Writing Direction Influences Spatial Cognition

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Abstract

The world's languages make use of different writing system orientations, running from left to right, from right to left, or from top to bottom. Interacting with writing systems is an important component of how literate humans gain and convey information, and as such the spatial routines we engage in while reading and writing may well have an impact on the spatial organization of other cognitive functions, like memory, visual attention, expectations about the orientations of processes, and so on. Three experiments tested for effects of writing system orientation on spatial cognition, using literate speakers of English, Mainland Chinese, and Taiwanese. The first experiment addressed memory for information in different parts of the visual field; the second, the differences in visual attention; and the third, the arrangement of sequential events in space. The results suggest that the orientation of a writing system is engrained in speakers' perceptual and motor routines to the point that it surfaces when they perform these other spatial tasks. More generally, the findings reported here support the idea that idiosyncratic characteristics of particular languages can influence general cognition.

Keywords: writing systems, relativity, attention, memory, sentence production, vision

Introduction

We live in a world replete with information, and for many literate people, reading and writing is one of the main channels by which it is accessed and conveyed. Writing systems vary across languages, in particular through the direction in which the text is written. While English runs from left to right, Japanese goes from top to bottom, and Arabic unrolls from right to left. Knowing how to read and write a particular language thus entails mastery of perceptual and motor routines whose spatial characteristics are determined by the conventional orientation of the writing system. (‘Orientation’ and ‘direction’ are used interchangeably in this paper to denote the systematic spatial organization of a written language.) To write in English, one starts on the left and moves rightward, while performing the same task in Arabic entails the reverse action. Similarly, reading in the two languages requires readers to begin collecting visual information in different parts of the visual field.

But does the conventional orientation of written systems affect how people interact with and think about space beyond language? For example, do different writing systems influence where in the visual field we tend to focus first for non-linguistic information? Do they influence how we package information about the world? Do differences in writing system orientation influence our spatial representations of sequences of events?

Some evidence suggests that writing system orientation may influence other aspects of cognition. For example, in speakers of some European languages, the mental representation of numerical magnitude is related to the left-right axis. Large numbers preferentially elicit rightwards responses, and small numbers leftward responses (the SNARC effect - Dehaene, et al. 1993). But when French speakers (French is written from left to right) are compared with Iranian speakers (who write from right to left), only French speakers but not Iranian speakers display the SNARC effect (Dehaene, et al. 1993). This suggests a significant relation between the mental number line and writing direction. Similar effects have been found for non-numerical ordinal information, which appears to also be spatially coded (Gevers et al. 2003).

Other evidence for relativistic effects of writing system direction is found in a study by Maas and Russo (2003), showing that in relating language about two-participant events to pictures, Italians (whose writing system runs from left to right) tend to place the agent on the left of the patient, while Arabic speaking participants (whose system goes from right to left) place the agent on the right of the patient.

The hypothesis that writings system direction can influence more general aspects of cognition is called into question by work by Tversky et al. (1991), who examined the relationship between the direction of different writing systems and people’s mental representation of temporal, spatial, quantitative and preference relations in English, Hebrew and Arabic speakers. Their subjects were asked to perform a sticker-placing task under various conditions and their responses were deemed to reflect spatial representations of time, quantity, and preference. The results showed a significant influence of writing system direction on spatial representation of temporal concepts, but not on the quantity or preference.

An even stronger argument against possible relativism caused by different orientations of writing systems is put forward by Chatterjee et al. (1999), who claim that normal right-handed subjects tend to process information from their left to their right hand side due not to their writing system but to the differential properties of right- and left-hemisphere possessing. They argue that the left cerebral hemisphere, where language is predominantly processed by right-handers, selectively directs attention with a left to right vector. So, normal right-handed subjects tend to pay attention to the left side of their visual field, which may influence their expectations about where events start (Chatterjee 2001). They further argue that this may lead to a similar preference for left to right actions, as well.

The question thus remains, what nonlinguistic cognitive processes, if any, can writing system orientation systematically influence? As shown by Griffin (2004), "eye movements are tied to our organization of information" (9). Patterns of interaction with writing may seep out beyond the borders of language. In order to test this hypothesis, we conducted three different experiments on speakers of Taiwanese, Mainland Chinese, and English, testing how subjects with different writing systems perform several spatially orientated tasks. The tasks tested whether learning to use a writing system creates routines of interaction with space, where the subjects tend to collect information or perform actions along the same orientation.

