Research Report

How Writing System and Age Influence Spatial Representations of Actions

A Developmental, Cross-Linguistic Study

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ABSTRACT—*Recently, researchers reported a bias for placing agents predominantly on the left side of pictures. Both hemispheric specialization and cultural preferences have been hypothesized to be the origin of this bias. To evaluate these hypotheses, we conducted a study with participants exposed to different reading and writing systems: Germans, who use a left-to-right system, and Israelis, who use a right-to-left system. In addition, we manipulated the degree of exposure to the writing systems by testing preschoolers and adults. Participants heard agent-first or recipient-first sentences and were asked to draw the content of the sentences or to arrange transparencies of protagonists and objects such that their arrangement depicted the sentences. Although preschool-age children in both countries showed no directional bias, adults manifested a bias that was consistent with the writing system of their language. These results support the cultural hypothesis regarding the origin of spatial-representational biases.*

The human cognitive system organizes the external world into categories such as "persons," "objects," or "actions." Propositional network stores are composed of entities from these categories. Links between these entities represent the nature and strength of their relation (e.g., Anderson, 1983; Dell, 1986; Levelt, Roelofs, & Meyer, 1999). Nonetheless, a number of early studies using various methods revealed that the manner in which adults organize events seems to reflect an additional left-to-right spatial bias. For instance, Christman and Pinger (1997) found that adults prefer pictures and events with a left-to-right directionality and also seem to process events from left to right. These findings of a spatial bias were originally interpreted as reflecting hemispheric biases in the processing of visual stimuli (e.g., Beaumont, 1985; Levy, 1976).

Chatterjee (for an overview, see Chatterjee, 2001) advanced the hypothesis that a left-to-right bias is manifest not only in the processing of visual stimuli, but also in semantic representations of actions such as "pushing" and "feeding." In a thematic-role-assignment task, an aphasic patient described a figure on the left of a picture as the agent (i.e., a person causing an event; Levelt, 1989) regardless of whether this figure was the agent or recipient of an action (Chatterjee, Maher, & Heilman, 1995). Similarly, neurologically healthy control participants displayed a preference to draw agents on the left side of a picture and responded faster in sentence-picture matching tasks when the pictures showed agents to the left of patients (Chatterjee, Southwood, & Basilico, 1999). Chatterjee (2001) suggested on neuropsychological grounds (Heilman & Gonzales-Rothi, 1993; Kinsbourne, 1987) that functional properties of the left hemisphere are responsible for this left-side bias for agents. In other words, he argued that a left-to-right bias is a universal property of brain functioning, manifest in processing of visual stimuli and spatial representation of events (see Barrett, Kim, Crucian, & Heilman, 2002, for empirical tests).

A number of studies support an alternative interpretation of this spatial bias, however. Specifically, the bias might derive from the direction in which a participant's native language is written (Chokron & De Agostini, 2000; Nachson, Argaman, & Luria, 1999; Spalek & Hammad, 2005; Tversky, Kugelmass, & Winter, 1991). Indeed, these studies have found that adults exposed to right-to-left writing systems (e.g., Hebrew or

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Arabic)—as opposed to the left-to-right systems predominant in Western languages—do not manifest a left-to-right spatial bias in their aesthetic judgments or processing of visual or temporal events; in fact, they often show the reverse bias.

Maass and Russo (2003), following up on the research of Chatterjee et al. (1999), investigated cultural influences on the semantic representation of actions among Italian and Arab students. Using tasks similar to those employed by Chatterjee et al., Maass and Russo found a strong cultural effect. Italians (living in their native country) showed a clear left-to-right preference, whereas Arabs showed the reverse pattern. The right-to-left preference was strongest in monolingual Arabs living in their native country, was weaker among Arab students who were studying in Italy but responded in Arabic, and was even weaker among Arabs who were studying in Italy and responded in Italian. The overall preference of Italians to draw an agent on the left (80% on the left vs. 20% on the right) was stronger than the preference of Arabs to draw an agent on the right (60% on the right vs. 40% on the left). Maass and Russo concluded that although there is a strong cultural effect on the spatial representation of events, there seems to be a weaker innate left-to-right bias.

