Space, agency and word order: Evidence from Greek

Spyridoula Cheimariou (spyridoula-cheimariou@uiowa.edu)
Department of Communication Sciences and Disorders, University of Iowa
250 Hawkins Drive, Iowa City, IA 52242 USA

Sonia Loui (sonialoui@gmail.com)
Department of Philosophy & History of Science (MITHE), Ano Ilissia University Campus
GR-15771 Zografos, Greece

Abstract

We examined the role of spatial representations and word order on thematic role assignment in Greek. Previous studies suggest that spatial representations influence thematic role assignment; agent is typically depicted on the left, and patient on the right. Here, we address this issue using a language with flexible word order which allows us to manipulate sentence structure (SVO–OVS) orthogonally to thematic role. Greek speakers heard SVO/OVS sentences while viewing depictions of actions involving two characters and they judged whether sentence and picture matched in meaning. The agent's position in the picture was directly manipulated. The results support the effect of left bias on language processing. However, this bias may be better understood when its interaction with other sources of information and language-specific constraints are taken into account. Theories of prediction may help us illuminate how spatial biases and linguistic factors interactively affect the way we process our world.

Keywords: spatial representation, language, thematic role assignment, word order, sentence comprehension, prediction, Greek.

Introduction

The combinatory study of language and space aims to shed light on how an analog, geometric and continuous representation is encoded into a propositional algebraic and discrete representation (Jackendoff, 1992; Geminiani, Bisiach, Berti & Rusconi, 1995; Hayward & Tarr, 1995; Jackendoff, 1996; Chatterjee, Southwood & Basilico, 1999; Levinson, 2003; Papafragou, Hulbert & Trueswell, 2008, among others). Recent research has inaugurated a discussion on how language structures are constrained by spatial biases (Chatterjee, Maher, Gonzales-Rothi, & Heilman, 1995; Chatterjee, Southwood, & Basilico, 1999). Researchers (Chatterjee et., al, 1995; Chatterjee, Southwood, & Basilico, 1999; Chatterjee, 2001; 2008) have entertained the claim that events are conceptualized spatially and prelinguistically proceeding from left towards the right. They assume that language development exploits systems meant for left-to-right spatial attention in the left hemisphere. Therefore, the left-to-right directional bias indicates primitive spatial representations and reflects a prelinguistic neural encoding of events and actions.

Evidence for this claim comes from case studies in agrammatic speech (Caplan & Futter, 1986; Caramazza & Miceli, 1991). In these studies, the person with agrammatism systematically assigned agency to the first noun heard or to the one located to the left of the verb. Chatterjee and colleagues (Chatterjee, et al. 1995; Chatterjee, Southwood, & Basilico, 1999), based on the Jacksonian notion that primitive cognitive functions are overlaid with more complex functions, hypothesized that people with agrammatic aphasia tend to follow a temporal or spatial strategy based on those primitive spatial representations in order to interpret a sentence once their more complex linguistic abilities fail. To test for their assumption they conducted studies in typical population (Chatterjee et al., 1995; Chatterjee, Southwood, & Basilico, 1999; Barrett & Craver-Lemley, 2008). In these studies, participants were asked to depict sentences describing an action with two persons involved or to match sentences to pictures. Participants tended to draw the agent of an action closer to the left side of the picture. For example, in the sentence «*The girl chased the boy*», it was more probable for the participants to depict the girl on the left side of the picture and the boy on the right side. Also, participants responded faster when the agent was located on the left side in sentence-picture matching tasks.

According to an alternative explanation, the left-to-right directional bias is culturally determined by the directionality of the reading/writing system (Maass & Russo, 2003; Chan & Bergen, 2005; Dobel, Diesendruck, & Bolte, 2007). Specifically, Maass and Russo (2003) investigated spatial biases in thematic role assignment in directionally opposite writing system, such as Italian (left-to-right) and Arabic (right-to-left). They found that Italian speakers tended to assign the agent on the left, while Arabic speakers had the reverse tendency. Furthermore, the more years Arabic speakers had spent abroad exposed to the opposite writing system, the more mitigated their right-to-left bias was.

Furthermore, Dobel, Diesendruck, and Bolte (2007) strengthened this argument by showing that the left or right bias in depicting agency is based not only on reading and writing practices, but also on the degree of exposure on those practices. Specifically, they tested spatial biases in German- and Hebrew-speaking adults and preschool children. They found that the writing system influenced thematic role assignment in adults, that is, German-speaking adults had a left-to-right spatial bias, while Hebrew-speaking adults had the opposite bias. However, this was not observed for preschool children who had no exposure to the reading and writing systems of their language.

