Spatial biases in understanding descriptions of static scenes: The role of reading and writing direction

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Abstract

Habitual reading and writing direction (RWD) is known to induce spatial biases in meaning construction from descriptions of actions. We extended prior studies to descriptions of static scenes and assessed the flexibility of these spatial habits in bicultural minds. Sentences like "the table is between the lamp and the TV" were auditorily presented, and the task was to draw the described situation. A Spanish group preferred to deploy the objects from left to right, whereas a Moroccan group preferred right to left. A third group of highly Spanish-acculturated Arabs showed a pattern very similar to Spanish, but milder. Despite these differences, the three groups equally preferred those options generating a lower memory load. We conclude that RWD is able to bias the understanding of static descriptions; that these spatial habits are flexible; and that memory management follows universal principles.

Keywords: reading-writing direction; spatial bias; mental model; flexibility; working memory; bilingualism.

Introduction

How is linguistic content represented such that people can reason about it? One theory that has received strong support in the literature is the theory of mental models (Johnson-Laird, 1983). Mental models are working memory representations about situations and events in the world. They are analogical (including spatial information when relevant) and populated by concrete contents, although by these means they can also represent abstract or temporal contents (Boroditsky, 2000; Goodwin & Johson-Laird, 2005).

The most important feature of mental models is that they act as a tool that allows us to represent, manipulate and understand reality in working memory in order to take decisions and deal with the situation. Working memory is characterized by limited capacity and effortful processing. Therefore, people tend to create only one such mental model, integrating in it all the information that is relevant to solving the problem at hand. The greater the amount of information that must be kept simultaneously in working memory, the more difficult the resolution of the problem.

Language serves to provide instructions that guide mental model construction in the interlocutor. From a linguistic statement such as "The table is between the lamp and the TV", the listener can construct a mental model that represents the spatial position between those three objects. Although many different spatial arrangements are consistent with the statement, people tend to create a single model that captures only one spatial configuration. Many results show that, in a task like this, the preferred mental model places the mentioned objects in a linear spatial array, either a horizontal or vertical one (see Evans, Newstead, & Byrne, 1993, for a review).

Jahn, Knauff, and Johnson-Laird (2007) studied how mental models are used to reason about static spatial configurations such as this one. They presented sets of descriptions of scenes, and asked participants to judge whether the set was consistent or not. To use their same example:

A table is between the TV and a chair
The light is on the left of the TV
The table is next to the light

They predicted that people tend to make a single mental model of the first statement, and then try to integrate the next two in it. Depending on the configuration of the initial model, the integration may be easy or difficult (as in the example above). In this example, the descriptions are consistent (that is, there is a single spatial layout where the three statements are true), but because the solution does not coincide with the initial model, participants tend to claim that the premises are inconsistent, or take longer to find the correct answer.

Jahn et al (2007) postulated that the preferred initial model should include the three mentioned objects in left-to-right order. For the example above, a schematic model would be:

TV table chair

This postulate was based on evidence of scanning biases linked to RWD (e.g., Spalek & Hammad, 2005; Nachson,

1981). Their data strongly supported that the preferred initial model of their German participants actually runs from left-to-right.

However, the interpretation of RWD effects in conceptual tasks is still being debated. It is well established that RWD is able to change the direction of the mapping of time to space (Furhman & Boroditsky, 2010; Ouellet, Santiago, Israeli & Gabay, 2010; Tversky, Kugelmass & Winter, 1991) and of numbers to space (Dehaene, Bossini & Giraux, 1993; Gevers & Lammertyn, 2005; Zebian, 2005). In contrast, evidence from language comprehension tasks is more mixed. Chatterjee, Southwood and Basilico (1999) observed a trend to locate agents on the left and patients on the right, as well as to depict push and pull actions as flowing from left to right, and Maass and Russo (2003) showed that this tendency reverses in users of languages with right-to-left RWD (see also Maass, Pagani & Berta, 2007). Nevertheless, there are two published failures at replicating this effect (Barrett, Kim, Crucian, & Heilman, 2002, with right-to-left vertical Korean readers, and Altmann, Saleem, Kendall, Heilman & Rothi, 2006, with Arabic readers). Finally, it is possible that the spatial bias in agent-patient organization is not related to language comprehension processes, as Maass, Suitner, Favaretto and Cignacchi (2009) found a tendency to place agentive social groups to the left of less agentive groups, which reversed in readers of right-to-left RWD.