The English writing system, written from left to right, contrasts with the Taiwanese writing system, which can be written in several directions: while most current writing runs top-to-bottom starting on the right, small amounts of current literature are beginning to adopt the English-like left-to-right style (shown in the small, grey box in Figure 1). It could be that differences in the direction of these different writing systems will affect aspect of general cognition like visual attention, and arranging of sequential information. In order to ensure that differences between Taiwanese and English speakers do not result from cultural differences other than writing system, we also include Mainland Chinese speakers (referred to as ‘Chinese’ at points in this paper). The Mainland Chinese writing system has been oriented from left-to-right horizontally, like English, for the past 50 years despite a long history of top-to-bottom writing. As a result, Mainland Chinese speakers represent a left-to-right writing system, in a culture that is much more similar in most ways to Taiwanese culture than is American culture.

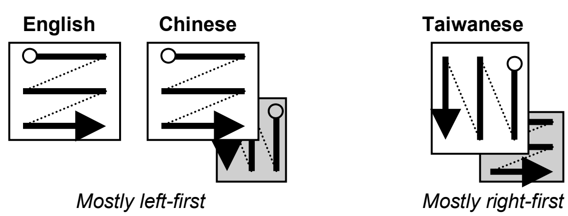

Figure 1: Writing system orientations

In all three experiments described below, all stimuli used were non-linguistic. There were two reasons for this. First, as argued by Tversky and et al. (1991) "many pictorial communiqués are produced similarly by and can be comprehended by speakers of different languages with little or no training" (516). So, pictorial stimuli can minimize any unnecessary bias provoked by linguistic codes (like numbers or words) on different language speakers. Second, our main interest is in the relationship between the direction of different writing systems (language) and general cognition, like how they represent sequences, attend to the visual field, and so on.

Experiment 1: Image Recall

The first experiment used an image recall task. Subjects saw an array of pictures on a screen and were asked to remember as many as they could. This task aimed to test how memory (mediated by visual attention) may be influenced by writing orientation.

As suggested above, eye movements are closely related to how we organize and perceive information (Griffin 2004). The way we gaze at locations is associated with how we process information. If we are used to collecting information from left to right, we may tend to look at things on the left side of our visual field first. This would suggest that English and Chinese speakers, accustomed as they are to the left-to-right writing system, should tend to process non-linguistic information from left to right, while Taiwanese speakers should start on the right. If attending first to a particular part of the visual field makes subjects more likely to recall objects located there, this would imply that Taiwanese speakers will be most likely to recall pictures in the upper, right-hand quadrant of the visual field, while English and Chinese speakers will recall more pictures in the upper, left-hand quadrant than their Taiwanese-speaking counterparts.

Method

Subjects Ten right-handed English speakers (9 Americans and 1 British), aged between 20-50 years (mean = 31.5, s.d. = 8.73), ten right-handed Chinese speakers, aged between 23-45 years (mean = 31.3, s.d. = 7.65), and ten right-handed Taiwanese speakers aged between 20-49 years (mean = 28.1, s.d. = 6.57), were tested individually. All English speakers were monolingual, except three who spoke some Spanish. All Taiwanese and Chinese speakers were native speakers of those languages and were L2 English speakers. All were born in Taiwan or Mainland China and received education there before leaving for the States between 0.2 years and 6 years before being tested (mean=2.8 years). All additionally stated that they still read Chinese occasionally even though they now reside in the United States.

All subjects in all three groups were either doing or had already finished their Bachelors, Masters or PhD degree, thus having reached an average or greater level of literacy. In tables and figures, we identify English speakers as E, Mainland Chinese as C and Taiwanese speakers as T.

Instructions Subjects were told that they would see multiple images on a single screen for three seconds. They were responsible for remembering as many of these items as possible, and would be asked to list them right afterwards. All instructions were provided orally in the first language of the subjects (i.e. Mandarin or English), and no written instructions were given at any point, in order to avoid the possibility that subjects might be primed by having recently read text in their native language.

Apparatus A portable laptop computer was used to run the experiment, which involved the presentation of an image in the Microsoft PowerPoint program. The images in the experiment were all selected from the Canvas program.

