

Mirror-symmetry invariance. Enantiomorphy. Literacy effects. Eye-tracking. Karaja.

PALAVRAS-CHAVE
Invariância do espelho. Enantiomorfismo. Efeitos da alfabetização. Rastreamento ocular. Karajá.

RESUMO PARA NÃO ESPECIALISTAS
Nas últimas décadas, a pesquisa na área da Psicolinguística alcançou alto nível técnico, bem como rigor experimental e estatístico, que requer que os estudos aconteçam preferivelmente em ambiente controlado de laboratório, a depender da técnica escolhida. O presente trabalho quebrou este paradigma, levando o método científico e um instrumental de ponta, o rastreador ocular, para uma aldeia indígena da etnia Karajá, na Ilha do Bananal, Tocantins. O objetivo foi verificar até que ponto ser ou não alfabetizado influía na forma como os participantes Karajá reconheciam faces, letras e desenhos gráficos. Este tema é muito relevante porque pode nos ajudar a entender se práticas e aprendizados sociais como a leitura podem influir em cognições que se desenvolvem naturalmente, como o reconhecimento de faces e objetos. Assim, os pesquisadores fizeram algumas concessões metodológicas, como ter um número menor de participantes e recolher dados de pessoas com idades mais variadas do que o usual, recortes sem os quais não se teria conseguido testar esse grupo especial. Os resultados permitiram reformular ideias consagradas na área, contribuindo para o conhecimento sobre os sistemas cognitivos nas populações oriundas de comunidades não urbanas, indicando que a pesquisa experimental de campo deve ser encarada como uma fonte seminal para estudos referentes ao debate fundamental sobre natureza e sociedade.

Introduction

A variety of researchers working with indigenous populations around the world usually agree that it is past time that the cognitive revolution reach field research in different domains, including Linguistics and Cultural Studies. This new endeavor, which is being called **experimental field work,** is facing the challenge of bringing together crucial dimensions of linguistics and anthropology, such as different theories, psycholinguistic methods and fieldwork procedures in order to attempt to uncover processes which could never be discovered solely on the basis of corpus building. Thus, there is principled reason to act out experimental procedures, sentence/picture matching, controlled speeded judgment, self-paced reading or listening, lexical decision, priming and even more sophisticated experimental techniques, such as eye-tracking and EEG in the field. Additionally, it seems clear that Western, educated, industrialized, rich and democratic (WEIRD) societies — that represent as much as 80 percent of study participants, but only 12 percent of the world's population — are not only unrepresentative of humans as a species, but on many measures are just outliers (cf. Heinrich, Heine and Norenzayan 2010). In this respect, we expect that by publishing cutting-edge eyetracking research data from a non-weird population, we will ultimately contribute to "decolonizing our teaching, our psyches, our institutions, and our field" as proposed in Arnold (2024).

Above all, as pointed out in a seminal paper by Whalen and McDonough (2015), "taking the laboratory into the field" to collect data on understudied populations brings challenges not only concerning logistics and ethics, but also in relation to the default standard procedures and scientific methods, which need to be adapted to less controlled conditions in the field.

The present research explores these frontiers reporting a pilot study that measures impact that reading may pose onto previously and implicitly developed object, face and other race face cognition. In this study,[1] participants belong to a non-WEIRD population – a Brazilian indigenous ethnic group – Karaja.

The Karaja are approximately 4,000 people, distributed in about 20 villages on and around the Bananal Island, in the state of Tocantins in Central Brazil (See Fig 1).

FIGURE 1 – Karajá land by the Araguaia river in central Brazil. Bananal Island highlighted by circle
Source: elaborated by the authors.

Although in contact for at least two centuries with the surrounding society, the Karaja preserve their language and culture. A Karajá child's first language is rarely not the language of their people, even though the learning of Portuguese as a second language takes place increasingly earlier in the

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[1] This study was performed by the joint effort of LAPEX and ACESIN labs, respectively coordinated by the two authors, during an experimental field work trip to Bananal Island in the state of Tocantins. It was a large research adventure in which many projects were developed, including this one. We are sincerely grateful to the amazing professors, students and collaborators that helped us: Aleria Lage, Chang Whan, Cristiane Oliveira, Daniela Cid de Garcia, Juliana Novo Gomes, Julius Britto, Mariana Chang Maia and Mei Chang Maia.

villages. Literacy at the villages' schools is carried out by indigenous teachers initially in the native language and, in a second moment, in Portuguese, since Karaja was given an orthography in the 1950s by missionaries from the Summer Institute of Linguistics. However, there are still many illiterate adults and adults who have only recently decided to become literate.

In our pilot study with Karaja participants, we compared the eye gaze of unschooled illiterate and literate participants to: (i) faces of Karaja, other indigenous and white people, (ii) graphemes and (iii) graphisms typically designed by western artists, by Karaja and by other indigenous people.

Since the visual inspection and processing of each of these visual elements has its own peculiarities, next we provide an overview of the literature focusing on eye tracking studies, even if applied to a WEIRD population as a reference point to our pilot investigation.

1. Exploring the ventral pathway: object recognition (graphism), face recognition and reading

Many details of vision psychophysics and neurophysiology are still very much unknown, such as the degree of the nature-nurture interplay in the development of these cognitions since childhood. But findings from multiple sources of research – vision behavior and physiology in humans and other primates, object agnosia and prosopagnosia patients, functional imaging, near-brain model systems, and, crucially for us, other-race studies, – have been providing clear advances into the field.

Concerning object recognition, whenever visual information related to an object flows in through the retina into V1 (the primary visual cortex), it gets transferred to neurons in the pulvinar inferior occipital gyrus, named object form area (OFA). Processing starts along this pathway transforming data into coherent perceptions that match mental representations of such objects stored in the brain (DiCarlo, Zoccolan, Rust 2012; Rossion, Hanseeuw, Dricot 2012).

The ability to recognize objects quickly, despite the substantial variation under different light and angles, is most probably resolved in the brain through a cascade of reflex calculations, culminating in a matching with a representation in inferior temporal cortex (ITC). Through recent imaging techniques, there is evidence that the whole processing of invariant object recognition takes a ventral stream (the What Pathway) that goes from V1 in the occipital lobe to ITC (Tang *et al*. 2017, Banich, Compton, 2018).

Besides, while predominant models of visual recognition argue for across-the-board recognition in the OFA, other accounts emphasize the recruitment of a complex of brain areas including connectivity with dorsal fronto-parietal attention networks underlying visuo-spatial attention and implicit memory, also known as (motor memory or *procedural memory*). This memory needs overt conscious motor appreciation (Chen *et al* 2019; Dharani 2015). This may be specially interesting to note in our study, since the Iny graphism is constantly practiced by the Karaja, so when judging takes place in the experiment, it will probably automatically engage motor memory as well as vision areas.

Although the algorithm that produces this identification solution is still partly under discussion, consolidating all these recent findings, there is evidence that object recognition processing activates several micro networks of retinotopic representations that are finally projected to higher cognitive regions of the brain, involved in decision making, action and memory (cf. DiCarlo, Zoccolan, Rust 2012 for a complete review).

As to methodological approaches, fundamental to the field have been the eye tracking investigations of the visual perception of images that go back to Buswell (1935). He presented results of ingenious experiments in which, the light reflected on the cornea of participants observing scenes through the blades of a fan was recorded. Buswell was thereby able to determine gaze direction and duration and concluded that the fixations were not randomly distributed in the 55 photographs presented to 200 participants, but tended to cluster into informative regions of the scenes, relating, pioneeringly, the movements and fixations to attentional processes. In addition to monitoring the gaze of participants looking at images, Buswell also did some unsystematic manipulations of what he called "mental set" of the participants when looking at the photographs, concluding that the experimental instructions or the reading of a paragraph of text prior to the presentation of the images could significantly influence the scanning of the images.

Russian psychologist Alfred Yarbus also reports, in a 1967 book, a series of eye monitoring studies, in which he established, in agreement with Buswell (1935), that the visual inspection patterns of scenes depend as much on the stimulus's informative properties as on the tasks and objectives of the observers. The literature on visual attention seems to agree, therefore, for a long time, that two complementary processes are in action in the eye inspection of scenes: a bottom-up algorithm, guided by intrinsic properties of the stimulus and a top-down mechanism, related to factors such as the interpretive disposition to the previous objectives of the observer.

In line with these studies, Maia (2008) reports an eye-tracking experiment in which 27 Brazilian Portuguese speaking participants were exposed during 10 seconds to versions of an image which contained either a [-animate -human], a [+animate -human] or a [+animate +human] element. Each version could be preceded or not by written information which remained on the screen during 5 seconds, indicating the topic of the image. Fixation times and saccadic movements (on-line measures) were registered and participants were also asked to write a one-paragraph report (off-line measure) immediately after viewing the scene. Based on the results obtained it is suggested that the previously presented topics (top-down effect) may influence the off-line measure, but cannot override the bottom-up computation of salient elements in the input in the on-line measures. A similar result of top-down heuristics interspersed with bottom-up morphosyntax calculations was found in Maia, Lemle, Franca (2007) that investigated whether the morphological composition is a fundamental property of lexical processing in Brazilian Portuguese isolated word reading, while participants performed a Stroop task. Results obtained brought evidence that, in the reading process, words are derived morpheme by morpheme, although there are also global vision heuristics that act simultaneously in reading processing.

Focusing more specifically on the visualization of art, Holmes & Zanker (2012) examined participant evaluations of aesthetic preference presenting participants a variety of art images and analyzed oculomotor statistics such as cumulative fixation duration, refixations, and the sequence of fixations while participants searched for their preferred images. The authors concluded that eye movements are strongly influenced by the task given to an observer and established oculomotor signatures that confirm a strong relationship between the conscious subjective decisions and the eye movements which precede expression of those conscious decisions.

As to face recognition, there is a cortical network primarily located in the ventral occipito-temporal cortex (VOTC) and secondarily located in the right middle fusiform gyrus that are more implicated in this special cognition, that places great demands on the visual system to accurately distinguish one among many visually similar face patterns (Rossion *et al*., 2012).

Face recognition activates patches of face-selective neurons close to object recognition areas. But these are apparently specific neural systems that are not implicated in object recognition (Tsao and Livingstone, 2008). They lie in the occipitotemporal fusiform face area (FFA) bilaterally: on the right hemisphere, they are more associated with holistic processing, while on the left, with analytic processing (Souza 2008; de Moraes *et al*., 2014). Thus, face recognition is thought to depend on an extended brain network (López-Barroso *et al* 2020).

Many early eye tracking experiments revealed that there was an observation pattern adopted for face recognition, made up of a sequence of fixations forming an upside-down triangle over the eyes, nose and the mouth, suggesting that faces elicit a universal, biologically-determined information extraction pattern (Groner *et al* 1984).

However, eye tracking experiments of other race face recognition contributed to the literature showing that, beyond general characteristics, face processing cannot be considered universal, since the strategy employed to extract visual information from faces also differs across cultures (Hugenberg *et al* 2010). This consolidated finding was considered an influential face recognition effect, called "Race Bias" or "Other Race Effect" (ORE) (Brigham & Malpass, 1985; Chance, Turner, Goldstein 1996; Rossion *et al*., 2012; Cao *et al* 2013).

The most striking effect of ORE is that own-race faces are more accurately recognized than faces of another race (Meissner and Brigham, 2001; Sporer, 2001). This phenomenon has been noticed across different cultures and races (Tanaka, Pierce 2009).

