Memory & Cognition (2019) 47:229–239
https://doi.org/10.3758/s13421-018-0861-1

The first, the least and the last: Spatial asymmetries in memory and their relation to script trajectory

Maria Laura Bettinsoli[1] · Anne Maass[2] · Caterina Suitner[2]

Published online: 6 September 2018

Abstract

Serial positioning biases are well documented and generally take a U-shaped form, with better memory for first (primacy) and last items (recency). Here, we test the hypothesis that the relative strength of primacy and recency depends on script direction. When presented with large arrays of images, people are expected to first direct attention to the side where they usually start reading (in our case, left among Italian, and right among Arabic speakers) and to then scan the remaining images along the habitual text trajectory. Besides supporting the predicted scanning direction with an eye-tracker methodology, Study 1a (n = 56 Italians) provides evidence for a spatial memory advantage for images positioned to the left. Study 1b (n = 34 Italians) shows that people are aware of the asymmetric scanning and the memory advantage deriving from it. Study 3 (n = 67 Italian and n = 44 Arabic speakers) shows opposite memory biases in the two samples, with best performance for images on the left among Italian and for images on the right among Arabic speakers. Together these studies contribute to the growing literature showing that scanning habits due to script direction exert a subtle influence on basic cognitive processes.

Keywords Cross-linguistic · Memory · Script trajectory · Serial positioning · Spatial asymmetry

Global literacy rates are currently estimated to be close to 85% worldwide, and in many countries people spend a remarkable portion of their time reading and writing (Roser & Ortiz-Ospina, 2017). Thus, they engage in an activity that is intrinsically asymmetric. Script direction determines both the location of the starting point (e.g., English readers start top left) and the primary trajectory (e.g., from left to right). There is now considerable evidence that such visual and motor routines influence mental processes that, at first sight, seem rather remote from reading and writing. Although asymmetries mimicking script direction tend to be of small magnitude, they are rather pervasive. For instance, the writing direction of language affects the way people envisage time (Casasanto & Bottini, 2014; Bergen & Lau, 2012; Ouellet, Santiago, Israeli, & Gabay, 2010; Tversky, Sol, & Winter, 1991) or numbers (i.e., the SNARC effect; Shaki, Fisher, & Petrusich, 2009; Zebian, 2005). It also affects everyday activities, such as placing books or arranging photographs on a shelf (Maass, Suitner, & Deconchy, 2014). The effect of spatial biases also emerges in social cognition—for instance, when envisaging social groups in space (Hegarty, Lemieux & McQueen, 2010; Maass, Suitner, Favaretto, & Cignacchi, 2009; Suitner & Maass, 2016). Similarly, aesthetic preferences in artworks (Chahboun, Flumini, Pérez González, McManus, & Santiago, 2017; Friedrich & Elias, 2016; Pérez González, 2012; Suitner & Maass, 2007) or interpretation of soccer games (Maass, Pagani, & Berta, 2007) are affected by script direction. In addition, and more relevant for our research, reading and writing direction has been shown to play a critical role in scanning habits (Afsari, Keshava, Ossandón, & König, 2018; Chokron, Kazandjian, & De Agostini, 2011).

However, the effect of script direction on memory has received very little attention. This is somewhat surprising given that memory is a fundamental feature of human existence and a central topic in psychological research. Two studies have investigated the link between script direction and attentional processes, finding a left-anchoring tendency in comparative judgments in cultures with left-to-right scripts, but a right-anchoring tendency in cultures with right-to-left scripts (von Hecker, Klauer, Wolf, & Fazilat-Pour, 2016) and demonstrating different patterns in attention allocation in unidirectionally versus bidirectionally readers (Hernandez, Wang, Sheng,

✉ Maria Laura Bettinsoli
mlaurabettinsoli@gmail.com

[1] Department of Psychology, New York University Abu Dhabi, Abu Dhabi, UAE

[2] University of Padova, Padua, Italy

Kalliny, & Minor, 2017). However, neither of these studies investigated memory processes. Indeed, we are aware of only two studies that have directly addressed this issue (Chan & Bergen, 2005, Experiment 1; Deconchy, 1956, as cited in Maass et al., 2014) providing only tentative evidence for the role of script direction in spatial memory.

Deconchy (1958) was probably the first to investigate memory biases as a function of script direction in his MS Thesis. He hypothesized that Arabic speakers would show better memory for objects located on the right side. To investigate this idea, he used an experimental task generally known as Kim's game. In this study (reported in Maass et al., 2014, pp. 52–53), native Arabic-speaking middle-school students in Lebanon were asked to observe, for 5 minutes, 24 pictures of common objects (such as a pencil, a key, a notebook, etc.) that were displayed in two rows and 12 columns. Students were then asked to name as many objects as they could remember. This same procedure was then repeated two further times over a several-weeks period, involving the same students, but each time changing the position of the objects. Overall, memory in this study was very good (71% correct recall). More interestingly, objects on the right side were remembered best, but there was an additional, more modest advantage for the objects on the far left (see Fig. 1). Assuming that the Lebanese students started scanning from the right, this would suggest a strong memory advantage for the first (primacy effect) and a weaker advantage for the last encountered stimuli (recency effect). However, the lack of a comparison group belonging to a left-to-right writing culture makes the interpretation of these data in terms of writing direction only speculative.