The goal of the present study was to investigate the origin of spatial bias in the representation of events. More specifically, we were interested in testing Maass and Russo's (2003) cultural proposal and Chatterjee's (2001) neuropsychological proposal. To do this, we investigated action representation of German- and Hebrew-speaking adults and preschool-age children. We reasoned that if writing direction influences people's spatial representation of events, as Maass and Russo claimed, then adults who have learned left-to-right writing systems will spatially represent events differently than will adults who have learned right-to-left writing systems. Specifically, German adults should show a tendency to represent events from left to right, whereas Israeli adults should show the reverse tendency. Moreover, young children from cultures with writing systems of different directions should manifest more similar representations than do adults from those cultures, because young children have had less systematic exposure to reading and writing than adults. Finally, if there is an innate left-to-right bias, then children should show a left-to-right bias regardless of the writing system used in their culture. In contrast, Chatterjee's neuropsychological proposal predicts that adults and children exposed to right-to-left and left-to-right writing systems should display similar left-to-right representational biases.

To gain converging evidence from two sources of data, we used two tasks: drawing and arrangement of transparencies. In addition, we used two syntactic structures in the verbal input, varying whether agents or recipients of actions were mentioned first. The purpose of this manipulation was to determine whether participants' placement of the agent would be influenced by the order in which the agent and recipient appeared in the verbal input.

METHOD

Participants

The German preschooler group consisted of 29 children (11 girls) between 3 and 6 years of age (M = 4.8 years ± 0.8 months). Twenty-two were right-handed, 4 were left-handed, and 3 were ambidextrous. These preschoolers could not yet read or write, according to their teacher. The German adult group consisted of 34 literate participants (17 women) between 16 and 65 years of age (M = 34.4 years ± 12.6 months). Six were left-handed. All the German participants lived in the area of Münster, Germany. None of them had any exposure to cultures using right-to-left writing systems. The Israeli preschooler group consisted of 20 children (9 girls) around 5 years of age (M = 5.3 years ± 4.0 months). Two of the children were left-handed. The Israeli preschoolers were in prekindergarten classes in which reading and writing were not taught. There were 20 participants (17 women) in the Israeli adult group (M = 21.7 years ± 9.0 months). One of these was left-handed. All of the Israeli adults, but few of the Israeli children, had exposure to English.

Procedure

Participants performed two tasks: a drawing task and a transparency-arrangement task. For each task, the experimenter read aloud six sentences, each containing three noun phrases (agent, object, and recipient).[1] In three of these sentences, the agent came first (e.g., "The mother gives the boy a ball": "Die Mutter gibt dem Jungen einen Ball" in German and "Ha-ima natna layeled kadur" in Hebrew), and in the other three, the recipient came first (e.g., "The boy gets a ball from his mother": "Der Junge bekommt von der Mutter einen Ball" in German and "Hayeled kibel kadur me-imo" in Hebrew). In all sentences, both the agent and the recipient were animate, to ensure that there was no visual and conceptual imbalance (e.g., a large animate agent on one side and a small inanimate object on the other). We did not use passive sentences because preschool-age children do not have perfect comprehension of passives (Caprez, Sinclair, & Studer, 1971; Maratsos, Fox, Becker, & Chalkley, 1985).

In the drawing task, participants were given paper and pencil to draw a picture of the content of each sentence (they were not told when to start drawing, but generally waited until the sentence was finished). After drawing, the preschoolers were asked which part of their drawing corresponded to each person in the sentence. These questions followed the order in which the characters were mentioned in the sentence. In the transparency-arrangement task, participants were asked to arrange three transparencies depicting the agent, object, and recipient so that their arrangement matched the sentence content. The transparency drawings were made by a graphic designer in a style

[1]We use the semantically motivated terms *agent*, *object*, and *recipient* in keeping with Chatterjee's (2001) terminological convention. Maass and Russo (2003) used syntactic terms such as *subject* and *object* instead.

appropriate for children. Because the transparencies were the same on both sides, it was possible to arrange agents and recipients to face left or right. The transparencies were given to the participants in a box and shuffled to make sure that agents and recipients faced randomly to the left or right, to avoid biasing direction of action in the participants' representations.