Procedure and materials Before a run, the experimenter made sure that 1) the subject could look at the computer screen comfortably and also that there was no unbalanced light reflection from the screen, and 2) the subject sat directly in front of the computer screen without leaning to either side. Then subjects were told the name of the experiment and the instructions, and the experiment began.

First, subjects saw a screen with 42 black-and white images (7 items on the vertical axis and 6 items on the horizontal axis) arranged in landscape format for 3 seconds. All these images ranged from 0.17 to 0.53 inches wide and from 0.29 to 0.49 inches high, and the centers were separated from each other by the same distance. Images were drawn from the graphics resources accompanying the Canvas program, and depicted common objects that were to the extent possible not culturally biased, such as fruits, household objects and appliances, and animals. After 3 seconds, the screen went blank and remained blank until the end of the task. After the screen went blank, subjects were asked to name all the images they could remember.

Results

Since no subjects recalled any items in the bottom row, this row is not included in the analysis. In order to analyze the relationship between native language and location of recalled items, the screen is divided into four quadrants (Qs), as seen in Figure 2.

X X X X Q1 X X X X	X X X X Q2 X X X X
X X X X Q3 X X X X	X X X X Q4 X X X X

Figure 2: The division of items into four quadrants

Thus, each of the four quadrants contains 9 items. The mean number of response per quadrant for the three native languages is shown in Figure 3.

E=3.0 C=2.8 T=1.5	E=0.9 C=1.6 T=3.0
E=1.4 C=0.8 T=0.5	E=0.02 C=0.4 T=1.2

Figure 3: Mean frequency of recall in Q1-Q4

Differences in recall among the groups for each quadrant were tested by a separate one-way ANOVA for each quadrant. We used this method rather than placing all quadrants in a single factorial analysis with quadrant as an independent variable because quadrant was strictly speaking not an independent variable, but a category of response. For quadrant 1, we see a marginally significant effect of native language on number of responses, $F(2,27) = 2.884$, $p=0.073$. Fisher's Post hoc tests show that there is a significant difference between English and Taiwanese speakers, $p<0.05$ and a marginally significant one between Chinese and Taiwanese speakers, $p=0.066$, but no difference between English and Chinese speakers. For quadrant 2, significant effect appears of native language on response number, $F(2,27)=4.587$, $p<0.05$. Fisher's post hoc test shows that the effect results from a significant difference between English and Taiwanese speakers, $p<0.01$ and a nearly significant one between Chinese and Taiwanese speakers, $p=0.058$. For quadrant 3, the result shows no significant effect, $F(2,27)=1.473$, $p=0.247$. For quadrant 4, the ANOVA shows a marginally significant effect of native language, $F(2,27)=2.953, p=0.069$, where post hoc tests show that the effect is significant between English and Taiwanese speakers, $p<0.05$ and close to significant between Chinese and Taiwanese speakers, $p=0.077$, but not significant between Chinese and English speakers.

Analysis

English and Chinese speakers were much more likely to remember an image that appeared in the top, left-hand side of the screen (Q1) than were Taiwanese speakers, and Taiwanese speakers were much more likely to remember an image in the upper right-hand side of the screen (Q2) than were Chinese and English speakers, respectively.

These results conform to the hypothesis offered above - that due to the orientations of their writing systems, English and Chinese speakers tend to attend to the upper, left-hand part of the visual field, while the upper, righthand part of the visual field get more attention from Taiwanese speakers.

They also tend to indicate that native speakers of Taiwanese recall more items in quadrant 4 than did English or Chinese speakers, though these effects only approached significance. This may be due to the variation in the Taiwanese writing system, which, as seen in Figure 1, can be written from top-to-bottom, starting on the right. If some Taiwanese speakers are using this gaze pattern, Q2 followed by Q4, then we would expect greater number of recalled objects in Q4 by Taiwanese speakers than by others, the effect observed to approach significance.

A finding of note is that while English speakers differed significantly from Taiwanese speakers in their behavior in the two upper quadrants, differences between Chinese and Taiwanese speakers, though showing the same trend, only approached significance. The heritage Chinese writing system, running from top to bottom, may still have lingering effects on modern-day Mainland Chinese speakers, which could explain why they attend more to the upper, right-hand quadrant, where this writing system begins.

Since this experiment involves a recall task, it is important to consider how memory effects might influence its results. In particular, what the relation was between the manner in which subjects scanned the scene, encoding objects, and the set of objects they recalled. Two effects are of interest, *primacy* and *recency* effects (Altmann, 2000): words presented at the beginning and the end of a list of items are recalled better than words presented in the middle. It could be that the tendency for subjects to recall objects in the location where their primary writing system starts is due to a recency effect.