When using factorial analysis techniques to test ORE, studies found that own-race faces also elicit longer saccade latency than other face races, indicating that own-race faces capture attention automatically with high-level configural processing (Fu *et al*., 2012; Caldara, Abdi, 2004).

Some researchers suggest that ORE can be explained by the fact that human beings develop specialized ways of perceiving the characteristics of the faces of their own race (Lindsay, Christian and Jack 1991). Other researchers suggest that the degree of contact and experience with people of other races decrease the ORE, explaining the mitigation of this effect by increasing experiences of global contact (Furl, O'Toole, Phillips 2000).

Another contrast that appears in the face recognition literature and that might bring light onto this study, as we shall see later, is the existence of two contrasting coding models for faces: The Standard or Prototype Model (Franks & Bransford, 1971) and the Exemplar Model (Rhodes *et al* 1983; Rosch 1983). They ultimately account for the basic face recognition tasks of telling faces apart (prototype), which favors recognition by features, and of telling faces together (exemplars), that favors holistic processing (Oruc *et al* 2019).

Prototype-based accounts propose that faces are encoded with respect to their deviation from the average face, or a prototype (e.g., Giese & Leopold, 2005; Rhodes & Jeffery, 2006; Valentine, 1991). In contrast, exemplar-based accounts defend that faces are encoded by their location in face space relative to exemplars of previously experienced faces (Lewis, 2004).

This prototype Vs exemplar distinction corresponds respectively to a bottom-up Vs top-down views of cognitive processing and which are central in the image visualization literature, as reviewed above. According to the Prototype Model, faces are coded in terms of the deviation or distance of their features in relation to a single, general facial prototype, which is located at the origin or center of a multidimensional space where faces are registered. So, face features are analyzed one by one in a relative measure compared to a model. In contrast, in the Exemplar Model, faces are coded as a whole and are classified and stored in memory based on similarity group of features (Rhodes *et al*. 1987; Valentine, 1991).

On its turn, learning to read, is a very a different sort of cognitive problem, because it does not undergo implicit development. Reading is a socially motivated task that is not adhered by every society. Yet recent neuroscience studies found that learning to read is revolutionary to cortical brain structures and ultimately to the individual. Solving this new task involves adapting the existing brain architecture that is originally devoted to evolutionarily older tasks such as object recognition and facial recognition (Cohen, Dehaene 2004; Morais, Kolinsky 2005; Dehaene *et al*. 2010; Dehaene, Cohen, 2011).

Attending literacy school promotes the reshaping and automation of synaptic connections in the fusiform gyrus, in the transition between the occipital and temporal cortices of the left hemisphere, to form a new cortical area termed the Letterbox or the Visual Word Form Area (VWFA). VWFA lies adjacent to OR and FR sites on the infero-lateral surface and is specified for identifying lower-level letters and words, before association with phonology or semantics (Cohen *et al*. 2002; McCandliss *et al*. 2003; Cohen, Dehaene 2004; cf. Price & Devlin, 2003).

Thus, learning to read involves adapting existing visual cognitive architecture once exclusively devoted to object and face recognition to recognize graphemes. During reading acquisition, the initial responses to faces are blocked and the homologous site on the right hemisphere is activated more strongly for faces, while the VWFA on the left becomes more responsive to letters. So, education seems to provide means to recycle the human brain by repurposing some visual regions towards the shapes of letters (Dehaene-Lambertz 2018; Kolinsky & Fernandes, 2014).

Comparing illiterate to literate adults, studies show that with increasing literacy, cortical responses to faces decrease slightly in the left fusiform region, and increase at FFA on the right hemisphere. Thus, right-hemispheric lateralization for faces is increased in literates when compared to illiterates. (Dehaene *et al.*, 2010; Ventura 2014). A similar pattern should thus be expected when contrasting saccadic patterns of literate and illiterate participants from a non-WEIRD population as the one in this study.

Another relevant set of findings in relation to reading is that it may be challenged by humans' spontaneous capacity to quickly recognize mirror images of previously exposed pictures. The VWFA was previously shown to discriminate words from their mirror images in literate adults. (cf. Pegado *et al*, 2011). But, this mirror invariance, though advantageous for object recognition and expected by human's symmetry bias, is not favorable when the task is distinguishing enantiomorphs (mirror images) like "b" and "d". This requires the suppression of symmetry in favor of asymmetry. While this cognitive stage is not overcome and the symmetric bias prevails, the result is the classical transitory mirror writing errors, so common in preschoolers. Mirror invariance must therefore be overcome for the student to reach a proficient literacy level (Kolinsky, Verhaeghe 2014).

Next, we report a pretest and a pilot study that might have less participants than ideal, but that might unveil new visual parameters coming from underrepresented ethnicities.

2. The eye-tracking experiments

The Pre-Test

Currently, literacy at the village schools is carried out by indigenous teachers initially in the Karajá language and, in a second moment, in Portuguese, since the Karaja language received an orthography, in the 1950s. There are, therefore, Karaja who have been literate for many years, as well as adults who, only more recently, decided to become literate.

Since the literature has pointed out differences between early and late literate people (Pegado *et al*, 2014; Kolinsky & Fernandes, 2014), we put together a pre-test, to allow us to discriminate between two groups of readers: early and late readers. First, we gathered self-reported data about their literacy history: when they went to literacy school and for how long. Then, we performed a qualitative screening test in which participants were instructed to silently read words written in Karajá and in Portuguese, while we eyetracked (on-line measure) their reading, followed by the loud pronunciation of the word just read (off-line measure).

Although all participants correctly pronounced the words they read, their eyetracked reading patterns, as reported in other studies, did indicate significant differences among participants. Such differences matched the self-reported classification and allowed us to accurately discriminate between early, more proficient readers (N=14) and late less proficient readers (N=10).

As indicated in the prototypical examples below (Fig.2), reading patterns of late literate adults, in red, are overall more costly both in terms of number of fixations and in terms of latencies than the reading patterns of early literate adults, in blue. Notice that this is the typical pattern both for reading Karaja and Portuguese.

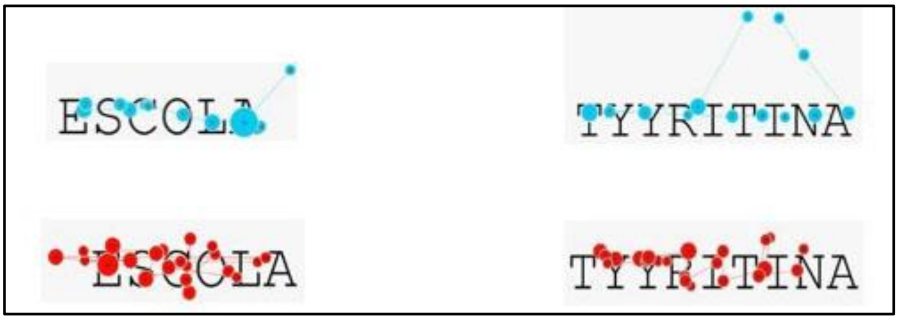

FIGURE 2 – Examples of contrasting reading patterns between early and late literates: the word *school* in Portuguese (*escola*) and then in Karaja (tyyritina). The eye gaze tracking in blue comes from early literate adults and the eye gaze tracking in red comes from recent literate adults.
Source: elaborated by the authors

Moreover, in relation to the gaze progress along the text line, the blue-coded reading of early literates presented a more linear fashion, with horizontal saccadic movements and virtually no regressions. In contrast, the red-coded reading of late literates showed, besides many regressions, some vertical saccadic movements, which are not common in reading and which are more reminiscent of iconic visual inspections.

Having observed these marked differences in all the participants, we decided to include in the pilot test only the 14 early literate adults, who had learned how to read and write as children, because they would present a sharper contrast to the illiterate adults we would recruit for the pilot test.

The Pilot-Test

Following the pretest, we ran the pilot test monitoring the eye gaze of early readers and illiterate participants as they performed the visualization of faces and graphisms. The objective of this test was to investigate the impact of the acquisition of reading on the processing of other visual categories such as faces and graphisms using the eye tracking methodology.

Participants

After identifying 14 early literate participants in the pre-test, we matched them with 14 illiterate Karaja, who had never attended school. Thus, we formed two groups of participants for the pilot study: (i) 14 early literate Karaja native speakers from Hawalo and Btoiry villages, aged between 30 and 45 yo (average 38 yo) 5 men, 9 women, who were selected by the pretest; (ii) 14 illiterate Karaja native speakers from Hawalo and Btoiry villages, aged between 42 and 60 yo (average 52 yo), 6 men, 8 women.

All participants included in both the literate and illiterate groups were active and functionally independent. All participants in both groups were right-handed, tested by standing in front of them and handing them objects which were always grabbed by the right hand. Concerning age differences, since the illiterate Karaja participants tend to be in average older than the literate, age effects could not be strictly controlled. Clothing and jewelry were not strictly controlled either, because they are default paraphernalia among the Karaja.

Methods

We put together an eye-tracking test monitored by a TOBII TX300Hz eye-tracker, used at its maximum sampling rate of 300Hz.

The eye-tracker was controlled by a test code that was put together using Tobii Studio 3.2.1, a comprehensive platform for the recording and analysis of eye gaze data, which provides a turn-key lab solution comprising of four parts: (i) The Project Overview that provides information about the elements of project, the gaze targets and the Events associated with the recordings; (ii) The Design module that defines how stimuli are presented to participants; (iii) The Record module, according to the programmed Timeline; and (iv) The Analysis module that reaches an overview of the data and allows for conclusions from the collected data.

Materials and Procedures[2]

The experiment consisted of 42 stimuli distributed across the six conditions in a 2x3 design, seven tokens by type (Fig 3). All input face pictures were controlled for emotions. A relaxed posture was emphasized as the pattern for all pictures.

Concerning the test task, participants in both groups were asked to make a decision, as fast as possible, whether the items they visualized – a graphism or a face - on a 23-inch computer screen were *iny* (Karaja), *tori* (non-indigenous) *or ixyju* (other indigenous than Karaja). Stimuli were randomized between graphisms and faces.

After a calibration session, during which participants were asked to follow a red ball moving on the screen with their gaze, three practice items were presented to ensure the correct comprehension of the task by the participants. During this practice, participants understood that they would answer the question using their eye gaze: their prolonged gaze to *iny* (Karaja), *tori* (non-indigenous) *or ixyju* (other indigenous than Karaja) would indicate their choice. After this practice, they were told to press the space bar to start the experiment as soon as the experimenter left the room, to start the test.

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[2] We thank Gabriel Xavier, undergraduate student at the Federal University of Rio de Janeiro, who helped to process the eye-tracking data.