The previous studies suggest that thematic role assignment is affected conceptually and spatially by the reading and writing systems. The present study extends the role of language on thematic role assignment bias by adding word order, that is, the within-sentence structure, as a possible variable. The methodological paradigm used in previous research (Chatterjee et al., 1995; Chatterjee, Southwood, & Basilico, 1999) was based on English, a language with highly restrictive word order. To manipulate temporally or spatially the agent or the patient of an action, previous studies either used active and passive voice (Chatterjee et al., 1995), or verbs with different trajectories (e.g. "The circle pushes the square", in which the circle is the agent and the action moves away from the agent, "The circle pulls the square" in which the circle is the agent and the action goes forward to the agent) (Chatterjee, Southwood, & Basilico, 1999).

A question arising from this manipulation is whether agency will be affected by the within-sentence structure, that is, the order that thematic roles are presented within the sentence. In Greek, which has a left-to right reading and writing system, grammatical information is conveyed through inflection, thus multiple word orders are allowed (SVO, OSV, VOS, VSO, OVS, OSV). The agent or the patient of an action can appear in any order within the sentence independently of whether the sentence is active or passive. For example, in active voice, structures such as "The $cook_{nom}$ kicks the $pirate_{acc}$" (the cook=agent) and "The $pirate_{acc}$ kicks the $cook_{nom}$" are both grammatical. Therefore, highly inflectional languages, such as Greek, allow us to manipulate word order without necessarily using the passive voice which is of less frequency. In our study, we assume that spatial biases will be influenced by the within-structure sentence. We predict that participants will be faster in responding to sentences that not only match in terms of agency, but also in terms of characters' position in the sentence independently of thematic role assignment, that is, even in conditions that characters' share the same location spatially and temporally, independently of meaning.

Methods

A sentence-picture verification task was used. Pairs of characters were presented in a 2x2x2 experimental design. Each picture involved two characters ($character_1$ – $character_2$; e.g. "cook", "pirate") and each sentence contained two nouns corresponding to those characters ($noun_1$ – $noun_2$), one in nominative (agent) and one in accusative (patient). The experimental stimuli were manipulated on three dimensions: 1. characters' position in the picture (left – right), by flipping the image, 2. characters' position in the sentence (e.g. SVO – OVS) and 3. characters' thematic role (agent – patient) in the sentence by interchanging nominative and accusative case. Therefore, thematic role assignment was actually the variable that produced either matched- or mismatched-in-meaning sentence-picture pairs. Eight experimental conditions were

created (see Table 1). Every pair of characters was presented in each of eight conditions.

Table 1: Experimental design for sentence-verification task

	Meaning			
	Match		Mismatch	
	Position in sentence			
	Match	Mismatch	Match	Mismatch
	"The $cook_{nom}$ kicks the $pirate_{acc}$"	"The $pirate_{acc}$ kicks the $cook_{nom}$"	"The $cook_{acc}$ kicks the $pirate_{nom}$"	"The $pirate_{nom}$ kicks the $cook_{acc}$"
	"The $pirate_{acc}$ kicks the $cook_{nom}$"	"The $cook_{nom}$ kicks the $pirate_{acc}$"	"The $pirate_{nom}$ kicks the $cook_{acc}$"	"The $cook_{acc}$ kicks the $pirate_{nom}$"

In half of the experimental conditions thematic role assignment reflected the depicted action resulting in matched-in-meaning pairs, whereas in the other half, thematic roles mismatched the depicted action (mismatched-in-meaning pairs). Furthermore, in half of the matched-in-meaning pairs, nouns' location in sentence matched characters' position in picture, whereas in the other half, nouns' location in sentence mismatched characters' position in picture. The same was true for the mismatched-in-meaning conditions. Our dependent variable was response times and our independent variables were character's position in the picture (left, right), and word order (SVO – OVS).

Participants

Thirty-three adults, 18-30 year olds, participated in the present experiment. They were all Greek native speakers. They did not receive any compensation for their participation.