Serial position effects have been extensively investigated in cognitive psychology (for an overview, see Hurlstone, Hitch, & Baddeley, 2014), but, differently from the present work, the majority of studies have focused on temporal rather than spatial order and on word lists rather than images. In a nutshell, when people are provided with lists of items, they are more likely to recall items positioned at the beginning and at the end of the list rather than those positioned in the middle (Postman & Phillips, 1965). Although these primacy and recency effects are well established in the literature, there is a longstanding debate about the underlying mechanisms (Bousfield, Esterson, & Whitmarsh, 1958; Glanzer & Cunitz, 1966; Murdoch, 1962). Primacy and recency effects seem to reflect separate memory stores (respectively, long-term and short-term memory), an interpretation that is supported by neuroimaging technics (Talmi, Grady, Goshen-Gottstein, & Moscovitch, 2005). At the same time, the relative magnitude of primacy versus recency effects varies depending on the retention interval (e.g., Postman & Phillips, 1965; Storm & Bjork, 2016), the domain (verbal, visual, spatial; Hurlstone, Hitch, & Baddeley, 2014), and the characteristics of the task (e.g., forward vs. backward recall; Guérard & Saint-Aubin, 2012; Morrison, Conway, & Chein, 2014). Of particular relevance to the current research are studies on temporal-spatial memory in which participants are generally asked to recall not only the temporal but also the spatial ordering of objects (such as dots or pictures). This literature generally reports a somewhat asymmetric serial position curve with a stronger primacy effect that may extend beyond the first item and a smaller and steeper recency effect that often involves only the last item (Farrand, Parmentier, & Jones, 2001; Jones, Farrand, Stuart, & Morris, 1995; Smyth, Hay, Hitch, & Horton, 2005). This corresponds exactly to the asymmetric curve observed by Deconchy (see Fig. 1) *if* one assumes that scanning started from the right in these Arabic-speaking participants.

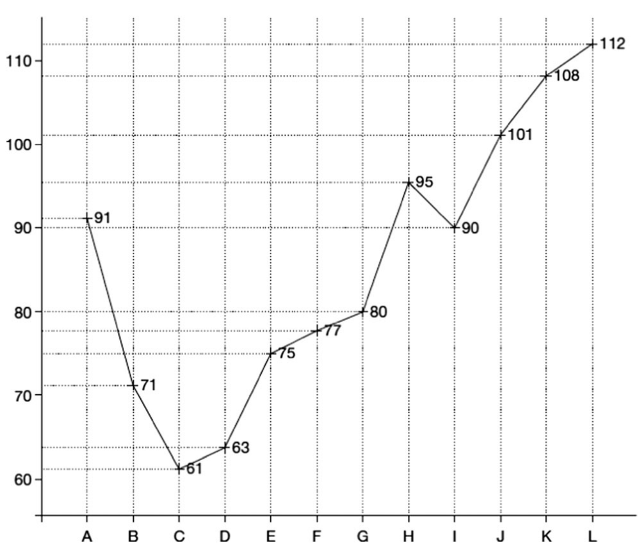

Fig. 1 Recall of objects among Arabic-speaking Lebanese (econchy, 1958). Reprinted from Maass, Suitner, and Deconchy (2014) with permission from Routledge

The literature on serial order has mainly focused on free recall of digits or words, while little is known about the recall of exact positioning of images, a task that is particularly important in everyday life, such as when we have to remember where an object was positioned in an environment. Moreover, to our knowledge, the role of scanning habits on memory has been investigated only by Deconchy (1958) and, almost 50 years later, by Chan and Bergen (2005). However, Deconchy focused only on Arabic-speaking participants, therefore not allowing any conclusion about the influence of script direction. Chan and Bergen used a similar procedure, investigating memory in three populations that were either accustomed to a left–right writing system (English speakers in the U.S. and Chinese speakers in Mainland China) or to a mixed system (Taiwanese speakers), in which traditional writing evolves top down with columns moving from right to left, whereas modern texts are arranged from left to right. In this study, participants observed a large number ($n = 42$) of black-and-white images displayed on a single screen for only 3 seconds (no information about any counterbalancing of object location in the grid was provided). Subsequently, participants were asked to name as many objects as they could. Overall, memory was weak, with an average of only 14% of the objects correctly remembered. All groups showed better memory for objects displayed in the upper half of the screen, suggesting that they all started scanning from the top. Although the study was clearly underpowered (with only 10 participants for each language), the descriptive data were in line with hypotheses: English and Mainland Chinese participants showed better memory for objects in the upper left quadrant, whereas Taiwanese participants showed an equally strong advantage for objects in the upper right quadrant (much like the Arabic speakers in Deconchy's study). These studies provide preliminary support for our hypothesis that memory is affected by script direction, but methodologically sounder testing is needed to corroborate the findings and to test the specific role of asymmetry in attention allocation due to writing habits. Such testing should ideally compare cultures with opposite script trajectories (left to right vs. right to left), rather than mixed systems.

Aims of research

Extending the above line of research, we propose that memory of spatial positioning depends on writing and reading habits that are determined by culturally defined script direction. Depending on their habitual writing/reading direction, people will either be better at remembering objects placed on the left side (in cultures with rightward script direction) or on the right side (in cultures with leftward script direction). This prediction rests on the assumption that participants explore spatially arranged stimuli in a specific temporal order and that this order is determined by script direction. When images are shown simultaneously (as in the present research), there is no intrinsic temporal order, and participants could theoretically explore the stimuli in any order they wish. Yet, in line with Deconchy (1958) and Chan and Bergen (2005), we expect them to spontaneously start scanning where writing/reading usually starts (e.g., on the left for English or Italian readers and on the right for Arabic or Hebrew readers). Assuming that script direction determines the starting point of scanning, we hypothesized that this will then result in corresponding memory processes resembling the usual serial positioning curve. In particular, we expect to replicate Deconchy's asymmetric primacy and recency effects, with the greatest memory advantage for images encountered first, followed by those encountered last and with the lowest performance for images in intermediate positions. In order to address these issues, we conducted a set of three studies.

In the first two studies (Study 1a and Study 1b), we investigated memory for simultaneously displayed images in Italian participants, using the Kim's game. Different from Deconchy's original study, we employed a spatial memory task that required participants to remember where objects were located. Besides being a highly ecological task (Postma, Kessels, & van Asselen, 2008), memory for object location seemed particularly well suited to test whether the serial-position effect is affected by script direction. Given the left–right script trajectory, we expected memory to be best for items on the left (primacy), followed by those on the right (recency), with performance being poorest for images in intermediate positions. Importantly, in Study 1a we also investigated spatial attention allocation by assessing participant's eye movements while observing the images to be memorized. We expected that Italian participants would start scanning the images on the left, thus engaging less time to reach that area, to then proceed in a rightward direction. Study 1b is a follow-up study addressing participants' awareness of the asymmetry in spatial attention allocation and in memory performance.