Participants were to look at the image and decide as fast as possible which image was their choice. The target image would remain on the screen for up to five seconds (timeout). In spite of this 5-second timeout, participants were instructed to press the spacebar to call the response screen as soon as they were ready to make a decision on the ethnicity of the stimulus. In fact, all participants pressed the bar before the 5 seconds and did not reach time-out. After that time lapse, the image screen would be automatically replaced by the response screen which unequivocally portrays *iny*, *tori and ixyju* faces, as it can be seen in the experiment's timeline (Fig 3)

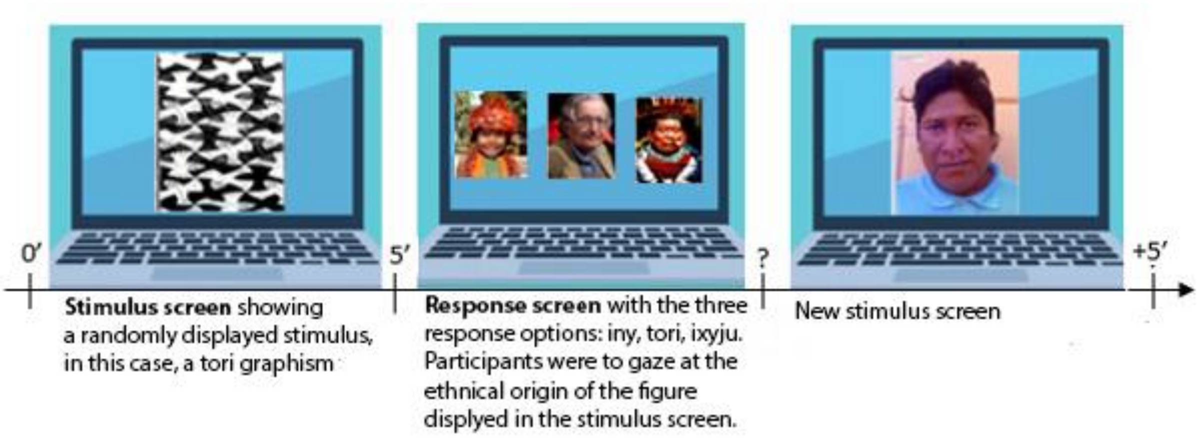

FIGURE 3 – illustrates the experiment timeline, which begins with the presentation of a stimulus screen displaying a randomly selected graphism. The stimulus remained visible for up to 5 seconds. Participants could move to the next screen by pressing the space bar. This response screen displayed three prototypical portraits: a Karajá individual, a non-indigenous individual, and an indigenous individual from a group other than the Karajá. Participants were instructed to classify the stimulus they had just seen (as iny, tori, or ixyju) by gazing at the corresponding image for two seconds. Afterward, they pressed the space bar to initiate the next trial.
Each subsequent trial presented another randomly chosen stimulus, either a graphism or a face, following the same sequence: a stimulus screen visible for up to 5 seconds, followed by the response screen. This cycle was repeated for a total of 42 stimuli, ensuring consistency in the procedure and allowing for systematic data collection across all conditions.
Source: elaborated by the authors

A sample of the graphic and the face stimuli is displayed in Fig 4.

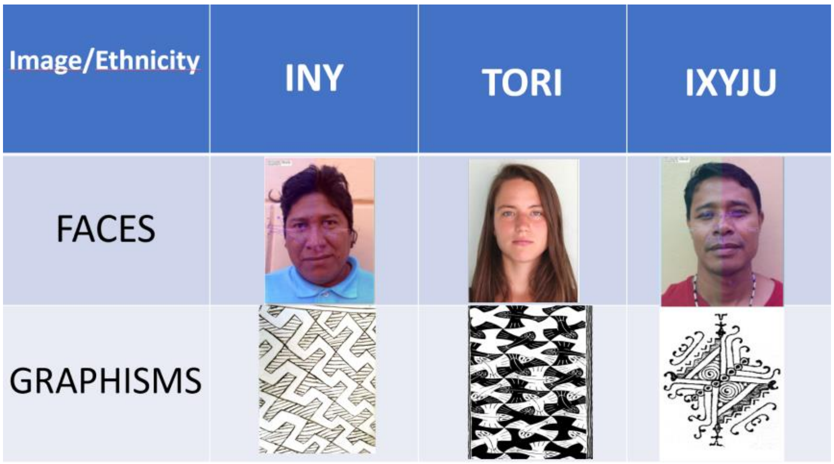

FIGURE 4 – Example of 3 faces and 3 graphisms out of the 42 used as stimuli
Source: produced by the authors

The independent variables were (1) visualized object: face and graphism and (2) object ethnicity: Karajá (Iny), nonindigenous (Tori), other non-Karaja indigenous (Ixyju). The dependent variables were the Total Fixation Durations (TFD) and Fixation Count (FC), during visualization (on-line measures) and the response accuracy to identification of ethnicity (Iny, Tori, Ixyju), as the off-line measure.

If left-right invariance was overcome during literacy acquisition, we hypothesized that the visual scanning of faces and graphisms would differ between literate and illiterate Karaja participants. The literate participants should display a more symmetrical visual inspection of faces and graphisms than the illiterate, who would not necessarily scan both sides of the faces and graphisms.

3. Results

We will first report and discuss results for the off-line and on-line measures related to the face and graphism stimuli separately. Then we will discuss both types of stimuli comparatively.

Faces

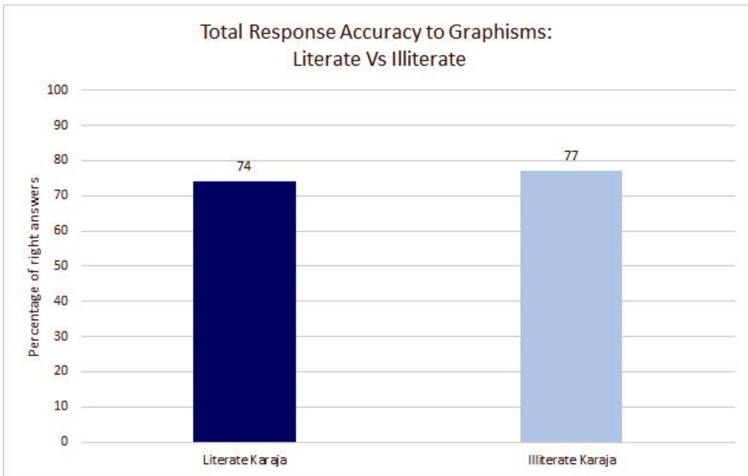

FIGURE 5 - Accuracy Responses: Total % of right answers
Source: elaborated by the authors

In Fig 5, we see that, taken together, both the literate and illiterate groups displayed similar accuracy rates. Fig 6 presents percentages of right answers in the off-line measure.

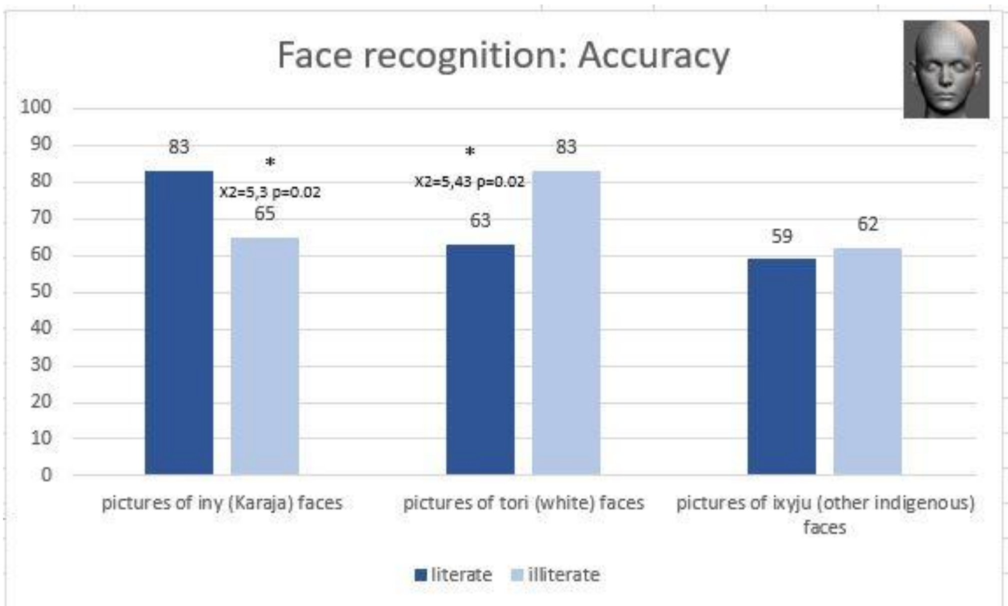

FIGURE 6 - Percentages of right answers in the off-line measure for the two groups of participants separated by specific recognition accuracy: pictures of *iny, tori* and *ixyju*.
Source: elaborated by the authors

As indicated in Fig 6, literates are significantly better than illiterates in recognizing faces of their own ethnicity Iny (X2= 5.3, p= 0.02*). Illiterates are significantly better than literates in the recognition of nonindigenous (*tori*) faces (X2= 5.4, p= 0.02*). Unlike the significant differences obtained in the non-indigenous and Karaja conditions, recognition of indigenous faces other than Karaja, ixyju, are at the same accuracy levels in the two groups (X2= 0.14, p= 0.6ns). In Fig 7, looking across conditions, we can see that the literates were more accurate when judging their own race faces, while illiterates were more accurate towards *tori* faces.

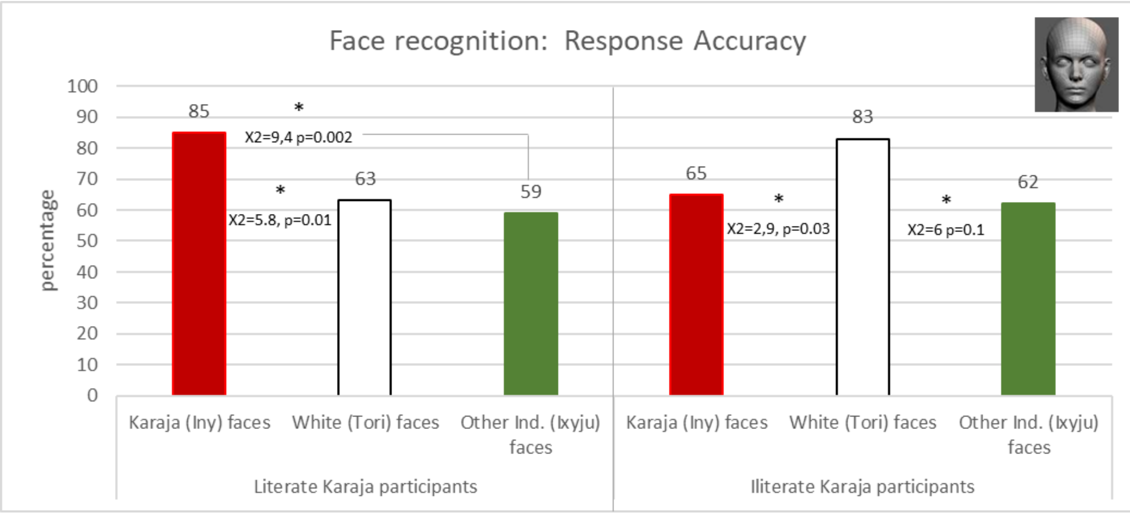

FIGURE 7 – Percentages of face accuracy responses across conditions

Source: elaborated by the authors

Concerning the online measures, Tobii TX300 allowed for a high accuracy rate and precision (Accuracy: 0.4°–0.9°; Precision: 0.04–0.15°), as it is generally recognized in the specialized literature. These values indicated to us the parameters of accuracy and precision values obtained in the study at the sampling rate of 300Hz in a nine-point calibration procedure. Tobii Studio (the software that accompanies the Tobii eye tracker systems) provided a schematic representation of calibration success, marking calibration points that were successfully calibrated with error vectors. Thus, we had a qualitative procedure whose precision was to double-checked by means of the circles in the spatial gaze fixation selected areas, which allowed for control of inaccuracies, which, whenever happened, were successfully recalibrated. For assessing the on-line measures, regions of interest were demarcated in two different ways: (i) eyes, mouth and nose; (ii) left and right sides of faces (Figs 8 and 9):

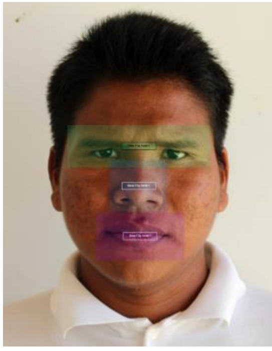

FIGURE 8 - eyes, nose, mouth

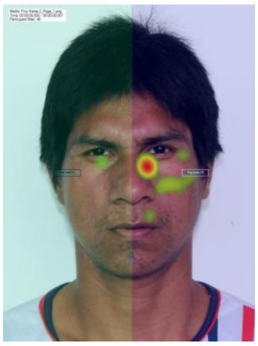

FIGURE 9 - left side, right side

FIGURE 8 - A face stimulus with regions of interest of eyes, mouth and nose demarcated so that eye gaze of participants could be compared among regions of interest and between the two group of participants.