Moreover, there is a total lack of evidence regarding the relevance of RWD for mental model construction from descriptions of static scenes. The present research was aimed to provide a first exploration of the influence of RWD on mental model construction avoiding any potential confounding with agentivity. In order to do so, we devised a simpler version of Jahn et al's (2007) task. Participants were asked to listen to sentences such as "The table is between the lamp and the TV", and then draw the scene described by the sentence. Both order of drawing the mentioned objects and order of filling the spatial locations in the paper were measured. These measures allow us to study independently working memory management processes and spatial biases in the construction of mental models (see below). In order to assess the effect of RWD, the task was carried out by two groups of participants: native Spanish users who read and write from left to right, and native Arabic users from Morocco who do it from right to left. A final goal was to evaluate the degree of flexibility of these mental habits, so we also included a group of native users of Arabic languages who had been living in Spain for a number of years and were highly acculturated into Spanish culture and language.

Method

Participants. There were three groups of participants. The Spanish group was composed of 21 Spanish Psychology students at the University of Granada (mean age 21 years, 5 males). All of them were native Spaniards, had never lived in an Arabic country for longer than an occasional stay and did not know any Arabic language.

The Moroccan group was made of 18 Moroccan students from the Abdelmalek Esaadi University, Tetouan, Morocco (mean age 22 years, 12 males). Linguistic and family information of three participants was lost due to a computer problem (which also affected information of three participants from the next group). All the remaining participants were born in Morocco and had never lived in a Western country. They all were native speakers of Moroccan Darija (the local Arabic dialect) and nine of them were also native speakers of Standard Arabic (starting before age 4). Fourteen of them were also highly fluent in French, and nine participants in this group also had some knowledge of Spanish (started in high school or university). All of them were highly proficient and habitual readers of Standard Arabic.[1] The Moroccan group did the task in Darija.

The Arabs-in-Spain group was composed of 26 Arab students at the University of Granada (mean age 22 years, 12 males). As mentioned above, information from three participants was lost. For the remaining sample, 18 were originally from Morocco, three from Jordan, one from Iraq and one from Mauritania. Their average number of years living in Spain was 5.8 (range 1-11). All of them were native speakers of at least one Arabic language (Standard Arabic, Moroccan Darija, Mauritanian Hassania, Jordanian Levantine, Iraqi Arabic). All of them were also native or highly fluent speakers of at least one European language (mostly French and/or Spanish). All of them were highly proficient readers of Standard Arabic, and only three of them reported not to read it on a daily basis. All of them were fluent in Spanish and had no problems in understanding the instructions or having a conversation in Spanish with the experimenter. As described in detail below, the Arabs-in-Spain group did the task in Spanish.

It is important to note that all participants in both Arab groups are bilingual (often multilingual), knowing at least one left-to-right RWD language (modally French). The difference between them is not so much a difference of bilingualism, but of immersion in a particular language and writing system, and intensive experience with it.

The Spanish Group received course credit, and the two Arabic groups received a small gift or monetary compensation.

Materials. Five sentences were constructed, all of which consisted of an assertion that referred to a between relation among three different entities.

1 - The table is between the lamp and the TV.
2 - The bike is between the lamppost and the car.
3 - The cup is between the bottle and the dish.
4 - The pencil is between the book and the eraser.
5 - The man is between the house and the tree.

[1] Standard Arabic is the only written Arabic language. Local Arabic languages are only oral (Lewis, 2009).

We selected those objects or entities because they are very common in both cultures, thereby avoiding comprehension problems or potential biases due to different degrees of familiarity. Importantly, all mentioned objects are inanimate entities (with the exception of "the man" in the last sentence), and they are embedded in sentences using a copulative verb. In other words, they all refer to completely static scenes without any agentive structure. Even in the case of the last sentence, the animate entity "the man" is located in the center of the scene carrying out no action, and thus, it is unlikely that its animacy or agentivity may bias the location of the surrounding objects in the mental model in any particular direction.