But there is reason to think this might not be the case. Due to the speed of the task (subjects only had three seconds to look at the screen) subjects, who remembered on average 5.7 items, would have had no more than 500ms to fixate on any single item thatthey recalled – suggesting that they recalled the majority of the items they looked at closely. Because of the small number of items they encoded, there was probably little time for loss of intermediate items.

This results described here demonstrate that differences in the direction of writing systems can have an impact on the spatial characteristics of visual attention. But since this task does not distinguish effects due to memory from effects due to attention, we conducted a second experiment focusing exclusively on visual attention.

Experiment 2: Sentence Composing Task

Memory for images, thus seems to differ significantly, depending on writing system orientation. But how much of this is due to memory and how much to visual attention? The second experiment tested visual attention through a different methodology, asking subjects to compose simple sentences based on two images, appearing on the right and left hand side of a paper respectively. The purpose of this task was to observe whether the side that subjects would tend to focus on first (as measured by their tendency to start the sentence with the image on that side) was again influenced by writing direction. English and Chinese speakers were hypothesized to be more likely to take the image on the left as the subject of the sentence, as their writing systems start there, while the Taiwanese speakers might tend to take the image on the right as the subject.

Method

Materials Subjects were presented with 10 pairs of black-and-white images. These included 5 pairs of animate objects and 5 pairs of inanimate objects. Each picture was non-directional - the picture was not oriented to either side, but was shown head-on. For example, a picture of a horse faced the reader without either being depicted as moving, looking, or leaning to either side. Each pair of pictures depicted entities with equivalent animacy[1], printed on the left and right sides of a landscape format sheet of paper. All pictures were taken from the ArtClip website and modified by the Microsoft Photo Edit program. The 10 sets of pictures were:

1) man / woman	6) cactus / flower
2) jellyfish / starfish	7) chair / table
3) monster / alien	8) house / castle
4) horse / zebra	9) tape / scissors
5) crab / lobster	10) car / motorcycle

Instructions The subjects were asked to compose a simple sentence (in their first language) based on each set of pictures as quickly as possible. There were four conditions they had to follow: 1) They had to mention the two objects shown in the picture in their sentence. 2) They could not use the conjunction 'and' to connect the two objects. 3) They were encouraged to use verbs to connect the objects. 4) They had to use the first object they saw as the subject of the sentence. Again, no written instructions were provided.

Procedure Subjects, who were the same 30 subjects used in Experiment 1, heard two sample sentences before the experiment began: 1) The long-eared dog is jealous of the short-eared dog. (sentence starting from R→L) [2]. 2) The baby girl makes the baby boy cry. (sentence starting from L→ R). During the experiment, each set of pictures was presented separately, directly in front of the subjects. All instructions were given in the first language of the subject.

Results

The results showed that, as predicted, English and Chinese speakers used the image on their left as the subject of the sentence more frequently than the object on their right hand side, and vice versa for Taiwanese speakers. Figure 4 provides the mean number of sentences starting with the object on the left and right by English, Chinese and Taiwanese speakers respectively.

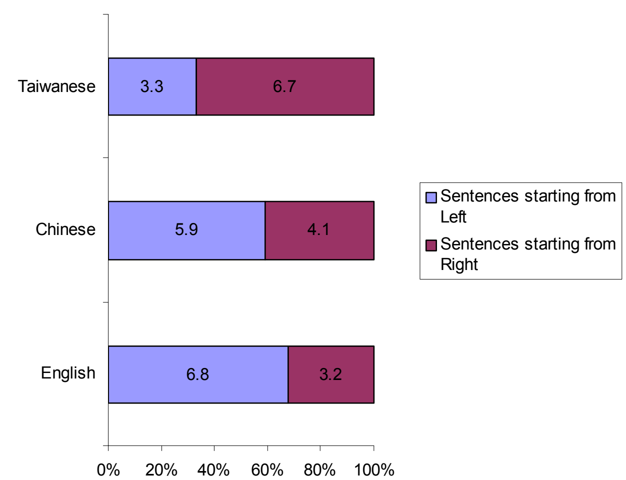

Figure 4: Sentences starting from the left and right

Native language significantly effects sentence orientation, as shown by a one-way ANOVA, $F(2,27)=7.275$, $p<0.01$. Fisher's post hoc test shows a significant difference between English and Taiwanese speakers, $p<0.01$ and between Chinese and Taiwanese speakers, $p<0.05$, but none between Chinese and English speakers, $p=0.353$.