FIGURE 9 - A face stimulus with the left and right sides of faces demarcated so that eye gaze of participants could be compared as to laterality and between the two group of participants.

The comparison between the two groups of participants, concerning the Total Fixation Durations for the eyes, mouth and nose regions, across conditions, is organized in Fig 10.

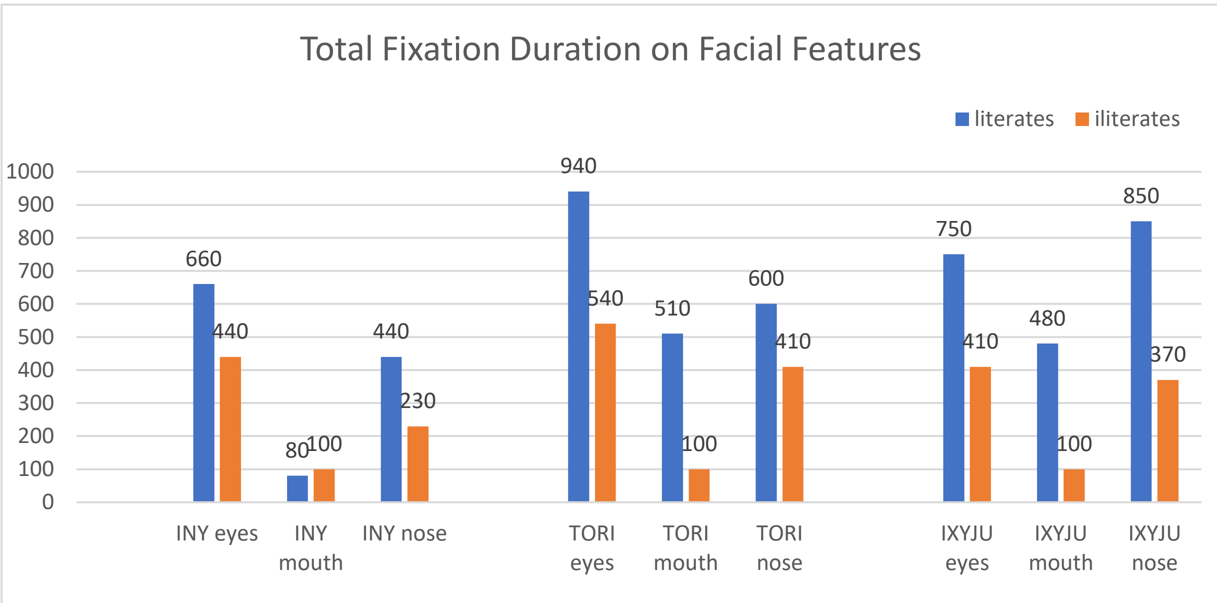

FIGURE 10 - Faces TFDs by ethnicity, features regions (ms) of the literate and the illiterate participants

Source: elaborated by the authors

A three-way ANOVA by subjects revealed significant main effects of the factors Literacy ($F1(1,84) = 21.7$ $p<0.00001$), Ethnicity ($F1(2,168) = 4.45$ $p<0.013$) and Region ($F1(2,168) = 44.4$ $p<0.000001$). Literates displayed overall higher fixation times in all regions than illiterates ($t(251)=3.41$ $p< 0.0008$), as indicated in Fig 11.

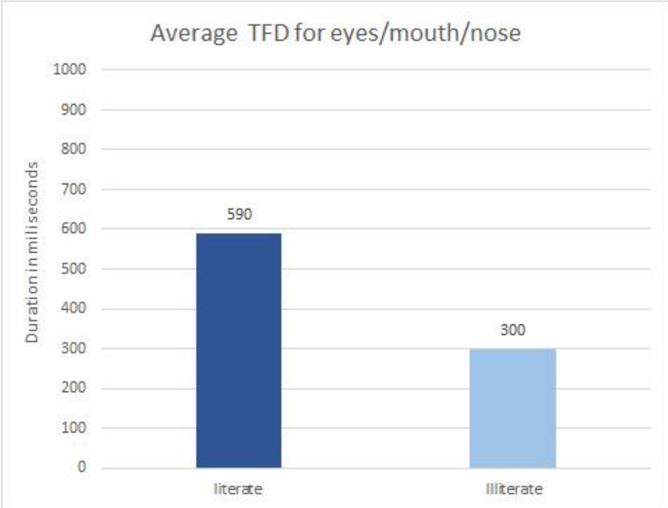

FIGURE 11 – TFDS in all regions
Source: elaborated by the authors

The region of the eyes was consistently more fixated than those of the nose and mouth by both subject groups across all conditions yielding significant differences, as expressed by the ascending ranking of fixation durations in Fig 12:

MOUTH < NOSE < EYES

FIGURE 12 - Ascending TFD ranking across participant groups and conditions
Source: elaborated by the authors

For the *iny* (Karaja) condition, pairwise t-tests indicated that the literate fixate more on the eyes than on the nose ($t(251)=1.89$, $p< 0.05$) and more on the nose than on the mouth ($t(251)=4.92$, $p< 0.0001$). In this same condition, the illiterate also fixated more on the eyes than on the nose ($t(251)=3.56$, $p< 0.0004$) and more on the nose than on the mouth ($t(251)=3.05$, $p< 0.0025$). The comparison of the visualization of the *iny* pictures across the two groups of participants also yields significant differences in the literate group consistently displays significantly higher TFDs in the eyes and nose regions than the illiterate: (eyes ($t(251)=2.45$, $p< 0.0151$), nose ($t(251)=3.41$ $p< 0.0008$. Thus, except for the mouth region, we found significant differences between the two participant groups ($t(251)=0.84$, $p< 0.40$).

For the *ixyju* (indigenous other than Karaja) condition, pairwise t-tests indicated that the literate participants fixate more on the eyes than on the nose ($t(251)=3.41$, $p< 0.001$) and more on the nose than on the mouth ($t(251)=5.42$, $p< 0.0001$). In this same condition, the illiterates, however, do not fixate significantly more on the eyes than on the nose (t(251)=0.22, p< 0.83) but they do fixate significantly more on the nose than on the mouth (t(251)=4.74, p< 0.0001). The comparison of the visualization of the IXYJU pictures across the two groups of participants also yields significant differences in which the literate group consistently displays significantly higher TFDs in each region than the illiterate: (eyes (t(251)=2.19, p< 0.03), nose(t(251)=2.94, p< 0.003) and mouth (t(251)=3.23, p< 0.001).

For the *tori* (nonindigenous) condition, pairwise t-tests indicated that the literate fixate more on the eyes than on the nose (t(251)=6.36, p< 0.0001) but they do not fixate more on the nose than on the mouth (t(251)=1.00, p< 0.31). In this same condition, the illiterate, however, do not fixate significantly more on the eyes than on the nose (t(251)=1.55 p< 0.12) but they do fixate significantly more on the nose than on the mouth (t(251)=3.05, p< 0.002). The comparison of the visualization of the *tori* pictures across the two groups of participants also yields significant differences in which the literate group consistently displays significantly higher TFDs in each region than the illiterate: (eyes (t(251)=6.77, p< 0.0001), nose (t(251)=3.41, p< 0.0008) and mouth (t(251)=5.79 p< 0.0001).

To avoid unnecessary complexity of the analyses, we did not carry the segregated controls per face regions for the left and right sides of the faces, because it is clear that across the board the eyes were indeed the most observed regions.

For the analyses of the demarcation of left and right sides of faces, TFDs and FCs were examined for both groups of participants, yielding basically the same pattern of differences, as illustrated in Fig.13 and Fig.14:

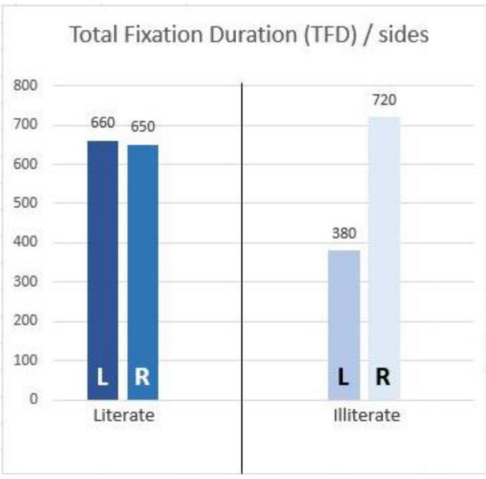

FIGURE 13 – TFD literacy vs. side
Source: elaborated by the authors

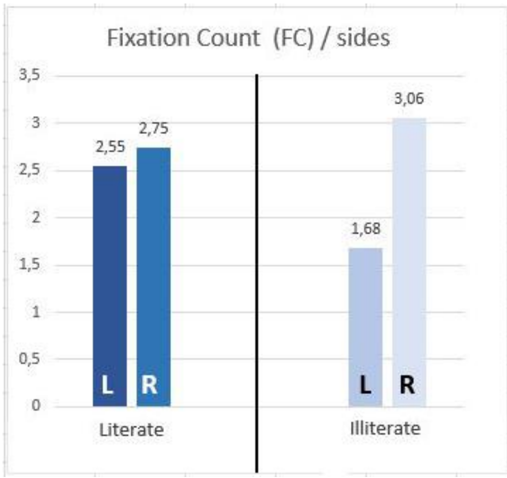

FIGURE 14 – FC literacy vs. side
Source: elaborated by the authors

For TFDs, a two-factor ANOVA by subjects indicated a highly significant main effect of the variable SIDE (F(1,293) = 13.3, p<0.0003). Even though there was not a significant main effect of the variable LITERACY (F(1,293) = 1.75, p<0.18), there is a highly significant interaction between the two factors

(Lit*Side F(1,293) = 15.7, p<0.00009), demonstrating that literacy is strongly influenced by the side main factor.

For FCs, a two factor ANOVA by subjects likewise indicated a highly significant main effect of the variable SIDE (F(1,293) = 19.2 p<0.000016), but did not capture a main effect of the variable LITERACY (F(1,293) = 0.705 p<0.401669). However, in the same lines as the TFD ANOVA, there was strong interaction of the two factors (Lit*Side F(1,293) = 11.4 p<0.0008), confirming the impact of the SIDE factor on the LITERACY factor.