The subsequent study (Study 2) investigated the relation between memory and script direction from a cross-cultural perspective, comparing Italian and Arabic speaking participants. The main purpose of this study consisted in providing evidence that scanning habits due to reading and writing direction are potentially responsible for the asymmetric memory bias. In line with contrasting script directions (rightward vs. leftward, respectively), Italian and Arabic samples were expected to show opposite patterns of directional memory bias. Specifically, we hypothesized that Italian participants would show the greatest memory advantage for images on the left and Arabic participants for those on the right (replicating Deconchy's results; see Fig. 1).

Study 1a: Italian language with eye-tracking evidence

The main aim of the first experiment was to provide process evidence by tracking the participants' eye movements while they were observing the images to be memorized. We expected Italian participants to explore first the left side and then the right side of the display, thus following the direction of their habitual script. In addition, we also hypothesized that participants would more likely direct their gaze and spend more time on the left side of the grid, rather than on the right side.

Method

Participants Fifty-six participants (21 males; M_{Age}= 23.8 years; eight self-defined left-handers) volunteered for this study. With one exception, all participants were born in Europe, and the remaining person had been living in Europe for 8 years. The first language all participants had learned to write and read was a left-right language (54 Italian, 1 English, 1 Spanish). None of the participants had spent extended time periods in countries with right–left scripts. Only one participant had rudimentary knowledge of a right-to-left written language (Arabic).

Procedure and materials After signing the informed consent form, participants were seated in front of a Tobii eye-tracking computer screen. Following the calibration phase, they were told that they would have 30 seconds to observe and to memorize a number of images that would appear on the screen. The first display contained 35 photos of food items of equal size, which were arranged on a grid of five rows by seven columns (see Appendix A, Table 1). This was followed by a memory test, in which participants were given a blank grid and 35 single cards, one for each object, and were asked to reconstruct the original grid within 90 seconds. The reconstruction was then photographed by the experimenter to allow subsequent response coding. Participants then observed a second grid of 35 animals (see Appendix A, Table 2), followed by the same memory test. After providing demographic information, participants were fully debriefed.

To avoid any order or orientation effects, we created 14 versions of each display. First of all, columns were rotated so that each column appeared in the first, second, and so forth, position, resulting in seven different versions. We then created a mirror image of each of the seven versions to avoid biases due to the leftward or rightward orientation of each image. Four participants were randomly assigned to each of the 14 versions.

Coding For the analyses of both Study 1a and Study 2, we computed two measures: exact positioning and accuracy index. Exact positioning consisted of the number of correct card placements in each column. To compute the accuracy index, responses were coded "2" when the object was positioned in the exact position (correct column and correct row) and as "1" when it was placed in the correct column but not in the correct row. Scores were summed separately for each column so that each participant received seven accuracy scores, one for each column (with values ranging from zero to a maximum of 10).

Results

As separate analyses for each type of pictures (i.e., food and animal) revealed practically identical patterns, we averaged the responses across the two stimulus types for all subsequent analyses.

Exact positioning A linear model with columns as an independent variable and the number of exactly positioned objects as a dependent variable revealed a main effect for column, $F(6, 330) = 21.003$, $p < .001$, $\eta_p^2 = .27$. The linear and the curvilinear trends were significant (all *p*s < .001). As can be seen in Fig. 2, memory for the first (left) column exceeded that for the last (right) column, $t(55) = 5.23$, $p < .001$.

Accuracy index The linear model revealed differences between columns, $F(6, 330) = 26.6$, $p < .001$, $\eta_p^2 = .33$ (see Fig. 3). Again, both the linear and the quadratic trends were significant (all *p*s < .001). Again, memory for images the first column exceeded that for images in the last column, $t(55) = 5.66$, $p < .001$.

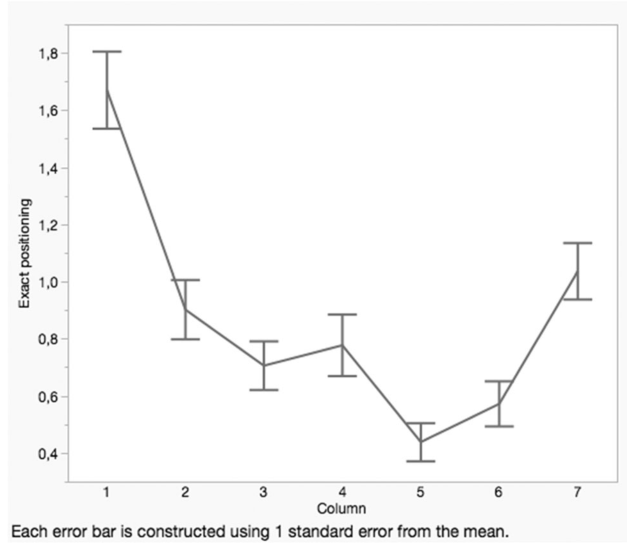

Fig. 2 Exact positioning per column (Study 1a)

Eye-tracking variables For these analyses, we considered 51 out of 56 participants because of malfunctioning of the Tobii in five cases.