Procedure. The participants were seated at a desk with a pile of five blank sheets and a pen. They then listened to the first sentence and were asked to draw the scene on a sheet. Once they were done, they put away the first sheet and were ready to listen to and draw the next sentence on a new sheet. The Spanish and Arabs-in-Spain groups were tested at the University of Granada, Spain, and did the task in Spanish. The Moroccan group was tested at the Abdelmalek Esaadi University and did the task in Darija.

Data coding. For each item, we measured the order in which each of the three mentioned objects were drawn (*mentioned object order*, or just *object order*) and the order in which the three positions (left, center, right) were filled (*spatial order*).

Each sentence presents auditorily the three objects in a temporal sequence or order of mention. In the sentence "The table is between the lamp and the TV", table is the first object mentioned, followed by lamp and then TV. Participants can draw the three objects in one out of six possible combinations of object order (see Table 1). For example, combination 213 means that the first object to be drawn is the second object mentioned in the sentence (lamp), followed by the object mentioned first (table) and then by the object mentioned third (TV).

Regarding the order of location filling, or spatial order, there are also six possible combinations (see Table 1). For example, LCR means that the object on the left was drawn first, then the central object, and then the object on the right. Combinations LCR, CLR, and LRC were grouped as pattern from left to right (L-R); and combinations RCL, CRL, and RLC were grouped as pattern from right to left (R-L).

The combination of each object order with one out of two possible spatial orders produce only one possible *drawn model* with the lateral objects (e.g., lamp and TV) in different positions (see Table 1 for details). To carry on with the example sentence "The table is between the lamp and the TV", suppose that a participant shows a 213 (Lamp-Table-TV) object order and a RCL (Right-Center-Left) spatial order. The resulting drawn model has the lamp on the right side and the TV on the left (which we call a right-to-left model). If the same object order is combined with a LCR spatial order, the resulting drawn model will have the lamp on the left side and the TV on the right side (a left-to-right model).

Our first hypothesis is that RWD will exert clear effects on the spatial order in which objects are drawn, and therefore, on the final spatial configuration of the drawn model. Spanish participants will tend to draw left-to-right models, with the lamp on the left and the TV on the right, whereas the Moroccan participants will prefer the opposite model, with the lamp on the right and the TV on the left. We had no specific expectations for the group of Spanish-acculturated Arabs. If the original habits of mental model construction are not flexible and remain unchanged after extended immersion in a language with a different RWD, they will show the same pattern as the Moroccan group. If these habits are flexible, they will tend to behave like Spanish participants.

Table 1: Mentioned object order and spatial order combinations, and the resulting drawn models.

Mentioned Object Order	In our example	Spatial Order	Pattern	Drawn Model
123	Table-Lamp-TV	CLR	L-R	Lamp-Table-TV
		CRL	R-L	TV-Table-Lamp
132	Table-TV-Lamp	CLR	R-L	TV-Table-Lamp
		CRL	L-R	Lamp-Table-TV
213	Lamp-Table-TV	RCL	R-L	TV-Table-Lamp
		LCR	L-R	Lamp-Table-TV
231	Lamp-TV-Table	LRC	L-R	Lamp-Table-TV
		RLC	R-L	TV-Table-Lamp
312	TV-Table-Lamp	RCL	L-R	Lamp-Table-TV
		LCR	R-L	TV-Table-Lamp
321	TV-Lamp-Table	LRC	R-L	TV-Table-Lamp
		RLC	L-R	Lamp-Table-TV

Our second hypothesis follows from the fact that each object order imposes different costs on working memory resources. For example, the pattern 123 means that we draw the objects in the same order as they appear auditorily. This pattern imposes the lowest memory load. The pattern 231 imposes a greater memory load because it draws last the object presented first. Table 1 lists the combinations of object order from the one requiring less cognitive resources (123) to the one requiring most (321). We expected that all the groups would prefer to use object orders that require fewer memory resources. For each one, the left-right spatial order will be preferred by Spanish participants and the right-left spatial order will be preferred by Moroccans.

