Spatial meanings for function words? The link between conjunctions and spatial representations

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Abstract

While formal theories of language consider function words to have little semantic content, more recent theoretical work has argued that even function words have meaning. Yet, there is little experimental work on the representations underlying the meaning of function words such as conjunctions. In two offline experiments, we examined whether conjunctions (*and, or, but, either…or*) are associated in systematic but distinctive ways with spatial information. In Experiment 1, participants drew schematic representations to depict how two abstract conjuncts might be connected by each of the four conjunctions. These drawing were evaluated on three spatial dimensions (*distance*, *containment* and *size*). In Experiment 2, participants evaluated how well schematic sketches (that differed in *distance*, *containment*, and *size*) represented different conjunctions. In both experiments, spatial information was systematically and distinctively associated with conjunctions. *Either… or* and *or* conjunctions were reliably associated with the use of large distance and separation via containment of the conjuncts. *And*, by contrast, was associated with shorter distance between, and no containment of, the conjuncts. Finally, *but* was associated with differences in *size*. We discuss implications of these results for the spatial foundation of linguistic meaning, and the link between lexical semantics and logic.

Keywords: Conjunctions, spatial representation, drawing, rating, simulation, embodiment.

Introduction

Natural language conjunctions such as *and* and *or* are used in ways that differ markedly from their logical or "truth-tabular" senses. For instance, *and* often expresses the temporal order of two conjoined events (Bloom et al, 1980). Thus, (1) and (2) mean quite different things:

(1) He ran through the door and slipped on a banana peel.
(2) He slipped on a banana peel and ran through the door.

While (1) and (2) differ only in the order of the conjuncts, this results in a different temporal ordering of the events. Conjunctions can also express causality, counterfactuals, or subordination (see Culicover & Jackendoff, 1997). This departure from formal logic has long been recognized by linguists of all stripes (e.g., Hoeksema, 1987; Klinedinst & Rothschild, 2012). But what about those cases where *and* and *or* are used in a sparse discursive context and actually appear to express a simple logical relation? What are the lexical semantics of *and* and *or* in their most austere uses?

On a classic formal account, the semantics of these function words is impoverished, contributing to the meaning of an utterance only in virtue of the meaning of the conjoined content words (e.g., Keenan & Faltz, 1985; cf. Boole, 1854). More recent work, however, has prompted a reconsideration of the semantics of function words, and of the semantic content of grammar more generally. Langacker (2008) has argued that grammar is inseparable from meaning, since it shapes conceptualization in subtle but reliable ways. According to Langacker (1987), conjunctions like *and* and *or* prompt the "juxtaposition" of two or more objects or events in a dynamic conceptualization. Moreover, he and others (e.g. Landau & Jackendoff, 2003; Talmy, 2000) have argued that schematic spatial information may lie at the core of linguistic meaning. Could the "juxtaposition" prompted by conjunctions rely on implicit spatial representations?

This possibility aligns with recent evidence that language comprehension involves the dynamic construction of an *embodied mental simulation*. In contrast with approaches that posit abstract, symbolic representations (e.g. Landauer & Dumais, 1997; Markman & Dietrich, 2000), embodied approaches argue that linguistic meaning is fundamentally tied to perceptual, motor and affective representations (Barsalou, 1999). Understanding "He threw the apple into the air," might involve activating cortical circuits implicated in perceiving the color red (Connell, 2007), perceiving motion (Saygin et al, 2012), or performing the action of throwing (Masson, Bub, & Warren 2008). To account for how less concrete language is grounded in perception and action, proponents of some embodied approaches to language comprehension have appealed to "metaphorical" representations that map concrete experience to abstract linguistic content (Gibbs, 2006; Gallese & Lakoff, 2005). For instance, *respect* can be conceptualized in terms of vertical height—"I look *up* to my superiors"—while similarity can be conceptualized in terms of closeness—"Our ideas are quite close" (Lakoff & Johnson, 1999). And, in fact, comprehending language about respect, similarity,

and other abstract concepts appears to involve schematic spatial representations (Guerra & Knoeferle, 2012; Richardson et al., 2003; but see Bergen et al., 2007). Thus, the meaning of content words—both concrete and abstract—may include schematic spatial information.