Time to first fixation We defined seven areas of interest (AOI), corresponding to the seven columns, and analyzed for each AOI the time to first fixation, which describes how fast participants attend to a specific area. Hence, this measure provides information on the order in which attention is allocated to different areas in space, which was of prime theoretical interest to this research. Supporting our hypothesis, results showed that participants attended earlier to the first AOIs, namely, the first,

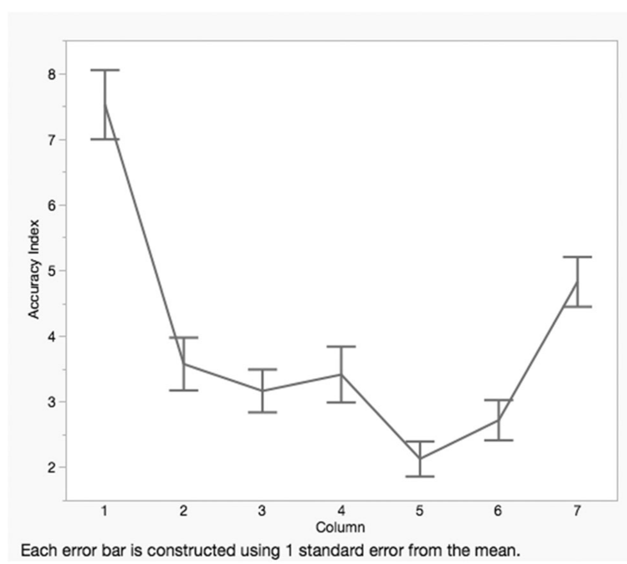

Fig. 3 Accuracy index per column (Study 1a)

the second, and the third columns rather than to the last columns, $F(6, 300) = 59.103$, $p < .001$, $\eta_p^2 = .54$ (see Fig. 4).

Fixation count For the same seven AOIs, we also analyzed the fixation count, which describes how often participants direct their gaze at a specific area, therefore providing information on the total number of fixations directed at a specific AOI. As hypothesized, results showed that the number of fixations was substantially greater on the left side of the grid, namely, the first three columns on the left, rather than on the right side, $F(6, 300) = 10.775$, $p < .001$, $\eta_p^2 = .18$ (see Fig. 5).

Observation length In addition, for each of the seven AOIs, we analyzed the observation length, which measures the amount of the time participants spend in a specific area. In line with previous findings, results showed that participants spent the majority of the time on the left side of the grid, namely, on the first three columns on the left, rather than on the right side, $F(6, 300) = 6.59$, $p < .001$, $\eta_p^2 = .116$ (see Fig. 6).

Discussion

Results of Study 1a fully confirmed our predictions. Our Italian participants showed better memory performance for objects placed in the far-left column (vs. far-right column), and this emerged consistently across measures (exact positioning and accuracy index) and across stimulus materials (food vs. animals). This memory advantage for objects on the left side is in line with the idea that scanning habits due to reading and writing direction produce an asymmetric directional bias in memory. This interpretation received additional support from our eye-tracking measures, showing that participants started exploring the images from the left, directed their gaze more often at the images to the left, and spent overall more time looking at the images to the left. However, the above study fails to assess participants' awareness of this asymmetry in attention allocation and mnemonic processes, a research question that was addressed in Study 1b.

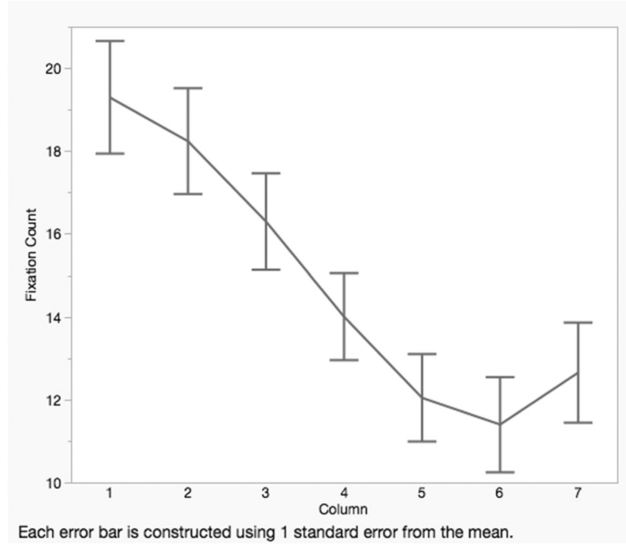

Fig. 5 Fixation count (Study 1a)

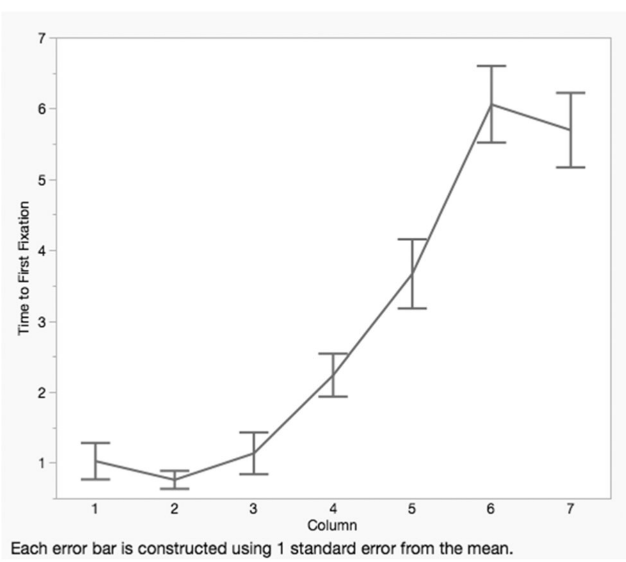

Fig. 4 Time to first fixation (Study 1a)

Study 1b: Awareness of scanning direction and its implications among Italian speakers

Spatial asymmetries are often considered a subtle index of cognitive processes (e.g., Suitner & Maass, 2016); however, little is known about the accessibility of these phenomena to conscious awareness. We usually ask our participants to guess the scope of the study, and—at least in our laboratory—participants typically are unable to guess that we are interested in horizontal biases in their responses. However, it is still unclear

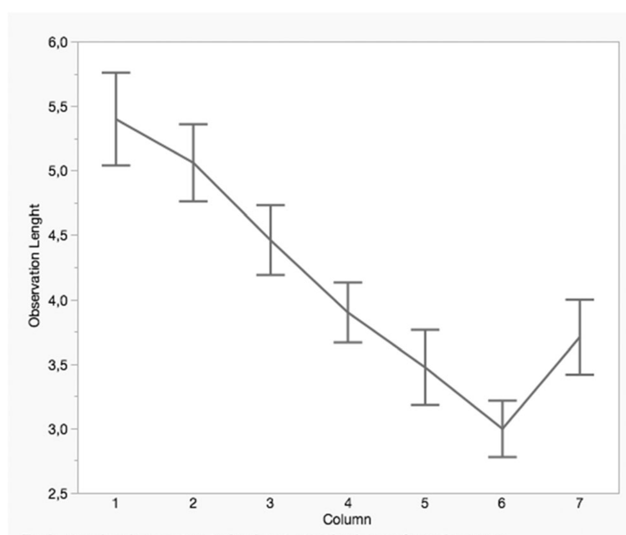

Fig. 6 Observation length (Study 1a)

whether participants are conscious of their asymmetric behaviors when asked to mindfully reflect on it.