Materials

Pictures The test stimuli consisted of 9 colored pictures. Each picture depicted two characters taking part in an action, and additional objects and people. The action presented in the picture was always the same, that is, $character_1$ was always doing the action and $character_2$ was receiving the action. However, there were two conditions. Half of the pictures depicted the agent on the left and half of them depicted the agent on the right. For each target picture, the agent of the action was either depicted on the left or on the right side of the screen by flipping the image. The filler items consisted of 60 colored pictures depicting objects and people. The order of experimental and filler items was pseudo-randomized, with the constraint that each experimental item was separated by a minimum of one filler item. All pictures were part of a larger set of pictures used in

Gennari, Mirkovic, and MacDonald (2012) and were appropriately adjusted for the purposes of this experiment.

Sentences For the test sentences, 9 verbs representing actions were used to construct quadruplets of active sentences, resulting in 36 Greek sentences as test items, ranging in length from 5 to 6 (mean = 5.5) words. These sentences had two possible word orders (SVO or OVS) and half of them were matching in meaning with the experimental pictures, whereas the other half were not. Examples of sentences are presented in Table 1. Additionally, 120 Greek sentences were used as filler items ranging in length from 3 to 10 words (mean = 4.9). Half of them matched in meaning the filler pictures and half of them did not. All sentences were recorded by a female native Greek speaker whose instructions were to read each sentence aloud in a natural, clear manner, in normal intonation.

Procedure

Each participant, after giving verbal consent to participate in the study was seated in a quiet room and given instructions about the experiment. DMDX (Forster & Forster, 2003) was used for the presentation of the stimuli. Visual stimuli were presented at the center of a laptop screen. Auditory stimuli were delivered over high quality headphones. In each trial, participants saw a picture and simultaneously heard a sentence corresponding or not to the picture. Participants had to perform a 2AFC task to indicate whether the sentence they heard matched the picture by pressing one of two buttons. Participants were given three practice trials at the beginning of the experiment in order to make sure they had understood the task. There was no feedback. The experiment lasted approximately 30 minutes.

Results

Data were analyzed with generalized linear mixed-effects modeling, with random effects for participants and items, employing function lmer of package lme4 (Bates, Maechler, & Bolker, 2012) in R (R Development Core Team, 2012). Response times were log-transformed. Only accurate responses were included in the analysis (2% excluded) and only those participants that had lower than 8% error rate. None of the participants was excluded from the analysis. Outliers were removed, that is, items with response time values below 500 msec or above two standard deviations from the mean. This resulted in excluding 4% of the total data.

We conducted separate analyses for matched- and mismatched-in-meaning stimuli. For the matched-in-meaning condition, a main effect of agents' position was found (t value = -5.19, p = 0.0001) (i.e. participants' responses were faster when the agent was depicted on the right) and a main effect of word order (t value = -9.29, p = 0.0001). However, agents' position interacted with word order (t value = 4.13, p = 0.0004). Contrasts among SVO and OVS conditions revealed that participants' reaction

times did not differ in the SVO condition (t = 0.65; p = 0.5306), that is, agent's position did not affect reaction times. However, in the OVS condition, participants were significantly faster in responding to pictures presenting the agent on the right compared to left (t = -5.56; p = 0.0001), i.e. when within-sentence structure matched in characters' position in the sentence (Figure 1).
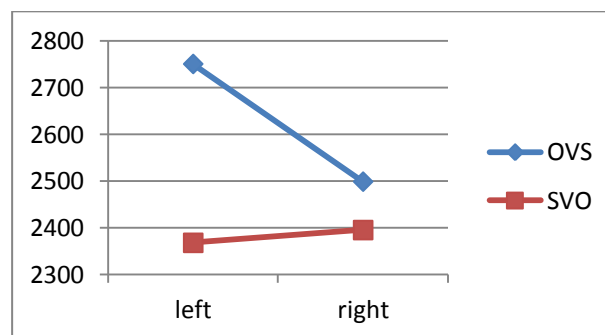

Figure 1: Agents' position and word order interaction in reaction times in matched-in-meaning pairs. In all figures, untransformed RTs are presented for ease of interpretation.