The six sentences for each task were taken out of a pool of six pairs of sentences. The two sentences in each pair had the same content but differed in whether the agent or recipient was mentioned first (as in the examples given earlier). In each task, each participant was randomly given three agent-first sentences and three recipient-first sentences, all with different content. Note that sentence content was kept simple (the animate agents and recipients were mother, father, boy, and girl; objects were repeated; the actions were "giving," "feeding," and "giving as a present") to make the tasks manageable for preschoolers.

RESULTS

Five German preschoolers were not able to complete both tasks and were excluded from the analyses. The proportion of agents drawn or placed on the left side (*agent-left placements*) was determined for each participant in each condition. These proportions were inverse-sine-transformed for statistical analyses (Kirk, 1982). Table 1 gives the average proportions and standard deviations of agent-left placements as a function of language, age, task, and order of the agent and recipient.

We present results of a four-way analysis of variance with language (German vs. Hebrew) and age (preschoolers vs. adults) as between-subjects factors and with task (drawings vs. transparencies) and order (agent first vs. recipient first) as within-subjects factors. Overall, there was a significant effect of language, $F(1, 94) = 5.09, p = .026, p_{rep} = .92, \eta_p^2 = .05$; German speakers ($M = .55$) were more likely than Hebrew speakers ($M = .45$) to place agents on the left. However, this effect was mediated by a language-by-age interaction, $F(1, 94) = 4.81$, $p = .031, p_{rep} = .91, \eta_p^2 = .05$. Post hoc comparisons revealed that although there was no difference between German-speaking ($M = .52$) and Hebrew-speaking ($M = .51$) children, $t(42) < 1$, adult Hebrew speakers placed agents on the left side less often than did adult German speakers (Ms = .40 and .58, respectively), $t(52) = -3.12, p = .003, p_{rep} = .97, d = 0.824$. In fact, comparisons against chance (chance = .50) showed that neither group of children preferred one side over the other (both ts < 1). However, Hebrew-speaking adults placed agents on the left side significantly less often than expected by chance, $t(19) = -2.27$, $p = .035, p_{rep} = .90, d = 0.51$, and German-speaking adults placed agents on the left side marginally more often than expected by chance, $t(33) = 1.98, p = .06, p_{rep} = .86, d = 0.34$.

The analysis of variance also revealed a significant effect of order, $F(1, 94) = 15.53, p < .001, p_{rep} = .99, \eta_p^2 = .14$; participants placed agents on the left side more often if the agents were mentioned first than if the recipients were mentioned first. This main effect was moderated by a significant language-by-order interaction, $F(1, 94) = 9.82, p = .002, p_{rep} = .98$, $\eta_p^2 = .09$. No other main effects or interactions were significant. To locate the source of the language-by-order interaction, we compared the arcsine proportion of agent-left placements between languages within each order type. We found that the difference between languages was significant only within agent-first sentences, for which German speakers were more likely than Hebrew speakers to place agents on the left side: agent-first sentences, $t(96) = -4.09, p < .001, p_{rep} = .99, d = 0.842$; recipient-first sentences, $t(96) < 1$.