Method

Participants Thirty-four native Italian speakers (19 males; $M_{\text{Age}} = 22.35$ years, $SD = 3.39$; one left-handed and one ambidextrous) volunteered for this study.

Procedure and materials Participants were shown the same two displays of Study 1a: first the one containing 35 food images and then the one containing 35 animal images. They were free to observe the images for as long as they wished and were asked to remember as many images as they could. After the observation phase, participants were asked to indicate in which order they had looked at the images (i.e., "Starting from the left" vs. "Starting from the right"), and which images they thought they would remember better (i.e., "Do you think you would better remember the images on the left or on the right?"). Demographic data about gender, age, handedness, and languages were collected at the end of the questionnaire.

Results

The majority of participants (79%) reported to have started viewing the display from the left, $\chi^2(1, N = 34) = 11.76$, $p < .001$, and 62% reported that they would remember the images on the left better, $\chi^2(1, N = 34) = 3.9$, $p < .001$.

Discussion

The results show that, when explicitly asked about it, participants are aware of the spatial bias. The majority reported that they were scanning the visual field starting from the left and that they were memorizing the information on the left side more accurately. This suggests that the writing direction offers a scanning path that not only is used to memorize information but that people are aware of it. Future research is needed to investigate whether this bias is also deliberate and whether this scanning path is an effective strategy to process information.

Together, the above studies provide first evidence that participants accustomed to left-to-right scripts scan images starting from left and that this enhances their memory for the first and, to a lesser degree, for the last images encountered. However, neither of the above studies speaks to the hypothesized underlying mechanism related to script direction. In Study 2, we therefore asked both Italian and Arabic speakers to perform the same task, but, for logistic reasons, without the eye-tracking equipment.

Study 2: Italian–Arabic comparison

The main aim of Study 2 was to provide cross-cultural evidence for the claim that habitual scanning habits are indeed at the basis of the asymmetric memory effect. For this study, we compared Italian and Arabic participants, given that they habitually read and write in a rightward versus leftward fashion, respectively. Both groups were expected to display the well-known U-shaped serial positioning curve, but, critically, Italian participants were expected to show the strongest memory advantage for images displayed in the far-left column and Arabic participants for those displayed in the far-right column.

Method

Italian participants Sixty-seven Italian native speaker participants (28 males; $M_{\text{Age}} = 24.8$ years, $SD = 8.2$; four self-defined left-handers) volunteered for this online study. The first language they had learned to write and read was a left–right language for all participants (Italian). None of the participants had knowledge of any right-to-left language. None of the participants had spent extended time periods in countries with right–left scripts.

Arabic participants Eighty-five Arabic native speaker participants (36 males; $M_{\text{Age}} = 36.4$ years, $SD = 12.06$; five self-defined left-handers) volunteered for this online study. The first language they had learned to write and read was a right-left language for all participants (Arabic). Almost all participants had knowledge of at least one left-to-right language (98%), only two participants reported to speak only Arabic and Berber languages. Moreover, 75% of the participants had spent extended time periods in countries with left–right scripts (mainly Italy and France). To assure "pure" writing/reading habits, for all analyses, we only included those Arabic speakers that reported to read and write Arabic "exclusively" or "mostly" ($n = 44$). We did not consider the bidirectional writers who used Arabic only "half of the time" or "rarely" ($n = 41$).

Procedure and materials The entire study was run through an online platform. Participants were provided with a link that automatically randomized the six counterbalanced conditions of the study. After reading the informed consent form, participants were asked to accept to take part in the study. They were then asked to observe and memorize 18 objects and their positions. The experimental display contained 18 photos of general items, arranged in a grid of three rows by six columns. Different from the materials of Study 1, where objects (food items and animals) varied in terms of lighting, background, size, and style, we decided to create pictures for Study 2 ourselves, so as to guarantee that images were as neutral and as similar as possible. All images represented everyday domestic objects or utensils (e.g., box, cup, coffee can) and were photographed by the first author to ensure similar features (lighting, background, style, size) among all the objects. Each object was photographed frontally, to assure a symmetric representation, and then, photoshopped by including a white background (see Appendix A, Table 3).

Participants were exposed to the grid for 30 seconds. They were then provided with a blank 3 × 6 grid on the computer screen and asked to try to reconstruct the original grid. The single cards representing each of the objects appeared, one at a time, in the central position below the grid. Participants were asked to place each object in the correct position within the grid. Objects appeared sequentially and in random order. Once participants had placed an object within the grid, the following object appeared. Participants were not allowed to change the position of the object once it had been placed. Unbeknownst to the participants, a number ranging from 1 to 18 marked each object. The program recorded automatically the experimental condition, the order in which objects appeared during the memory-test phase, and the order and the position in which participants placed the objects in the grid. This task was the first of three tasks, all of which were part of a larger project on spatial biases. None of the other tasks is relevant for the aims of the present manuscript as they assessed intergroup bias and comparison processes.

Coding As for the analyses of Study 1a, we computed two measures, the exact positioning measure (number of correct card placements in each column) and the accuracy index (responses coded as "2" when the object was positioned in the exact position and as "1" when it was placed in the correct column but not in the correct row). Scores were summed separately for each column so that each participant received six accuracy scores, one for each column (with values ranging from zero to 6).