Same effects were found for the mismatched-in-meaning condition. A main effect of agents' position, (-6.06, p = 0.0001), word order (t value = -10.12, p = 0.0001) and an interaction between agents' position and word order was found (t value = 4.13, p = 0.0001). Contrasts among SVO and OVS conditions revealed that participants were slower in responding to pictures that depicted the agent on the right compared to left in the SVO condition (6.07; p = 0.0001). However, in the OVS condition, people were faster when the agent was presented on the right compared to left (t = -6.24; p = 0.0001). That is, participants were faster in rejecting a mismatched-in-meaning pair when characters' position in the sentence and characters' position in the picture matched (Figure 2).
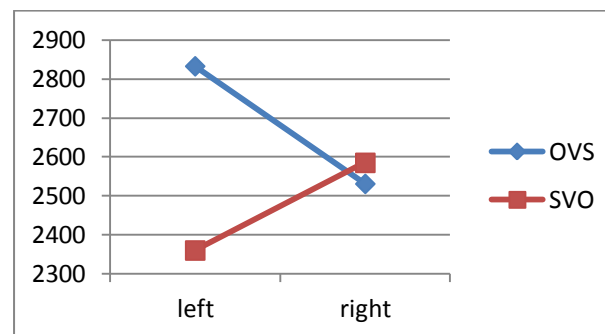

Figure 2: Agents' position and word order interaction in reaction times in mismatched-in-meaning pairs.

Discussion

The interaction between spatial and linguistic representations was investigated in a sentence-picture

verification task. Stimuli were manipulated in order to explore the role of word order in spatial representation of agency in a language with flexibility in word order. Our experimental manipulation allowed us to disentangle sentence structure and thematic role, in that agents could appear in one of two positions in the sentence. We found that when word order matched agents' position latencies dropped. This effect was not only observed in matched-in-meaning pairs, i.e. pairs in which both structure and thematic role represented the depicted action, but also, in mismatched-in-meaning pairs, i.e. pairs that only matched in sentence structure independently of thematic role.

However, a robust finding in literature, that processing of spatial representations is influenced by the directionality of the reading and writing system, was not obtained in this study. Since Greek is a left-to-right language we expected that participants would be faster in responding to pictures representing the agent on the left. In our study, participants were faster responding to pictures presenting the agent on the left only when the paired sentence was presented in SVO structure. In the other conditions, left agency did not facilitate participants' responses. We suggest that this seemingly contradictory result could be explained by the interaction between agents' spatial position and word order.

Specifically, we suggest that when the agent was presented on the left it was consistent with the left-to-right bias. This led to the formation of a strong expectation about the upcoming sentence structure (i.e. SVO). When this expectation was violated (i.e. OVS), reaction times became longer. In contrast, when the expectation was fulfilled, processing was significantly faster and reaction times dropped. However, when the agent was presented on the right side, no strong expectations were formed because the two effects (agent's position and left-to-right bias) partly canceled each other out. Therefore, the differences in latency between SVO and OVS structures should be much smaller in this case. Moreover, since SVOs are more frequent (and therefore easier to process), the mismatching between the agent's position and the sentence structure, should affect to a greater extent the processing of the less frequent OVS structures. Indeed, our results are in accordance with this prediction. In sum, the seeming absence of a left-to-right effect may be due to the violation of a strong left expectation.

Our explanation seems compatible with recent theories of prediction in cognition (Clark, 2012) and in sentence processing (Kamide, Altmann, & Haywood, 2003; Dikker & Indefrey, 2007; Altman & Mirkovic, 2009; Farmer, Brown, & Tanenhaus, in press). Specifically, a way of explaining the rapid nature of language comprehension stems from the idea of prediction. Comprehenders exploit all available information, integrate contextual constraints rapidly and generate predictions about upcoming stimuli. In our study, stimuli pairs were presented simultaneously. However, auditory stimuli are inherently more dynamic than visual stimuli. Sentences take longer to be presented and thus are processed later than a static picture. Therefore, we assume

that participants had the opportunity to process the picture longer and faster than the sentence, arguably allowing them to formulate predictions about the sentence structure. To test for this hypothesis, a future experimental manipulation could involve pictures and sentences presented not simultaneously but in different time points so that expectations about upcoming stimuli could be enhanced. For example, a sentence presented first in SVO structure may formulate the expectation of left agency, whereas an OVS structure may formulate the reverse expectation. If this turns out to be correct, then language may impose strong constraints and guide the way we conceptualize spatially thematic roles.

To conclude, we found that sentence processing not only reflects generic language characteristics, such the directionality of the writing system, but is also sensitive to frequency-driven effects, such as the occurrence rate of specific syntactic structures (i.e. SVO versus OVS). In addition, online language processing seems to be affected by non-linguistic information, which is in line with other findings (Tanenhaus, Spivey-Knowlton, Eberhard, & Sedivy, 1995). Crucially, our findings are consistent with the left-bias account according to which language-specific factors may constrain and affect our conceptual representations. In sum, our findings suggest that different sources of information (both linguistic and non-linguistic) are interactively used in forming expectations about upcoming material.