Results

If any central entity (e.g., the table) was drawn anywhere else than the center, the trial was considered invalid and was not included in the final analysis. We also excluded those items drawn vertically or however differently from the horizontal axis. The number of items rejected by these reasons amounted to 12%.

In the analysis of drawn models, the proportion of valid L-R trials was submitted to a one-way ANOVA, which found significant differences ($F(2,58) = 5.52$, $p = 0.006$) among the groups. Planned comparisons showed that the

Spanish and Moroccan groups were significantly different ($F(1,58) = 10.86$, $p = 0.001$). Consistent with the findings of Jahn et al (2007) with German participants, Spanish participants preferred to represent the mentioned objects from left to right (with the lamp on the left and the TV on the right). In contrast, Moroccan participants showed the opposite trend (see Figure 1).

The Arabs-in-Spain group did not differ from the Spanish group ($F(1,58) = 1.78$, $p = 0.18$), whereas it differed from the Moroccan group ($F(1,58) = 4.87$, $p = 0.03$). Thus, the Spanish-acculturated Arabs behaved more like Spaniards than like Moroccans immersed in their culture.

Regarding spatial order, a one-way ANOVA on the proportion of valid L-R trials showed a significant effect of Group ($F(2, 58) = 5.36$, $p = 0.007$; see Figure 2). Spanish participants tended to fill up before the left than the right space (combinations LCR, CLR, LRC). In contrast, the Moroccan group showed the opposite preference (RCL, CRL, RLC), a significant difference in planned comparisons ($F(1,58) = 9.68$, $p = 0.002$). Again, the comparison between the Spanish and the Arabs-in-Spain groups failed to be significant ($F < 1$), whereas the Arabs-in-Spain differed from the Moroccan group ($F(1,58) = 6.71$, $p = 0.01$).

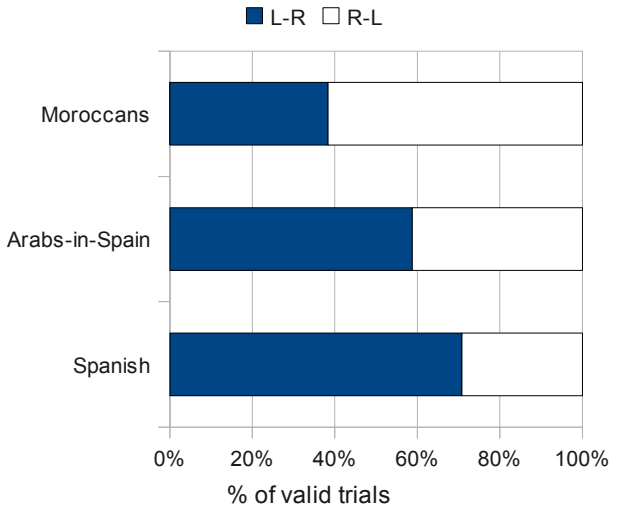

Figure 1: Drawn model preference in each group.

We then turned to analyze the differences in preferred object orders. Here, we expected no cultural differences: in both cultures, participants would prefer the orders that impose a smaller working memory load. Figure 3 shows the frequency of each order combination. All groups preferred the 123 order, followed at a great distance by 132, from where proportions decreased progressively as memory load increases. An ANOVA with object order as within-subject factor and the three groups found a highly significant effect of the former ($F(5,290) = 43.99$, $p < 0.001$), a null effect of group ($F < 1$) and a null interaction between object order and group ($F < 1$).