Results

Exact positioning A 6 (column) × 2 (Arabic vs. Italian speakers) ANOVA with column varying within and language between participants revealed a curvilinear trend with memory being better for the extreme columns, $F(1, 109) = 50.27$, $p < .001$, $\eta_p^2 = .32$. However, as can be seen in Fig. 7, the curve took a somewhat different shape and was differently tilted for Arabic and Italian speakers. A 2 (extreme left vs. extreme right column) × 2 (Arabic vs. Italian) ANOVA confirmed the predicted interaction, $F(1, 109) = 12.55$, $p = .001$, $\eta_p^2 = .103$. Italian speakers showed a significant memory advantage for the left ($M = 1.93$, $SD = 1.01$) over the right ($M = 1.56$, $SD = 1.02$) column, $t(66) = 2.49$, $p = .015$, whereas Arabic speakers showed a significant opposite trend with memory being better

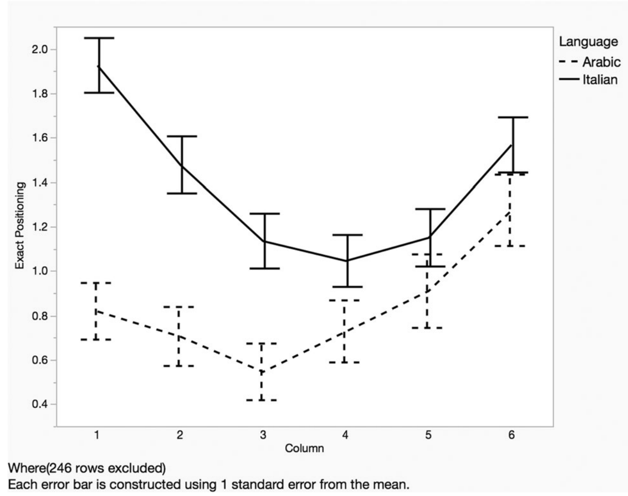

Fig. 7 Exact positioning per column for Arabic speakers and Italian speakers (Study 2)

for the extreme right ($M = 1.27$, $SD = 1.06$) than for the extreme left column ($M = .82$, $SD = .84$) $t(43) = -2.53$, $p = .015$.[1]

Accuracy index As for exact positioning, a 6 (column) × 2 (Arabic vs. Italian speakers) ANOVA, this time using the accuracy index as dependent variable, revealed the same curvilinear trend for column with memory being better for the extreme columns, $F(1, 109) = 67.84$, $p < .001$, $\eta_p^2 = .38$, but the shape again was different for Arabic and Italian speakers (see Fig. 8). A 2 (extreme left vs. extreme right column) × 2 (Arabic vs. Italian) ANOVA comparing the two extreme columns again confirmed the predicted interaction, $F(1, 109) = 15.33$, $p < .001$, $\eta_p^2 = .123$. Italian speakers showed a significant memory advantage for the left ($M = 4.03$, $SD = 1.77$) over the right column ($M = 3.45$, $SD = 1.81$), $t(66) = 2.42$, $p = .018$, whereas Arabic speakers showed a significant trend in the opposite direction, with memory being better for the extreme right ($M = 2.88$, $SD = 1.89$) than for the extreme left column ($M = 1.97$, $SD = 1.47$), $t(43) = 2.42$, $p = .003$.[2]

Discussion

In the last study, we investigated the underlying role of script direction from a cross-cultural perspective, finding a different pattern in spatial memory for Italian and Arabic speakers. Specifically, Italian participants showed a better memory for objects placed in the left column (a primacy effect) and linearly reducing toward the right, with a steep increment for the last column (a recency effect). Arabic participants provided a different pattern, with a better memory performance for objects

[1] When including Arabic speakers with bidirectional writing/reading habits as a third group in the analyses, these tended to occupy an intermediate position, with no memory advantage for either the left ($M = 1.39$) or the right ($M = 1.26$) column.

[2] When including Arabic speakers with bidirectional writing/reading habits as a third group in the analyses, these tended to occupy an intermediate position, with no reliable memory advantage for either the left ($M = 3.24$) or the right ($M = 2.95$) column.

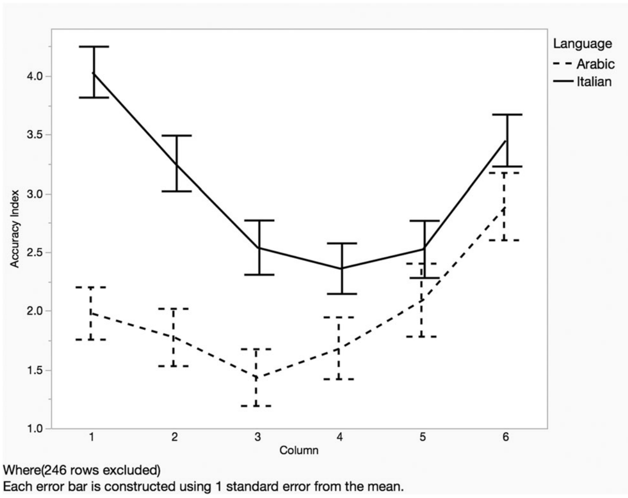

Fig. 8 Accuracy index per column for Arabic speakers and Italian speakers (Study 2)

presented on the right (vs. left) of the grid. Although we are not excluding that part of the observed asymmetry is due to culture-independent factors, the difference between Italian and Arabic is clearly in line with the hypothesis that script direction plays a major role in the asymmetric directional bias in memory.

General discussion

Whereas a few centuries ago only a small portion of the world population was able to read and write, today the pattern is almost reversed. In fact, global literacy rates are such that only 17% of the world population is still illiterate (Roser & Ortiz-Ospina, 2017). Besides playing a fundamental role in education and knowledge acquisition, engaging in reading and writing has been shown to influence different cognitive processes that are not directly linked to specific language features. For instance, script direction influences representations and interpretation of both abstract concepts (e.g., time and number) and social relations (e.g., relative power and agency; Suitner & Maass, 2014). Here, we take this idea one step further by arguing that even memory is systematically affected by writing/reading habits.