Acknowledgments

References

Altmann, G.T.M. & Mirkovic, J. (2009). Incrementality and prediction in human sentence processing. *Cognitive Science*, *33*(4), 583-609.

Barrett, A.M., & Craver-Lemley, C.E. (2008). Is it what you see, or how you say it? Spatial bias in young and aged subjects. *Journal of the International Neuropsychological Society*, *14*(4), 562–570.doi:10.1017/s1355617708080764

Bates, D., Maechler, M., & Bolker, B. (2012). lme4: Linear mixed-effects models using S4 classes. Available from http://CRAN.R-project.org/package=lme4 (R package version 0.999999-0).

Caplan, D., & Futter, C. 1986. Assignment of thematic roles to nouns in sentence comprehension by an agrammatic aphasic patient. *Brain and Language*, *27*(1), 117–134.

Caramazza, A., & Miceli, G. (1991). Selective impairment of thematic role assignment in sentence processing. *Brain and Language*, *41*(3), 402–436.

Chatterjee, A. (2001). Language and space: some interactions. *Trends in Cognitive Science*, *5*, 55–61.

Chatterjee, A., (2008). The neural organization of spatial thought and language. *Seminars in Speech and Language*, *29*, 226–38 .

Chatterjee, A., Maher, L.M., Gonzales-Rothi, L.J., & Heilman, K.M. (1995). Asyntactic thematic role assignment: The use of a temporal-spatial strategy. *Brain and Language*, *49*, 125–139.

Chatterjee, A., Southwood, M.H., & Basilico, D. (1999). Verbs, events and spatial representations. *Neuropsychologia*, *37*, 395–402.

Chan, T.T. & Bergen, B. (2005). Writing Direction Influences Spatial Cognition. In Proceedings of the *Twenty-Seventh Annual Conference of the Cognitive Science Society*, 412–417 .

Clark, A. (2012). Whatever next? Predictive brains, situated agents, and the future of cognitive science. *Behavioral and Brain Sciences* (in press).

Dikker, S. & Indefrey, P. (2007). Fine-graining structure prediction in sentence processing: How language mixing reveals an economic parser. 20th Annual CUNY Conference on Human Sentence Processing, La Jolla, CA.

Dobel, C., Diesendruck, G., & Bolte, J. (2007). How writing system and age influence spatial representations of actions: A developmental, cross-linguistic study. *Psychological Science*, *18*(6), 487–491.

Farmer, T.A., Brown, M., & Tanenhaus, M.K. (2012). Prediction, explanation, and the role of generative models in language processing. *Behavioral and Brain Sciences* (Commentary Article) (in press).

Forster, K., & Forster, J. (2003). DMDX: A Windows display program with millisecond accuracy. *Behavior Research Methods*, *35*(1), 116–124.

Geminiani, G., Bisiach, E., Berti, A., & Rusconi, M.L. (1995). Analogical representation and language structure. *Neuropsychologia*, *33*, 1565–1574.

Gennari, S.P., Mirkovic, J., MacDonald, M.C. (2012) Animacy and competition in relative clause production: a cross-linguistic investigation, *Cognitive Psychology*, *65*, 141-176.

Hayward, W.G., & Tarr, M.J. (1995). Spatial language and spatial representation. *Cognition*, *55*, 39–84 .

Jackendoff, R. (1996). The architecture of the linguistic-spatial interface. In P. Bloom, M.A. Peterson, L. Nadel, & M. F. Garrett (Eds.), *Language and space*, Cambridge, MA: MIT Press.

Kamide, Y, Altmann, G.T.M, Haywood S. L. (2003). The time-course of prediction in incremental sentence processing: Evidence from anticipatory eye movements. *Journal of Memory and Language*, *49*, 133–159.

Levinson, S.C. (2003). *Space in language and cognition: Explorations in cognitive diversity*. Cambridge: Cambridge University Press.

Maas, A. & Russo, A. (2003). Directional bias in the mental representation of spatial events: nature or culture? *Psychological Science*, *14*(4), 296–301.

Papafragou, A., Hulbert, J., & Trueswell, J. (2008). Does language guide event perception? Evidence from eye movements. *Cognition*, 108, 155–184.

R Core Team. (2012). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Available from http://www.R-project.org/ (ISBN 3-900051-07-0).

Tanenhaus, M.K., Spivey-Knowlton, M.J., Eberhard, K.M., & Sedivy, J.E. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, *268*, 632–634.