Fig.15 and Fig.16 display TFDs and FCs, taking into consideration the crossings between the factors LITERACY, SIDE and the ETHNICITY of the stimuli and also indicate striking similarities between the two measures:

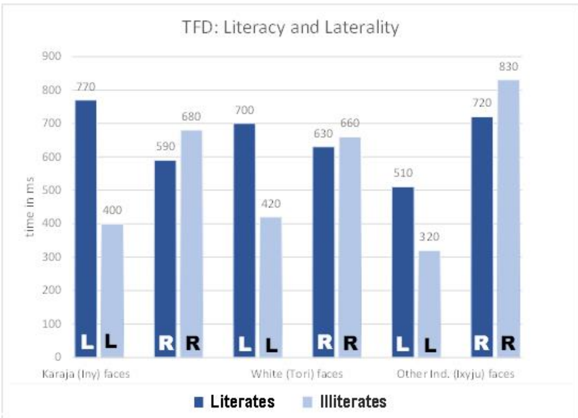

FIGURE 15 – TFD: Literacy x Side x Ethnicity

Source: elaborated by the authors

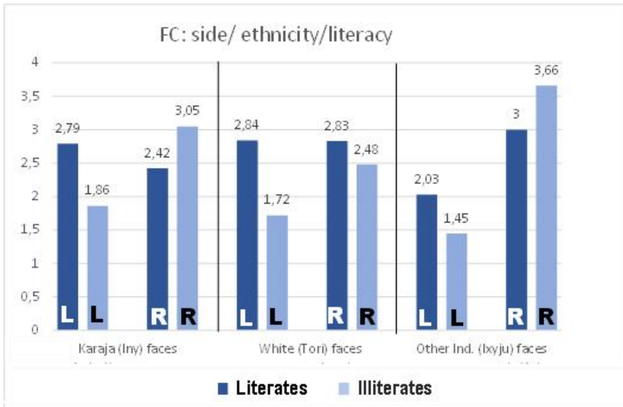

FIGURE 16 – FC: Literacy x Side x ethnicity

Source: elaborated by the authors

For TFDs, a three-way ANOVA by subjects displays significant main effects of LITERACY (F(1,97) = 16.9, p<0.00008) and SIDE (F(1,97) = 11.3 p<0.0011). Even though there is no main effect of ETHNICITY (F(2,194) = 0.007 p<0.99), there is significant interaction between ETHNICITY and SIDE (Side*Ethnicity)F(2,194) = 5.65 p<0.004)), as well as between LITERACY and SIDE (Literacy*Side (F(1,97) = 25.0 p<0.000003)). There are no interactions, however between Literacy*Side*Ethnicity (F(2,194) = 0.286 p<0.75).

For FCs, a three-way ANOVA by subjects also displays significant main effects of LITERACY (F(1,97) = 5.48, p<0.02) and SIDE (F(1,97) = 16.2, p<0.0001). In the same lines as the TFD analyses, there is no main effect of ETHNICITY (F(2,194) = 0.015, p<0.98), but there is significant interaction between ETHNICITY and SIDE (F(2,194) = 5.64 p<0.004), as well as between LITERACY and SIDE (F(1,97) = 19.0, p<0.00003). Again, in the same line as the TFD measure, the FC analyses did not yield any main effects of the triple interaction between the three factors (Literacy*Side*Ethnicity (F(2,194) = 0.357, p<0.70)).

Discussion of Faces: offline results

As the off-line results reported above clearly indicate, literate participants identified their own ethnical group faces in 85% of the trials, whereas illiterate participants got only 65% right. The findings in relation to the literate participants are clearly in accordance with the ORE studies that report that compared to other-race faces, own-race faces elicit longer saccade latency indicating that own-race faces capture attention automatically with high-level configural processing (Meissner and Brigham, 2001; Sporer, 2001; Fu *et al* 2012; Caldara & Abdi, 2004). In terms of coding strategy, we speculate that because among the Karaja the literates are younger, move about more and tend to be exposed to significantly more face exemplars outside their community, their globalization weakens the attention devoted to faces of other races (Furl, O'Toole and Phillips 2000) while making own race discrimination more careful and consequently more accurate. In our analysis, literates, thus, gain an excess of experiences favoring the application of top-down heuristics to separate their own faces (iny) from a group of all other faces together (tori and ixyju)[3].

This leads us to conclude that as to group faces other than their own, they would use the exemplar coding strategy, but to identify faces of their own ethnicity they would settle for the prototype (cf. Franks & Bransford, 1971) coding strategy, that is able to distinguish among the features of people from those of their own race, focusing on their own features (bottom-up). This is, in fact, the strategy used in the urban societies, which might be reinforced by literacy training. For the literate, their own race is the figure and all the multiple exemplars of other people, indigenous or not, become ground. This might also have a reflection on the degree of ethnic empowerment: literates tend to be able to have stronger perceptions of their own ethnicity than illiterates. In a global setting, their own race stands out.

The illiterate Karaja have far less exposure to face diversity, because they travel less or do not travel at all. Whenever they perceive white (tori) faces, they consider it figure and not ground. We speculate that they use the prototype coding and bottom-up processing to distinguish among tori faces and therefore are more accurate toward the non-indigenous tori faces. At the same time, they lump all indigenous faces together exactly because they have to deal with significantly fewer exemplars than the literates do. So, it seems more economical to establish a type with less tokens (top-down heuristics) than resorting to detailed bottom-up inspection. On their turn, we speculate that this strategy to inspect the faces, giving figure-status to the tori and lumping all other indigenous together, weakens their ethnicity and Karaja identity recognition. Tori stands out.

Thus, their results are in complementary distribution with that of the literate participants, who got higher accuracy rates for the TORI faces (83% of times in comparison with the 63% of the literates). For the illiterates, indigenous people are ground and the less conspicuous, non-indigenous, are figure and the strategy to read other race faces is more bottom-up as predicted by the prototype theory. We

---

[3] Due to the well-known intense miscegenation in the Brazilian society, it is not uncommon to hear from literate indigenous people in urban environments that they do not really know if someone is non-indigenous or indigenous from other ethnic groups.

speculate that the illiterates' strategy to distinguish all indigenous faces from others is compatible with the exemplar heuristics. When they are exposed to tori features that are less common to them, these faces become ground and they apply the bottom-up scrutiny suggested in the prototype theory.

Since the Karaja were participant to the oldest literacy program put forth by the Summer Institute of Linguistics in Brazil, most Karaja nowadays are actually literate. Thus, as stated in the introduction, there is an unavoidable bias among the Karaja, that the old participants are the ones in the illiterate group. This made it impossible to properly control for age-effects among those participants. However, under these conditions, there was no significant difference when illiterates vs literates were compared in the IXYJU condition. Literates gave correct answers in 59% of the trials and the illiterates in 62%.

This pattern suggests that literacy seems to reinforce the own race bias in face identification, since literates had a better performance in identifying their own ethnicity than illiterates, as it is amply testified in the literature (Meissner and Brigham, 2001; Sporer, 2001; Tanaka, Pierce 2009).

Alternatively, it could be speculated that illiteracy might be related to the better performance exhibited by illiterates in the recognition of nonindigenous faces. We cannot, however, discard age and experience acting as extraneous variables in these results, since age differences between the two groups of participants could not be strictly controlled. Illiterate participants are typically older than literates and the latter tend to be more able to travel away from their own villages than the former, establishing more relations with non-indigenous than the illiterates. The higher levels of interactions with the nonindigenous community and its inherent variation of types might have ended up causing literates to be less accurate in the identification of nonindigenous. The fact that both groups were equally proficient in the identification of indigenous other than Karaja seem to support this conclusion, since even though literates and illiterates are at the same levels in the identification of indigenous other than Karajá, the combined results of the two groups suggest that literates group Tori and Ixyju (63% and 59 %) in opposition to Iny (85%), whereas illiterates seem to group Iny and Ixyju (65% and 62%) in opposition to Tori (83%). If illiterates differentiate nonindigenous in opposition to indigenous, including their own ethnicity, isolating more clearly the nonindigenous from both indigenous groups, the literate, on the other hand, seem to exhibit a better sense of recognition of their own ethnic group and recognize the other two groups at poorer performance levels, maybe as a result of their more intense interactions with these two groups of non Karaja people and their inherent wide typology, which might lead them to difficulty in ascertaining whether a face is actually nonindigenous or indigenous other than Karaja.

Discussion of Faces: on-line results

The analysis of online results provides more definitive insights into the impact of literacy on face processing. Literate participants exhibit a more symmetrical visual inspection of faces, overcoming the natural left-right invariance seen in illiterates. This symmetry, however, does not extend to the inspection of graphisms (as will be discussed later). In contrast, illiterates tend to cluster their fixations predominantly on the right side of faces, displaying asymmetrical scanning patterns. Figures 17 and 18 present heatmaps illustrating the prototypical visualization of INY faces respectively by literate and illiterate participants.

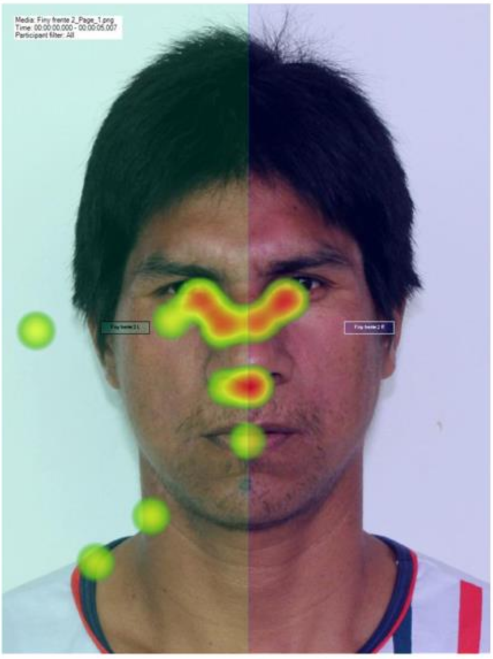

FIGURE 17 – Literate gaze to INY inspecting both sides of face in a pattern similar to that of reading.

Source: elaborated by the authors

FIGURA 18 - Illiterate gaze and fixations only on one side of INY face. Asymmetry is typical of the left-right invariance bias, leading to one side (right) gaze, that is, an enatiomorphic fixation.

Source: e laborated by the authors

The heatmaps reveal distinct differences in visual behavior. Literate participants not only demonstrate enantiomorphic fixation distributions (as shown in Fig. 18) but also exhibit higher levels of total fixation duration (TFD) and fixation count (FC) compared to illiterate participants (see Fig. 17). This contrast highlights a more detailed and distributed visual exploration among literates.