Both Italian and Arabic participants in our last study show a U-shaped serial order curve, which, in line with hypotheses, is differentially tilted. If primacy outweighs recency in spatial tasks, as many prior studies suggests (e.g., Farrand et al., 2001; Jones et al., 1995; Smyth et al., 2005), then the memory advantage should be greatest for the far-left column for Italian-speaking participants, but for the far-right column for Arabic-speaking participants. This is exactly what emerged in Study 2. Attesting to the robustness of this effect, the pattern for our Italian participants emerged in almost identical form in Study 1a, although the procedure was different in many respects (manual vs. computerized placement of objects, free vs. predetermined ordering of images during test phase, presence vs. absence of possibility to rearrange the objects on the grid).

Our argument rests on the assumption that people explore visual images with a temporal trajectory that matches their writing habits, starting either from the left or from the right. Study 1a provides direct evidence for this assumption, showing that Italians start scanning from the left, proceeding toward the right. Although this study was, for logistical reasons, limited to Italian participants, it does speak to the underlying attentional process (for eye-tracking evidence of cross-cultural differences in attention allocation, see Hernandez et al., 2017). Study 1b further shows that people are aware of this directional bias and of its implications for memory if asked to express their opinion. Together, our studies provide first evidence that, even when exploring language-free images, the focus of attention follows the same trajectory as script direction, which in turn affects memory, a path that is known to people if asked to reflect on it (Study 1b).

These findings are relevant because they show that even very basic processes such as memory for spatial location are intrinsically linked to visual and motor habits related to script direction. Although we are obviously not claiming that script direction is the only mechanism through which culture affects memory, our findings add to the growing literature showing that scanning habits exert a subtle influence on several cognitive dimensions that were initially conceived as "culture free."

Being the first of its kind, it is not surprising that our research has a number of limits. First, due to constraints in recruitment, we were unable to identify a sample of "pure" Arabic participants with no knowledge of or exposure to left-to-right languages. Whereas our Italian participants were perfectly unidirectional writers and readers, most of our Arabic participants had some exposure to left–right writing languages. We partially resolved this problem by maintaining only those participants in the sample that wrote and read mainly or exclusively in Arabic. Although this method is not perfect, it is reassuring that we did find a reversal of the serial positioning curve despite the fact that the Arabic participants were less unidirectional than the Italian participants. In addition, we were not able to collect eye-tracking data with the Arabic sample because we did not have a portable eye tracker at the time the study was run. Hence, it remains to be shown that Arabic participants do, indeed, allocate attention in a right-to-left fashion.

Another limitation is the fact that we only assessed memory for location. Thus, it remains to be seen whether similar asymmetries emerge on different memory tasks such as free recall of objects rather than of their location (see Deconchy, 1958).

Our results may have a number of important applied implications. First, one may easily envisage that these findings are relevant to culture-specific advertising and marketing (see also Hernandez et al., 2017). They provide potentially useful information about the use of space in order to ensure that the advertised product receives the user's attention and remains in memory. A similar argument applies to social and health communication, where health-promoting messages may be arranged in space so as to attract people's immediate attention and to be recalled later on. Last, but not least, our findings may speak to any process involving the relation between spatial orientation and memory, for example, in forensic contexts. Memory is critically involved in eyewitness testimony and in suspect identification from lineups. Here, the order in which objects and persons are arranged in space may have a considerable impact on the way we perceive, choose, and remember facts.

Author note Acknowledgement: We thank Serena Filieri for the data collection of Studies 1a and 1b and Mariam Aidi for having collected part of the data of Study 2. We are very grateful to Stefano Andriolo for setting up the online platform of Study 2.

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Appendix A

Table 1 Example of stimulus materials used in Study 1a (food)

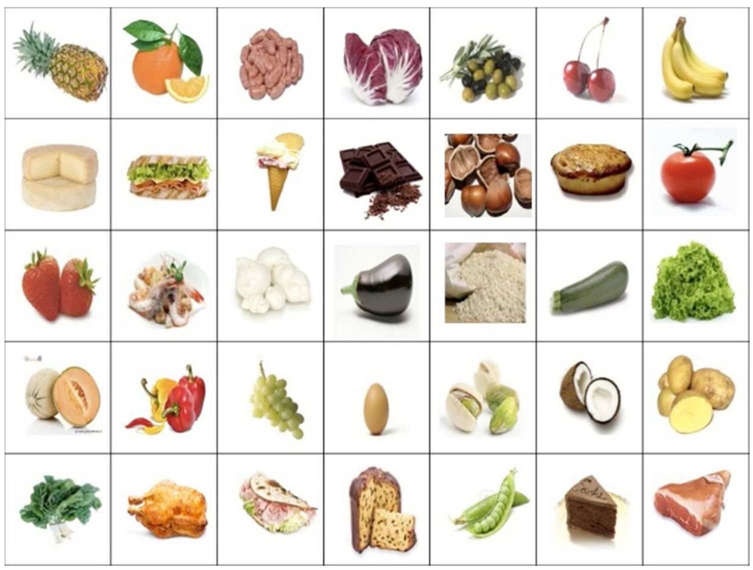

Table 2 Example of stimulus materials used in Study 1a (animals)

Table 3 Example of stimulus materials used in Study 2

References

Afsari, Z., Keshava, A., Ossandón, J. P., & König, P. (2018). Interindividual differences among native right-to-left readers and native left-to-right readers during free viewing task. *Visual Cognition, 26*(6), 430–441.

Bergen, B. K., & Lau, T. T. C. (2012). Writing direction affects how people map space onto time. *Frontiers in Psychology, 3*. https://doi.org/10.3389/fpsyg.2012.00109

Bousfield, W. A., Esterson, J., & Whitmarsh, G. A. (1958). A study of developmental changes in conceptual and perceptual associative clustering. *The Journal of Genetic Psychology, 92*(1), 95–102.

Casasanto, D., & Bottini, R. (2014). Mirror reading can reverse the flow of time. *Journal of Experimental Psychology: General, 143,* 473–479.

Chahboun, S., Flumini, A., Pérez González, C., McManus, I. C., & Santiago, J. (2017). Reading and writing direction effects on the aesthetic perception of photographs. *Laterality: Asymmetries of Body, Brain and Cognition, 22*(3), 313–339.