Analysis

These results show that how speakers' native languages are written has an influence on how they compose sentences – specifically whether they begin their sentences with an object appearing on the left or the right. One interpretation of this result is that this is due to a sort of visual iconicity, where subjects relate the images they see to their orthographic representations, and then in generating sentences read off these written words in their minds eye. Another interpretation is that the effect is directly due to how their visual attention passes over the presented images.

[1] The two objects had the same animacy since sentential subjects tend to have higher animacy than sentential objects (Forrest, 1993).

[2] R-right/ L-left are from the perspective of the subjects.

English and Chinese speakers might be more likely to start looking at an image from the left, and thus begin a sentence with the entity depicted there, while Taiwanese speakers begin on the right with the same effect.

Importantly, both explanations depend on differences in the order in which attention is placed on the visual field – the main difference being whether it is the actual perceived visual field or the imagined one. Consequently, regardless of which account is correct, the results suggest that where people attend first depends on their writing system. Differences in visual attention may thus indeed explain the tendency in the first experiment for subjects to recall objects appearing in the part of their visual field where their writing system begins. It remains to be seen, however, whether writing system orientation affects higher cognitive capacities as well. This is the topic of the third experiment.

Experiment 3: Arrangement Task

If low-level cognitive processes like visual attention can be influenced by writing system orientation, higher ones might be as well. This third experiment was an arrangement task, in which subjects were asked to spatially arrange pictures depicting three stages of development of a natural entity, like a plant or a human, from the earliest to the latest stage. The aim was to examine whether speakers of the different language arrange sequences in different directions. We focus in this experiment on temporal sequences because they are known to be structured at least partly in terms of space, and differently across languages (Boroditsky 2001). Hypothetically, conventional writing orientation may affect the orientation of sequential information. Thus, Taiwanese speakers may arrange pictures from right to left or top to bottom while English and Chinese speakers could tend to arrange them from left to right.

Method

Materials The materials were composed of 5 sets of black-and-white images. Each set contained 3 pictures depicting a living thing’s growth process. The 5 sets of pictures were:

1) Seed / sapling / big tree
2) Egg/ little chicken/ big chicken
3) Larva / pupa / butterfly
4) Tadpole / young frog/ adult frog
5) Baby / girl / woman

Each picture was printed on a round piece of white paper with a 3-inch diameter. Another, bigger round piece of white cardboard with a 9.1-inch diameter was prepared as the tray for subjects to arrange the small paper circles on.

Subjects. Subjects were the same 30 participants in the previous two studies, in addition to 23 more Chinese and 28 Taiwanese speakers, who were included because of the larger number of cells, seen in Figure 5.

Instructions Subjects arranged each set of three pictures in sequence from the earliest to the latest stage, on the cardboard, and were limited to only 6-8 seconds. Again, no written materials of any sort were provided

Procedure After receiving instructions, subjects had the larger cardboard circle placed in front of them. They were handed the three pictures in a stack (randomized for each set of pictures, and for each subject), face-down. Subjects flipped them over at the same time and started arranging them in a sequential order. Each set of pictures was given separately and was to be analyzed individually. Again, all instructions were given in the subject's native language.

Results

Most arrangements were clear and easy to score and there were no missing data. There were five patterns: left to right, right to left, top to bottom, bottom to top and clockwise starting from the top. In this paper, we will code them as LR, RL, TB, BT and CW respectively (Figure 5). All these directions are defined from the perspective of the subjects.

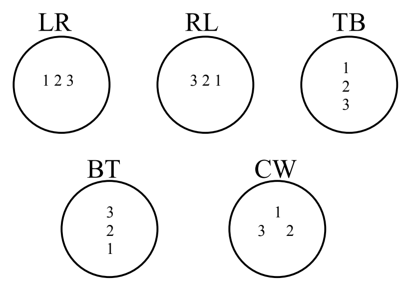

Figure 5: The five observed arrangement patterns

All but three subjects used exactly the same orientation for each of the sets of pictures (s)he ordered. In the remaining cases, the orientation a subject used for the majority of the responses was coded as his/her response pattern. English speakers only used the LR arrangement pattern. Chinese speakers also displayed a strong tendency for LR, though a few also used a TB orientation. The Taiwanese speakers displayed all five patterns, with the most common being the LR and TB orientations. By contrast with the English and Chinese subjects, who never placed the images in a RL orientation, the Taiwanese speakers did so about 20% of the time (Figure 5).