Similarly, Figures 19 and 20 depict the typical gaze patterns of literate and illiterate participants when viewing TORI faces:

FIGURE 19 - Literate gaze to TORI face also showing distributed TFD and FC.
Source: elaborated by the authors

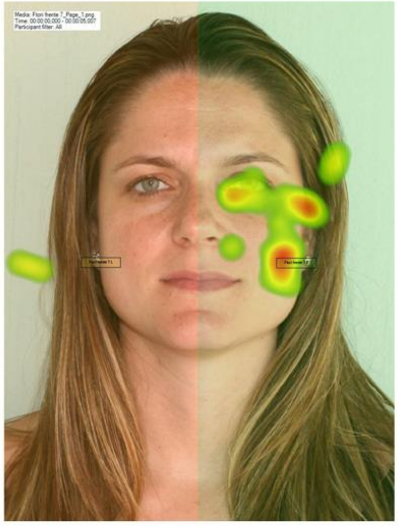

FIGURE 20 – Illiterate gaze to TORI face also showing concentration of TFD and FC on the right side.
Source: elaborated by the authors

In the TORI condition, literates again display a symmetrical pattern, scanning both sides of the face with comparable TFDs and FCs. By contrast, illiterates adhere to the left-right invariance principle, focusing their visual attention primarily on one side of the face. These findings are consistent with the enantiomorphism hypothesis, which predicts that literacy influences the distribution of visual fixations, promoting symmetry in face inspection. Statistical analyses further corroborate these observations, confirming significant differences in visual scanning behaviors between literates and illiterates, while the symmetric scanning patterns of literates show no significant bias toward either side of the face.

Finally, Figures 21 and 22 illustrate the results for TFD and FC during the visualization of IXYJU faces by literate and illiterate participants. The data reiterate the distinctive visual strategies employed by the two groups: literates apply a balanced, enantiomorphic approach, whereas illiterates maintain their asymmetric, side-biased scanning behavior. These differences underscore the profound influence of literacy on visual processing strategies, particularly in the context of face recognition.

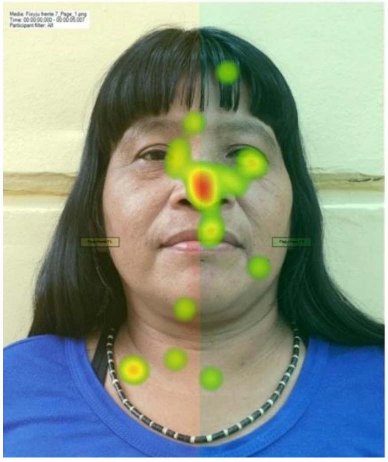

FIGURE 21 - Literate gaze to IXYJU face also showing distributed TFD and FC.
Source: elaborated by the authors

FIGURE 22 – Illiterate gaze to IXYJU face also showing concentration of TFD and FC on the right.
Source: elaborated by the authors

Even though the statistical analyses presented above yielded significant differences between left and right sides in the ixyju face inspection by literates, it seems uncontroversial that there is actually an important difference in the scanning of the faces by literates and illiterates, since the latter concentrate clearly on the right side of the face.

Concerning the default side of inspection, it would certainly be quite interesting to compare patterns of facial scanning between speakers of a head-final language such as Karaja with speakers of another head-initial Brazilian indigenous language such as Kadiweu (Guaikuru Family). Would it be the case that Kadiweu illiterates would also concentrate their fixations on the right side of the faces? Promising new venues of research relating cognition, language and culture seem to be open if the study of non-WEIRD populations is given a chance to proceed. Challenging questions about what we can only speculate at this point may be soon recast revealing new breakthroughs as advances are made.

Graphisms

Figure 23 shows that the accuracy responses for the identification of graphisms did not differ across literates and illiterates:

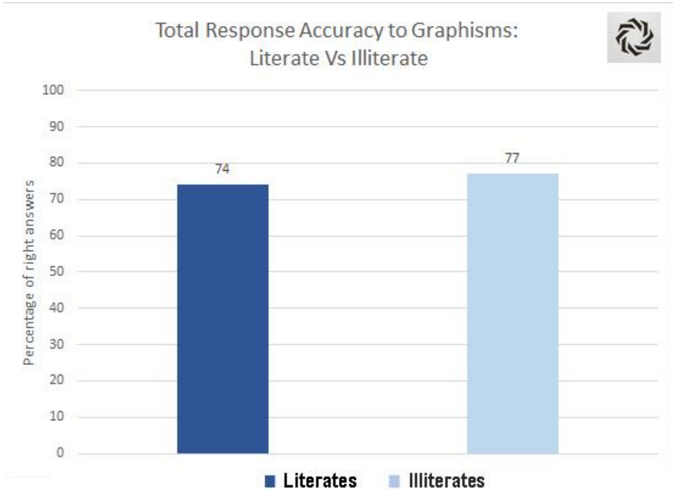

FIGURE. 23 - Accuracy Responses: Total % of right answers
Source: elaborated by the authors

These off-line results obtained in the recognition of graphisms are in line with those obtained for the overall recognition of faces. Literates and illiterates do not significantly differ neither between themselves nor in their levels of correct responses in both kinds of stimuli. However, unlike face inspection, only few differences emerge when we look at accuracy rates across conditions, as shown in Fig. 24[4]:

---

[4] Error rates were randomly distributed among the observations for each condition, as indicated below:
Literate wrong decisions for Tori graphisms: 11% Iny, 17% Ixyju
Illiterate wrong decisions tor Tori graphisms:6% Iny , 10% Ixyju
Literate wrong decisions for Iny graphisms: 2% Tori, 4% Ixyju
Illiterate wrong decisions for Iny graphisms: 6% Tori, 7% Ixyju
Literate wrong decisions for Ixyju graphisms: 20% Tori; 24% Iny
Illiterate wrong decisions for Ixyju graphisms: 24% Tori; 16% Iny

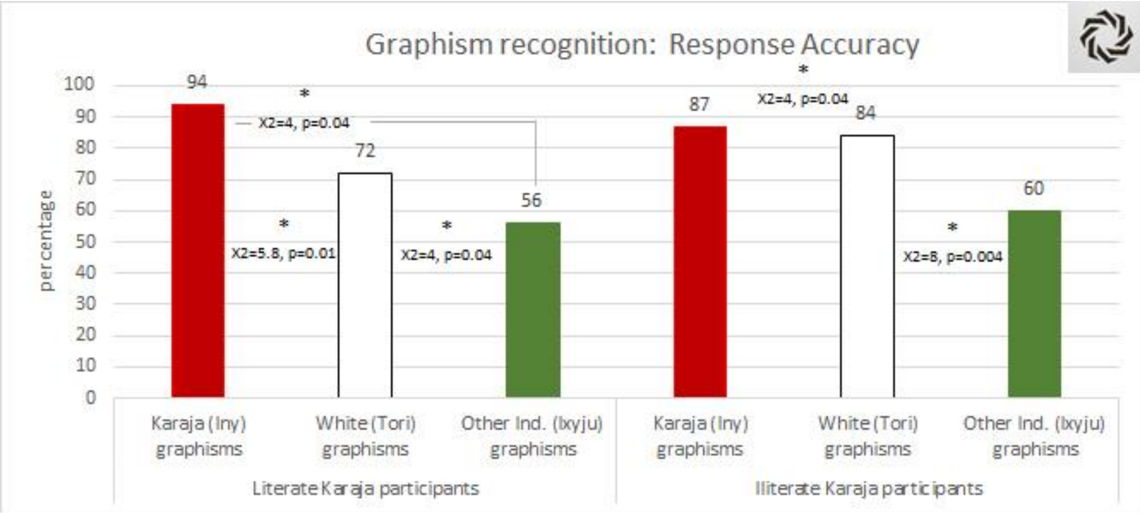

FIGURE 24 – Accuracy rates in percentage across conditions recognizing graphisms

Source: elaborated by the authors

Differences between literates and illiterates are neither significant in the recognition of nonindigenous (tori) graphisms (X^2= 1.8, p= 0.17), nor in the recognition of iny graphisms (X^2= 0.5, p= 0.4), nor in the recognition of ixyju graphisms (X^2= 0.27, p= 0.59). The only noteworthy difference that emerges is the fact that both literates and illiterates are equally less accurate in the ixyju condition than in the other two types of stimuli. Literates make significantly more mistakes in the ixyju condition than in the Iny condition ((X^2= 19.2, p= 0.0001) and the Tori condition (X^2= 4, p= 0.04). Likewise, illiterates get significantly less correct in responses in their identification of ixyju graphisms than in the identification of iny graphisms (X^2= 9.9, p= 0.001) and tori graphisms ((X^2= 8, p= 0.005).

Graphisms TFD and FC on-line measures were demarcated in terms of left and right sides only. Fig. 25 and Fig. 26 display the two measures which yield basically the same pattern of differences:

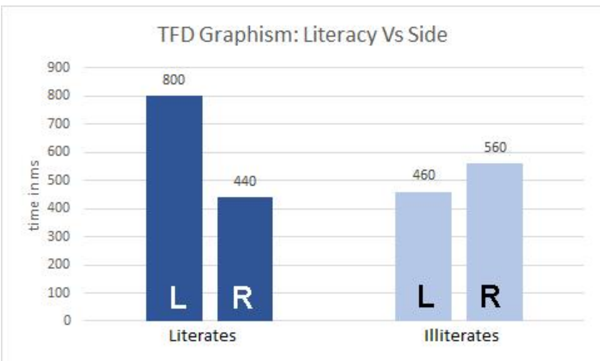

FIGURE 25 – Graphisms TFD: Literacy x Side

Source: elaborated by the authors

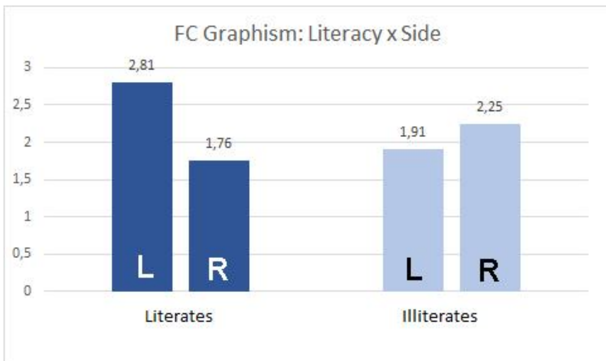

FIGURE 26– Graphisms FC: Literacy x Side

Source: elaborated by the authors

For TFDs, a two-factor ANOVA by participants indicated neither significant main effects of LITERACY (F(1,293) = 0.56, p<0.45) nor of SIDE (F(1,293) = 2.96, p<0.09), but there is interaction between the two factors (Literacy*Side (F(1,293) = 11.1, p<0.0009)). Pairwise t-tests show that, unlike the patterns obtained for faces, illiterates do not significantly differ in TFDs in their scan of the left and right sides of graphisms ([I_L]vs[I_R] t (293)=1.02 p< 0.31)). However, now, unlike their symmetrical scan of faces, literates do differ in their visualization of both sides of graphism, fixating significantly longer on the left side than on the right side ([L_L]vs[L_R] (t(293)=4.09, p< 0.0001)). The comparison between the two groups show that literates do fixate longer on the left side than illiterates ([I_L]vs[L_L] (t(293)=2, p< 0.01)), even though they display basically the same duration averages as illiterates in the scanning of the right sides of graphisms ([I_R]vs[L_R] (t(293)=1.6, p< 0.11)).

The same patterns obtained in the TFD measure also emerges when we look at FCs, making even more robust the findings for the overall scanning of graphisms by literates and illiterates. There are no main effects of Literacy (F(1,293) = 0.5, p<0.45) and of Side (F(1,293) = 2.9, p<0.09), even though both factors interact ((Literacy*Side F(1,293) = 11.1, p<0.0009)). In line with the TFD measures, in the pairwise comparisons, illiterates do not significantly differ in FCs in their scan of the left and right sides of graphisms ([I_L]vs[I_R] (t(293)=1.02, p< 0.30)).