Chan, T. T., & Bergen, B. (2005). Writing direction influences spatial cognition. In B. G. Bara, L. Barsalou, & M. Bucciarelli (Eds.), Proceedings of the 27th annual conference of the Cognitive Science Society (pp. 412–417). Mahwah, NJ: Erlbaum.

Chokron, S., Kazandjian, S., & De Agostini, M. (2011). Cultural and biological interaction in visuospatial organization. In T. Schubert & A. Maass (Eds.), *Spatial dimensions of social thought. Berlin*, Germany: Mouton de Gruyter.

Deconchy, J. P. (1958). *La lecture de Francaise et la tendance a l'orientament droite-gauche chez les infants delangue arabe [Reading in French and the tendency to a right-to-left direction among Arabic-speaker children]*. (Unpublished MS thesis, Lyon University).

Farrand, P., Parmentier, F. B., & Jones, D. M. (2001). Temporal–spatial memory: Retrieval of spatial information does not reduce recency. *Acta Psychologica, 106*(3), 285–301.

Friedrich, T. E., & Elias, L. J. (2016). The write bias: The influence of native writing direction on aesthetic preference biases. *Psychology of Aesthetics, Creativity, and the Arts, 10*(2), 128–133.

Guérard, K., & Saint-Aubin, J. (2012). Assessing the effect of lexical variables in backward recall. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 38*(2), 312–324.

Glanzer, M., & Cunitz, A. R. (1966). Two storage mechanisms in free recall. *Journal of Verbal Learning and Verbal Behavior, 5*(4), 351–360.

Hegarty, P., Lemieux, A. F., & McQueen, G. (2010). Graphing the order of the sexes: Constructing, recalling, interpreting, and putting the self in gender difference graphs. *Journal of Personality and Social Psychology, 98*(3), 375–391.

Hernandez, M. D., Wang, Y., Sheng, H., Kalliny, M., & Minor, M. (2017). Escaping the corner of death? An eye-tracking study of reading direction influence on attention and memory. *Journal of Consumer Marketing, 34*(1), 1–10.

Hurlstone, M. J., Hitch, G. J., & Baddeley, A. D. (2014). Memory for serial order across domains: An overview of the literature and directions for future research. *Psychological Bulletin, 140*(2), 339.

Jones, D., Farrand, P., Stuart, G., & Morris, N. (1995). Functional equivalence of verbal and spatial information in serial short-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(4), 1008.

Maass, A., Pagani, D., & Berta, E. (2007). How beautiful is the goal and how violent is the fistfight? Spatial bias in the interpretation of human behavior. *Social Cognition, 25,* 833–852.

Maass, A., Suitner, C., & Deconchy, J.-P. (2014). Living in an asymmetrical world. London, UK: Routledge.

Maass, A., Suitner, C., Favaretto, X., & Cignacchi, M. (2009). Groups in space: Stereotypes and the spatial agency bias. *Journal of Experimental Social Psychology, 45,* 496–504.

Morrison, A. B., Conway, A. R., & Chein, J. M. (2014). Primacy and recency effects as indices of the focus of attention. *Frontiers in Human Neuroscience, 8,* 6. https://doi.org/10.3389/fnhum.2014.00006

Murdoch, I. (1962). The idea of perfection. In E. Millgram (Ed.), *Varieties of practical reasoning*. Cambridge: Harvard University Press.

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (2010). Is the future the right time? *Experimental Psychology, 57*(4), 308–314.

Pérez González, C. (2012). Lateral organisation in nineteenth-century studio photographs is influenced by the direction of writing: A comparison of Iranian and Spanish photographs. *Laterality, 17*(5), 515–532.

Postma, A., Kessels, R. P., & van Asselen, M. (2008). How the brain remembers and forgets where things are: The neurocognition of object–location memory. *Neuroscience & Biobehavioral Reviews, 32*(8), 1339–1345.

Postman, L., & Phillips, L. W. (1965). Short-term temporal changes in free recall. *Quarterly Journal of Experimental Psychology, 17*(2), 132–138.

Roser, M. & Ortiz-Ospina, E. (2017). *Global Extreme Poverty. Our World in Data*. https://ourworldindata.org/extreme-poverty/. Accessed 21 March 2017.

Shaki, S., Fischer, M. H., & Petrusic, W. M. (2009). Reading habits for both words and numbers contribute to the SNARC effect. *Psychonomic Bulletin & Review, 16*(2), 328–331.

Smyth, M. M., Hay, D. C., Hitch, G. J., & Horton, N. J. (2005). Serial position memory in the visual—spatial domain: Reconstructing sequences of unfamiliar faces. *The Quarterly Journal of Experimental Psychology Section A, 58*(5), 909–930.

Storm, B. C., & Bjork, R. A. (2016). Do learners predict a shift from recency to primacy with delay?. *Memory & Cognition, 44*(8), 1204–1214.

Suitner, C., & Maass, A. (2007). Positioning bias in portraits and self-portraits: Do female artists make different choices?. *Empirical Studies of the Arts, 25*(1), 71–95.

Suitner, C., & Maass, A. (2016). Spatial agency bias: Representing people in space. *Advances in Experimental Social Psychology, 53,* 245–301.

Talmi, D., Grady, C. L., Goshen-Gottstein, Y., & Moscovitch, M. (2005). Neuroimaging the serial position curve: A test of single-store versus dual-store models. *Psychological Science, 16*(9), 716–723.

Tversky, B., Sol, K., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology, 23,* 515–557.

Von Hecker, U., Klauer, K. C., Wolf, L., & Fazilat-Pour, M. (2016). Spatial processes in linear ordering. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 42*(7), 1003–1033.

Zebian, S. (2005). Linkages between number concepts, spatial thinking, and directionality of writing: The SNARC effect and the reverse SNARC effect in English and Arabic monoliterates, biliterates, and illiterate Arabic speakers. *Journal of Cognition and Culture, 5*(1), 165–190.