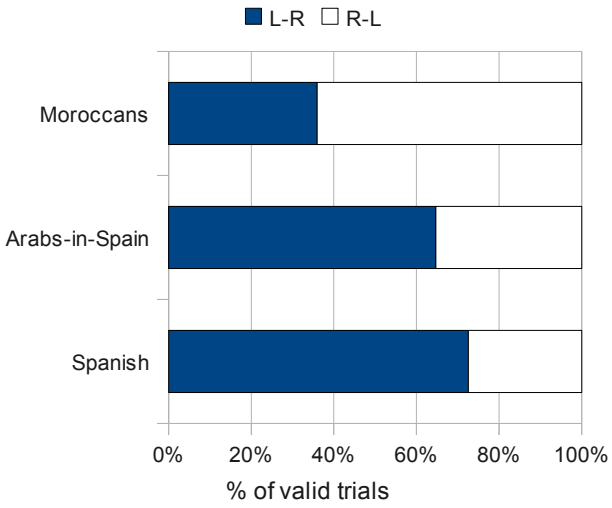

Figure 2: Spatial order preference in each group.

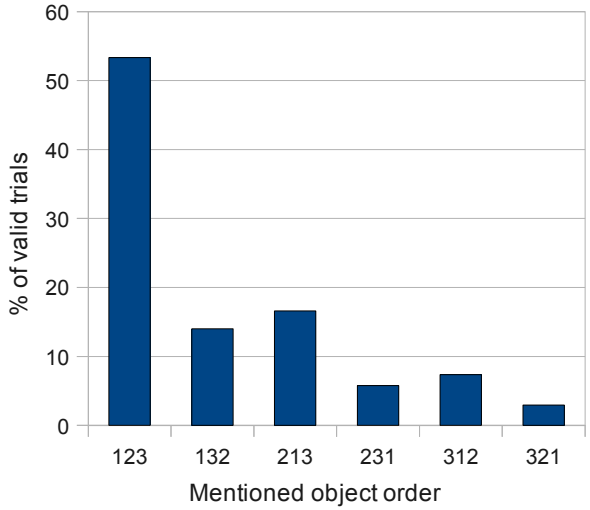

Figure 3: Percentage of trials for each combination of object order.

Conclusion

A first conclusion to be obtained from present data is that readers of Spanish (a language with left-to-right RWD) and Arabic (right-to-left RWD), when tested in their native language and immersed in their own culture, differ in their spatial choices when constructing mental models of static scenes from auditory input: Spanish prefer left-to-right models and Arabic prefer right-to-left models. We suggest that this difference is mediated by their habitual RWD. Effects of habitual RWD can, therefore, be observed also in static scenes, as well as in the dynamic events which have received attention so far in the literature (e.g., Chatterjee et al, 1999; Maass & Russo, 2003).

Prior reports of spatial biases in the comprehension of linguistic descriptions of scenes with an agent-patient structure may reflect wider biases toward locating agents and patients in left or right space (Maass et al, 2009) that do

not necessarily involve the intermediation of mental model construction processes from linguistic input. Because of the use of static scenes, present data do not suffer from this potential confound, and allow us to assert that RWD affects how mental models are created on-line as the referents of heared words are accessed. Thus, the resulting picture is one in which reading and writing habits affect the position where word referents are placed in the mental space. As agents tend to be mentioned earlier than patients in most languages, mental models constructed from auditory input will tend to place them in earlier locations as defined by reading habits. This tendency is then, probably, the cause of the observed overall bias that affects the relative location of more agentive groups with respect to less agentive groups (Maass et al, 2009).

Present results also reveal that cultural differences in mental model construction due to RWD are confined to spatial preferences, but the management of working memory resources follows common, possibly universal principles.

Finally, present results show that Spanish-acculturated Arabs tested in Spanish do not behave like Arabic participants immersed in their culture and tested in their native Arabic dialect. The habits of mental model construction from language are, therefore, flexible.

What the present study cannot discern is the nature of this flexibility. As the two Arabic groups were tested in conditions that differed both in the language used in the experiment (Spanish versus Darija) as well as in the cultural context (Spain versus Morocco), there remains the possibility that any (or both) of these factors is responsible for the observed differences in mental habits. If language is responsible, mental model construction would be highly context-dependent: mental models would be generated in the spatial format linked to the language in use in that moment. If cultural immersion and extended experience is necessary, mental model construction would show a greater inertia, and a relative independence of the particular language used at a given moment and task. Research is currently under course to try to disentangle these possibilities.

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