In contrast, as in the TFD measure, literates do differ in their visualization of both sides of graphism, fixating significantly more on the left side than on the right side ([L_L]vs[L_R] (t(293)=4.09, p< 0.0001). The comparison between the two groups show that literates do fixate significantly more times on the left side than illiterates ([I_L]vs[L_L] (t(293)=2.45, p< 0.01)), even though they display basically the same FCs as illiterates in the scanning of the right sides of graphisms [I_R]vs[L_R] t(293)=1.6, p< 0.11)).

Figure 27 displays the average FCs in the visualization of Graphisms[5], taking into consideration now the crossings between the factors LITERACY, SIDE and the ETHNICITY of the stimuli.

[5] TFDs display similar patterns as FCs and for reasons of space are not reported.

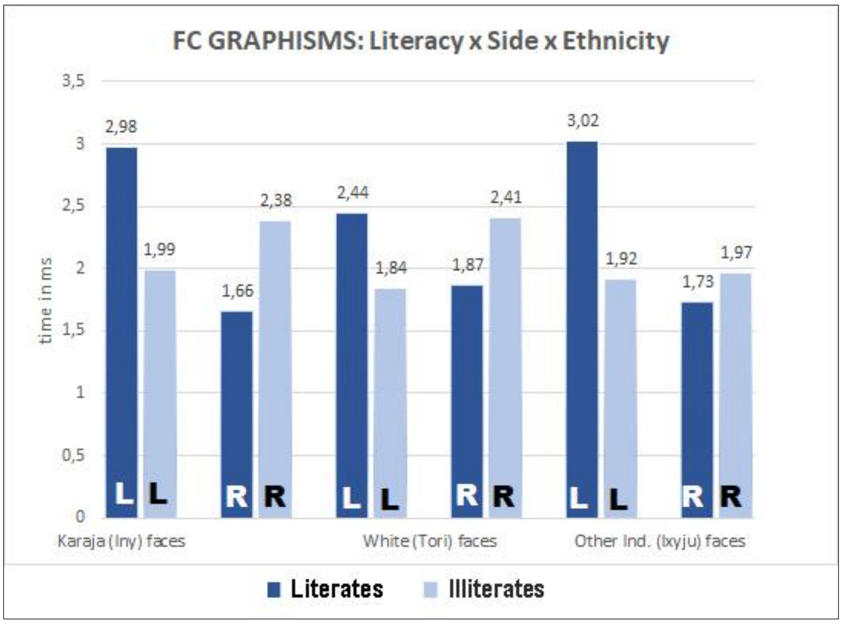

FIGURE 27 - FC GRAPHISMS: Literacy x Side x Ethnicity
Source: elaborated by the authors

A three-way ANOVA by participants does not indicate significant main effects neither of Literacy (F(1,97) = 2.32, p<0.13) nor of Ethnicity (F(2,194) = 0.045, p<0.95), but shows a significant main effect of Side (F(1,97) = 4.5, p<0.03). The only significant interaction of factors is actually the crossing of Literacy*Side (F(1,97) = 20.7, p<0.00001). Pairwise comparisons are displayed in Fig. 28:

[I_L_Iny]vs[I_R_Iny] t(97)=1.03 p< 0.30
[L_L_Iny]vs[L_R_Iny] t(97)=3.08 p< 0.002
[I_L_Tori]vs[I_R_Tori] t(97)=1.45 p< 0.150
[L_L_Tori]vs[L_R_Tori] t(97)=1.29 p< 0.200
[I_L_Ixyju]vs[I_R_Ixyju] t(97)=0.15 p< 0.88
[L_L_Ixyju]vs[L_R_Ixyju] t(97)=2.71 p< 0.008

FIGURE 28 - Graphism FC pairwise comparisons
Source: elaborated by the authors

The only significant differences arise in the comparison of the visualization of left and right sides of graphisms by literates in the iny and ixyju conditions, in which this group of participants consistently fixate more on the left side. Perhaps the lower subject power played a role in not allowing the disentangling among these conditions. In any case, we mapped the ground for further studies.

Discussion of Graphisms eye-tracking results

As shown in detail in the Graphism Results section above, both literates and illiterates display the same levels of accuracy in all conditions, but both make more mistakes in the identification of IXYJU graphisms than in the identification of the INY graphisms. As to the TORI graphism identification, analyses showed significant differences only for the illiterate group who also make more mistakes in the IXYJU condition than in the TORI condition. This may change in case the subject power is increased in future studies.

The FC on-line measures indicate crucially that the symmetry captured in the literate group visualization of faces is not instantiated in the visualization of graphisms. Literates now exhibit a more asymmetrical scanning, concentrating the largest number of fixations on the left side of graphisms in contrast with illiterates who tend to look at both sides of graphisms more symmetrically. Figures 29 and 30 show the heatmaps of prototypical visualization of INY graphisms respectively by literate and illiterate participants:

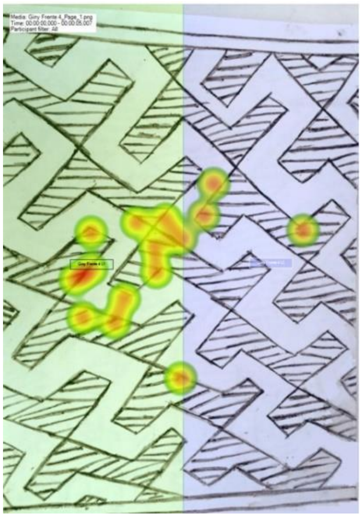

FIGURE 29 – Literate gaze to INY Graphism shows an asymmetrical pattern of fixations
Source: elaborated by the authors

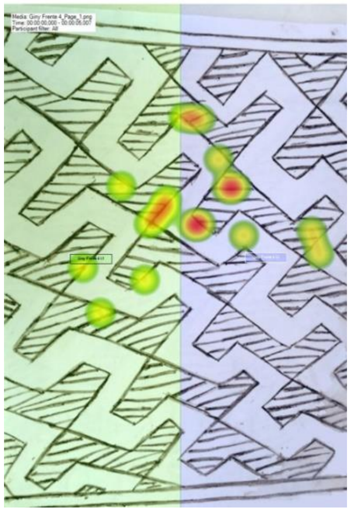

FIGURE 30 – Illiterate gaze to INY Graphism shows a more symmetrical pattern. fixations.
Source: elabo rated by the authors

The comparison between the two typical visualization heatmap patterns illustrates the concentration of fixations in the literate gaze vis à vis the more even distribution of fixations in the example of the illiterate gaze.

The same patterns are also instantiated in the ixyju condition, as exemplified by the gaze patterns in Fig.31 and Fig. 32:

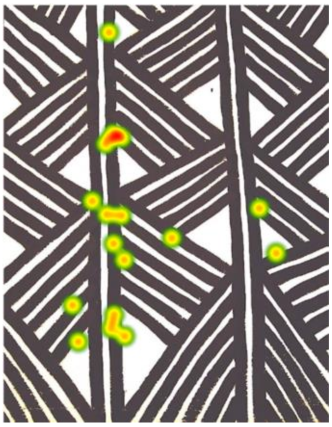

FIGURE 31 – literate gaze to IXYJU Graphism
Source: elaborated by the authors

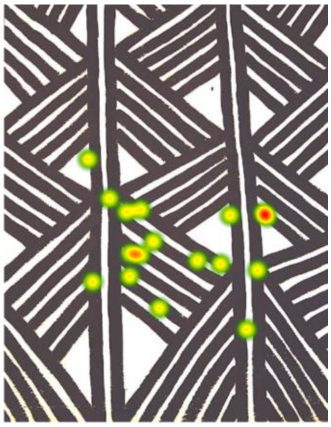

FIGURE 32 – Illiterate gaze to IXYJU Graphism
Source: elaborated by the authors

Again, the same concentration of fixations on the left side in the literate gaze is observed to the IXYJU graphism, in contrast with the more evenly distributed pattern in the illiterate gaze. Figures 33 and 34 illustrate gazes using the distribution of gazeplots in the visualization of a TORI graphism by literate and illiterate participants:

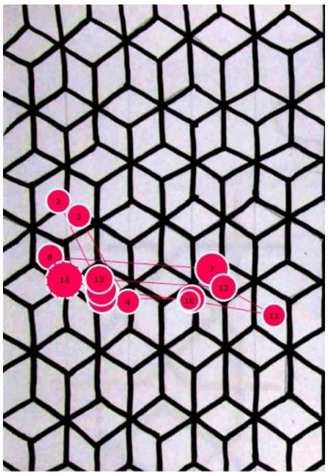

FIGURE 33 – Literate gaze to TORI Graphism
Source: elaborated by the authors

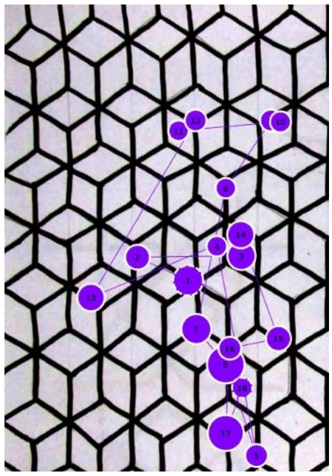

FIGURE 34 – Illiterate gaze to Graphism
Source: elaborated by the auth ors

Even though the figures are not statistically robust in the TORI condition as shown in the Results section above, by visual inspection the differences seem to go in the same direction at least in the literate TORI gaze pattern, in which most fixations concentrate on the left side. Maybe this can help us single out the effect evidenced here: as far as the literate visualizations go, there is indeed an important concentration of fixations on the left side of graphisms.

As suggested to us by Régine Kolinsky (personal communication, 2020), we might speculate whether literacy influences the visualization of graphisms in a way which is different from the enantiomorphism that prevails in the visualization of faces.

In contrast with the literate enantiomorphic visualization of faces, which is characterized by the application of the symmetrical inspection of letters, overcoming the left-right invariance and extending it to the inspection of faces, the literate visualization of graphisms is influenced by the directionality of reading from left to right. We therefore speculate that, in a language written from left to right, literate people who "read" the graphisms also tend to do so in the same direction, whereas the illiterate would not have the influence of reading directionality and thus would tend to look at both sides basically with the same gaze rates.

To conclude this section, we would like to add that it seems interesting to note in favor of this preliminary hypothesis, that in many indigenous languages, including Karajá, the expression for writing on paper originates from a semantic extension of the expression drawing on the skin, as illustrated in Fig. 36, which depicts on the left side the writing of letters and on the right side the drawing of patterns on the skin, both actions named by the same expression *tyy ràti* , in the Karaja language.