TABLE 1

Average Proportion of Sentences for Which Participants Placed the Agent on the Left (Displayed as a Function of Age, Language, Task, and Relative Order of the Agent and Recipient in the Sentence)

	Agent-first sentences		Recipient-first sentences		
Participant group	Drawing task	Transparency task	Drawing task	Transparency task	*M*
Preschoolers					
German	.64 (.07)	.60 (.05)	.38 (.06)	.47 (.07)	.52
Hebrew	.48 (.08)	.55 (.06)	.55 (.07)	.45 (.07)	.51
M	.56	.58	.47	.46	
Adults					
German	.76 (.06)	.75 (.05)	.34 (.05)	.46 (.06)	.58
Hebrew	.45 (.08)	.40 (.06)	.35 (.07)	.38 (.07)	.40
M	.61	.58	.35	.42	

Note. Standard errors are given in parentheses.

DISCUSSION

The goal of the present study was to investigate the developmental origin of a spatial bias in action representations. According to a neuropsychological hypothesis, people organize spatial events from left to right because of universal properties of brain architecture and functioning (Chatterjee, 2001). Thus, in our study, finding that both preschoolers and adults exposed to diverse writing systems exhibited the same left-side bias for agents would support the neuropsychological hypothesis. According to a cultural hypothesis, people organize spatial events on the basis of the directionality of the writing system of their native language (Maass & Russo, 2003). Thus, in our study, finding that German adults showed a left-to-right bias in representing actions, whereas Israeli adults showed a right-to-left bias, would support the cultural hypothesis.

Our results were consistent with the cultural hypothesis. Across tasks, German-speaking adults showed a preference for placing agents on the left side, whereas Hebrew-speaking adults showed a preference for placing agents on the right side. These findings extend previous results on the effect of writing direction

on adults' representation of visual stimuli (Chokron & De Agostini, 2000; Spalek & Hammad, 2005) to the spatial representation of semantic relations.

The difference between languages was accentuated for agent-first sentences. One possible explanation for this finding is that although the cues of agency and temporality matched in agent-first sentences (i.e., the first character was the agent), these two cues conflicted in recipient-first sentences. Thus, in agent-first sentences, the presence of two consistent cues may have reinforced the representational bias of participants' writing system, leading to a stronger effect size.

Most important, our findings reveal that this spatial bias is not present prior to children's intensive exposure to reading and writing, but in fact might be derived from this exposure. Specifically, German- and Hebrew-speaking preschoolers did not differ in their overall preferences regarding spatial placement of agents, and in fact, both groups made such placements randomly, without any statistically distinguishable bias. This finding counters Maass and Russo's (2003) hypothesis that there might be an innate bias for representing events from left to right and that right-to-left writing systems superimpose an opposite bias. Our findings instead show that children are born with a flexible capacity for spatially representing semantic relations and that a bias might derive entirely from exposure to a writing system.

This conclusion resonates with current findings from the literature on the relation between language and spatial concepts. In particular, Hespos and Spelke (2004) found that young infants seem sensitive to spatial relations that are not even represented in their language. And yet, by their second birthday—that is, after considerable exposure to their language's particular categorization of spatial relations—children already manifest language-specific spatial representations (Bowerman, 1996), a tendency that is accentuated in adulthood (Levinson, 2003).

We speculate that the effect of writing system on spatial representations shows a similar developmental trajectory. Children are first exposed to written texts primarily via adult mediation (e.g., listening to someone reading). This might be enough for children to start developing a spatial bias toward visual stimuli (e.g., children who are read to from Hebrew books will see that the first page is on the right side and the opening is on the left). In a study consistent with this hypothesis, Chokron and De Agostini (1995) found a difference between French- and Hebrew-speaking preschoolers in a line-bisection task (i.e., a strictly visual task). Exposure to writing via adult mediation, however, might not be enough for children to develop a conceptually grounded spatial bias. As children get firsthand experience in reading and writing text, their conceptual representations of events become influenced by the directionality of their writing system. In fact, as Tversky et al. (1991) reported, by the time children are of school age, even their spatial ordering of temporal relations seems to be affected by their writing system.

In conclusion, the present cross-linguistic developmental study illustrates how cultural habits influence children's and adults' spatial representations of events. As children are exposed to their culture's writing system, they begin to develop spatial biases for the representation of visual and eventually semantic relations.

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