Direction	English	Chinese	Taiwanese	Total
LR	10	26	13	49
RL	0	0	7	7
TB	0	5	13	18
BT	0	1	2	3
CW	0	1	3	4
Total	10	33	38	81

Figure 5: Direction Frequencies by Language

The expected differences are for English and Chinese speakers to have proportionally more responses in the LR pattern than Taiwanese speakers, who are anticipated to have relatively more responses in the RL and TB patterns. Pairwise chi-square tests comparing these three critical conditions reveal a significant relationship between native language and the direction of arrangement of sequences for both the comparison of English and Taiwanese, χ^2=11.33, p<0.01 and Chinese and Taiwanese, χ^2=14.84, p<0.001. As predicted, English and Chinese speakers have different preferences for arranging sequential information from Taiwanese speakers.

Analysis

Chinese speakers, as expected, displayed a dominant LR pattern, consistent with their writing and reading direction. The overall result supports a relationship between writing system orientation and spatial representations of sequences.

The results from the Taiwanese speakers ranged broadly. Responses from the post-test interview may help us understand the broad range of responses the experiment elicited. We asked each subject why they arranged the pictures in the particular pattern. For LR, RL and TB patterns, the answers were predictable. They reported arranging these pictures mainly based on their reading and writing habits. As Taiwanese can be written in all three directions, heterogeneous results are not surprising.

In addition, the TB pattern may result from how time is understood in Chinese and Taiwanese culture. As shown by Boroditsky (2001), in Chinese culture, the past is described and thought about as up, while the future is described and thought about as down. This cultural concept may help to explain the result why a significant portion of Taiwanese and Chinese speakers placed the earliest picture at the top and the latest at the bottom, but no English speakers did so.

General Discussion

In line with the original hypothesis, the studies described above provide clear evidence that the direction of different writing systems does influence nonlinguistic aspects of spatial cognition. The results of the first experiment supported the hypothesis that the direction of writing systems would affect the location where speakers tend to remember information, perhaps influenced by where they tend to place visual attention first. The same effect was seen in the results of the second experiment, which showed that the location subjects look first is consistent with writing system orientation. As a result, speakers with different writing systems displayed different patterns of sentence production. English and Chinese speakers focused on the left first, composing most of the sentences from the left and vice versa for the Taiwanese speakers.

When we look at the results of the third experiment, we find that, more interestingly, the direction of a writing system doesn't affect just attention, but also active production of sequential arrangements. For English speakers, the exceptionless LR pattern demonstrates that spatial representations for sequences take left as the beginning, proceeding towards the right, while this tendency is slightly less strong among Chinese speakers. For Taiwanese speakers, the various patterns, as discussed above, tell us that not just the writing systems (though this may be the most important factor) but also other factors like cultural values and individual variation may affect people's representation of sequences.

The experiments seen above offer counterevidence to Chatterjee's (2001) claim that spatial orientation is controlled by universal properties the hemispheres of the brain. In our experiments, writing system orientation mattered, and if a pre-linguistic left-to-right preference exists, it was obscured by differences in writing systems.

Though there are many other possible factors, writing system appears to be particularly influential on people's use of space. Since Chinese and Taiwanese speakers share many of the same core cultural values, traditions, and history, if it were other cultural factors than writing direction that were causing differences between English and Taiwanese speakers, Chinese speakers should pattern with Taiwanese speakers. Yet, as we have seen, the behavior of the Chinese speakers is closely aligned with that of the English speakers and different in each task from that of the Taiwanese speakers, though not necessarily as different as the English speakers' behavior is.

To conclude, these results support the proposal that writing system orientation influences spatial cognition. We have seen that the location where a writing system starts is where speakers attend first, where they remember objects best, and where they spatially represent the beginnings of temporal sequences. These differences in behavior may in turn influence how we interpret the world and language about it. More broadly, it seems that writing system orientation is another idiosyncratic linguistic characteristic that can have an impact on our cognitive system in general.

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