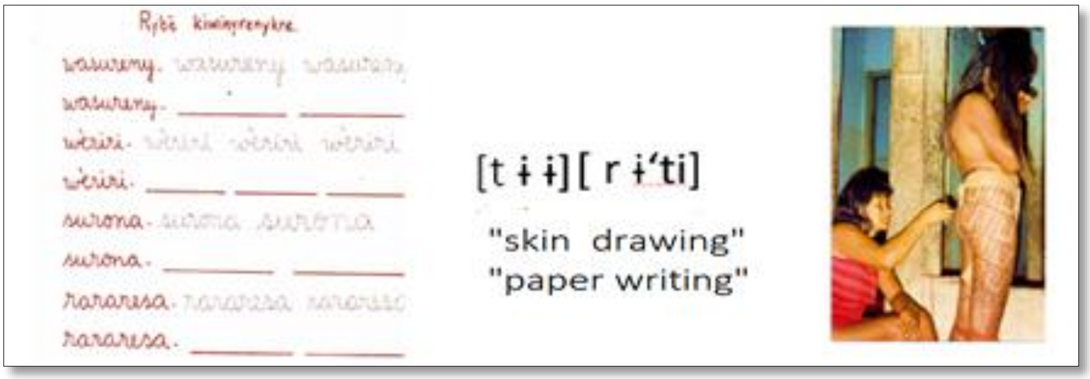

FIGURA 36 – Skin drawing and paper writing are expressed by the same phrase in Karaja
Source: elaborated by the authors

In this respect, Franchetto (2020) mentions that the relationship between mnemonic iconography and linguistic writing signs is present, in addition to Karaja, in many other Amazonian languages, such as Kuikuro, Huni Kui, Shipibo, Piro, and even outside the Amazon, in Kadiweu. Such languages present basic graphic forms that are recursively encapsulated producing complex designs and many display terms for writing which are related to graphisms.

3. Concluding remarks

To conclude, we first summarize some of the preliminary points we have been able to reach and then we draw some perspectives to enhance the field of experimental studies in non-weird populations:

• Literacy significantly affects the processing of faces: overcoming the left-right invariance, literate participants exhibit a more symmetric visual inspection of the faces (but not graphics) than the illiterate ones who do not necessarily inspect both sides of the faces, presenting average fixation times and fixation counts significantly higher on the right side of the faces.

• The visualization of the graphics seems to be influenced by the reading direction from left to right, distinguishing the visual inspection of literate and illiterate people.

• Literacy seems to somehow indirectly reinforce the own race bias, the bias in identifying faces of the same ethnicity: literate individuals correctly identified the faces of their own ethnic group in 85% of cases, while the illiterate got only 65% correct responses.

• Conversely, illiterate participants demonstrated greater accuracy in identifying non-indigenous faces compared to their literate counterparts. This difference may stem from variations in the allocation of attention to facial features (cf. Hills & Lewis, 2011). Literate individuals, exposed to a broader range of social interactions with non-indigenous communities and diverse ethnic groups, might find it harder to differentiate among the wide variety of non-indigenous faces. In contrast, illiterate individuals, with more limited exposure, may develop a more focused visual strategy that enhances their accuracy. However, the broader exposure of literates to the non-indigenous world might also enhance their ability to recognize faces within their own ethnic group. If this interpretation holds, such patterns likely arise as indirect consequences of literacy rather than as direct effects of literacy itself. These hypotheses warrant further investigation.

Despite the preliminary nature of this pilot study, the reported patterns in face and graphism categorization and visualization decisions suggest that literacy may influence visual processing through enantiomorphic, nonconscious top-down mechanisms. These mechanisms could potentially override default bottom-up visual scanning strategies, distinguishing literate individuals from their illiterate peers. For facial recognition, literates typically exhibit enantiomorphic fixations across both sides of a face, whereas illiterates tend to focus predominantly on the right side. Similarly, in the categorization of graphisms, the habitual left-to-right reading direction in Portuguese and Karajá appears to guide literate participants to process graphisms as if reading words or sentences. These findings, if corroborated in future research, could shed light on how literacy shapes fundamental visual and cognitive processes.

In terms of accuracy in the categorization task, the results reveal cultural effects that are difficult to disentangle from literacy effects but are likely related to them. Regarding facial recognition, the broader exposure of literate participants to a diverse range of both indigenous and non-indigenous faces—characteristic of Brazil's intensely miscegenated society—seems to play a significant role. Literate individuals, who tend to travel more frequently beyond the borders of their indigenous territories compared to their illiterate relatives, achieved higher accuracy in recognizing their own facial features. Interestingly, they recognized non-indigenous and other indigenous faces with similar accuracy levels.

In contrast, compared to literates, illiterate participants grouped indigenous categories (iny and ixyju) together and demonstrated higher accuracy in recognizing non-indigenous faces. This pattern suggests that illiterates may rely on prototype encoding and bottom-up processing when distinguishing among non-indigenous faces. With less exposure to facial diversity than literates, their recognition strategy likely involves focusing on prototypical features, which enhances accuracy. Conversely, their limited exposure to indigenous faces may lead them to lump these categories together, adopting a more economical approach by forming a single type rather than relying on detailed bottom-up inspections.

For graphisms, literate participants recognized their own drawings with higher accuracy than those of non-indigenous or other indigenous groups. Unlike face recognition, however, literates were able to distinguish non-indigenous (tori) art from that of other indigenous groups, recognizing the latter with less accuracy. Illiterate participants, on the other hand, maintained high accuracy in recognizing both tori art and their own group's drawings. This contrast may reflect inherent differences in the cognitive demands of face and graphism recognition.

The iny motifs in Karajá graphisms are extensively practiced within their community, and the implicit memory associated with the motor actions involved in creating these motifs likely reinforces recognition among illiterates (cf. Dharani, 2015). This motor-based implicit memory might explain the high levels of accuracy for indigenous graphisms among illiterates, contrasting with their grouping tendencies in face recognition.

These findings suggest complementary roles for prototype and exemplar models in explaining the observed patterns. Greater exposure to exemplars seems to facilitate top-down decision-making processes, while limited exposure favors bottom-up strategies. Traditionally, these differences between bottom-up computational algorithms and top-down heuristics are viewed as irreconcilable in cognitive science.

However, as implied in this study, a nuanced and less rigid examination of the interplay between cognitive and cultural factors in non-WEIRD populations holds the potential to bridge this divide. By incorporating cultural variability into cognitive analyses, we may develop a more harmonized framework to explain the interplay of nature and nurture in shaping cognitive processes.

Additional information

Evaluation and author´s answers

Evaluation: https://doi.org/10.25189/rabralin.v23i1.2279.R
Author´s answers: https://doi.org/10.25189/rabralin.v23i1.2279.A

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EVALUATION ROUNDS

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EVALUATOR 1

After reading the manuscript titled Eye-tracking literacy effects in face and graphism recognition in a non-weird population: the Karaja of central Brazil in which the authors report an experimental study using eye-tracking in a non-weird population, I am fully convinced of the scientific relevance of the report, nevertheless, there are a series of important adjustment needed to ensure the replicability of the study. The following is a list of the adjustments that I consider to be necessary.

- With regard to the experimental procedure, it is essential to provide details regarding the software utilized for stimulus presentation control and the eye-tracking sample rate employed.

- With regard to the manner in which the participant responses were recorded, the precise methodology employed remains unclear. In the text, the authors indicated that the participants were required to observe one of three images (Fig. 4) for a specified period of time. However, it is unclear whether the gaze was recorded and, if so, how it was processed to determine the participant's response (frequency or duration of fixation?)

- In relation to the results, it is necessary that the authors report the quality of the calibration, reporting the mean and standard deviation of the accuracy and precision.

- Regarding the analysis of total fixation duration, it is not clear whether the times in question were normalized by the duration of the stimulus presentation. This normalization is important because the duration of stimulus presentation was not the same for all participants, as described in the Methods section: the participants were instructed to press the spacebar to call the response screen as soon as they were ready to make a decision on the ethnicity of the stimulus, and it is possible that some participants did not need to explore all the details of the stimuli to be ready to make a decision, pressing the space bar and then ending their visual exploration of the stimuli. Figure 12, shows that the illiterate group took half the average TFD time to observe the faces than the literate group. So, I suggest that the comparison between groups be performed normalizing the TFD by the duration of the stimulus presentation.

- Related to the above suggestion and the interesting finding that the illiterate group neglected the left side of the face when visually scanning it, I wondered if this pattern of visual exploration was due to the fact that it was a timed task, and if the illiterate were allowed to freely explore the faces, would the left side still be neglected? I know that it not possible to repeat the experiment setting a free exploration of the faces in order to answered my question; but, at the same time, I think that is possible to answered it with the data that you have recorded. In this regard, I suggest examining the fixation sequence of the literate group to determine whether the initial fixations of the literate group's gaze are concentrated on the right side of the face, or whether they begin to explore faces in a pattern similar to that used to explore graphemes, with a concentration of initial fixations on the left side of the image. I am convinced that this new analysis could better contextualize your conclusions, showing the way in which literacy affects the visual exploration patterns and if that new gaze patterns are similar for any kind of stimuli or whether any pattern of visual exploration still remains, in case in which the literate group concentrating their initial fixation on the right side of the face.

Minor aspects

- Figure legends should be more specific about gaze behavior and distinguish gaze trajectories (Figs. 2, 34, 35) than heatmaps (Figs. 18, 19, 20, 21, 22, 23, 30, 31, 32, 33).

- The figure legend should contain all the information the reader would need to understand the figure, specifying whether the data shown correspond to the response of a participant or a group of them.

- All figures must have labels on the axes that indicate the measurement and units used in the figure.

- Font size in all figures should follow the journal's norms.

- Fig 10 and 11 could be joined into a single figure, similar to Fig. 16 or 17.

- All references must be presented in the same format.

EVALUATOR 2

The title of the paper is consistent with the proposed theme, the research execution and the results presented. The abstract includes the structural elements of a scientific article abstract The introduction presents a contextualization that culminates in the well-defined research objective and compatible with the objective presented in the abstract. The methodological procedures adopted by the authors are consistent with the proposed objective and the statistical tests applied are suitable for the experimental design. The applied experimental model is also appropriate to what is proposed in the research. The experimental paradigm used combines offline and online measurements, which makes it possible to produce evidence about language processing that would not be available from any of the methods alone. The findings, with offline and online measurements, are well explained in the manuscript, through verbal and non-verbal language (graphs and figures). The results of statistical tests are also properly presented and explained. The text is appropriate to the journal's standards.
In view of the above, I suggest that the paper be accepted.

AUTHOR´S ANSWER

Rio de Janeiro, December 1st, 2024.

Dear Professor Tejada,

Thank you for your detailed and constructive feedback on our manuscript. We deeply appreciate the time and effort you invested in your review, as your suggestions significantly enhanced the quality of the text.

I am particularly grateful for your insights regarding the reframing of the methodological section. Although at this point for technical reasons it is not possible to normalize data, your perspective helped to clarify and refine the presentation of the experiments and the methodological details, ensuring greater transparency and accessibility for readers.

We have carefully addressed most of the points raised in your review and, in the Word copy of the manuscript, we have marked the changes in red to facilitate your checking. We also incorporated other minor recommended revisions into the manuscript , such as joining two of the figures in one and revising the references according to the norm.

Thank you once again for contributing to the improvement of this work.

Kind regards,

Marcus Maia (UFRJ)

Aniela Improta França (UFRJ)

Conflicts of interest

On behalf of all authors, the corresponding author states that there is no conflict of interest.

Acknowledgments

This study was performed by the joint effort of the staff of LAPEX and ACESIN labs, respectively coordinated by the two authors, during an experimental field work trip to Bananal Island in the state of Tocantins. It was a large research adventure in which many projects were developed, including this one. We are sincerely grateful to the amazing professors, students and collaborators that helped us: Aleria Lage, Chang Whan, Cristiane Oliveira, Daniela Cid de Garcia, Juliana Novo Gomes, Julius Britto, Mariana Chang Maia and Mei Chang Maia.

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