But what about function words, such as conjunctions? Could their meaning also involve schematic spatial information, co-opting space to juxtapose conjuncts? There is evidence that grammatical tense, for instance, activates spatial representations. Santiago and colleagues (2007) found that participants were faster to categorize words as referring in the past tense when words were presented on the left (vs. right) side of the screen, but faster for words in the future tense when presented on the right (vs. left)—as if grammatical tense activated a left-to-right mental timeline (see also Torralbo, Santiago & Lupiáñez, 2006). The "juxtaposition" prompted by conjunctions may also rely on schematic spatial representations, such as containment (see Glenberg, 2010). Comprehension of *and*, for instance, could involve a spatial grouping of the conjuncts, while *or* could mark alternatives by separating them spatially via containment. However, there is no clear experimental evidence showing that function words such as conjunctions are indeed related to spatial representations.

In the present two studies, we used two offline tasks to probe spatial representations underlying the meaning of conjunctions. In the first drawing study, participants created schematic sketches of conjunctions; in the second rating study, they rated schematic spatial diagrams on how well they represented different conjunctions. Both drawing and rating tasks have been used to study spatial representations activated by language, but only for concrete and abstract *content* words (Richardson et al, 2001). If conjunctions also co-opt spatial schemas to keep track of conceptual relations between conjuncts, then we should see a reliable, systematic use of spatial properties like *distance*, *size*, or *containment* to represent different conjunctions.

Experiment 1: Drawing study

Experiment 1 used a drawing paradigm to examine whether representations of space are used to understand and visually depict the relationships expressed by four conjunctions (*and*, *or*, *but*, and *either… or*). If spatial representations are co-opted, then participants should systematically use spatial information to differentially represent the relations expressed by conjunctions. Alternatively, if conjunctions relate the meaning of the conjuncts in an abstract or logical fashion, no reliable differences in the use of spatial information should emerge.

Method

Participants 108 native speakers of German completed the drawing task. They all gave informed consent and received monetary compensation for their participation.

Materials Three German conjunctions (*und* 'and'; *aber*, 'but'; and *oder* 'or') and a German correlative conjunction (*entweder… oder*, 'either… or') were presented on a single sheet of paper (Fig. 1). Each conjunction appeared as "Object X ***conjunction*** Object Y" at the top of a blank square. Participants could select objects and frames for their drawings (Fig. 2).

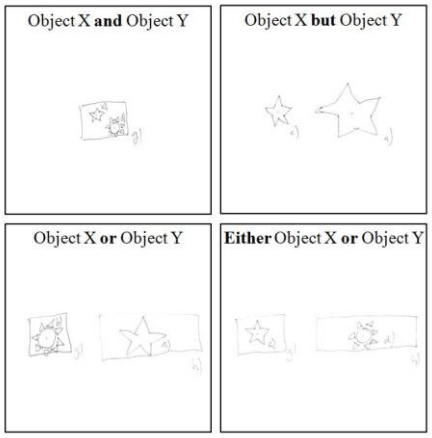

Figure 1: Example of the drawings from a single participant.

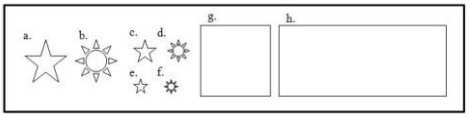

Figure 2: Objects and frames of different shapes and sizes to be used in the drawings.

Design and procedure In a within-subjects design, with conjunction as a factor ('and', 'but', 'or', 'either… or'), each participant was instructed to make one drawing for each conjunction (see Fig. 1) using the objects in Figure 2. Participants saw two examples for the prepositions *with* and *without*. They were told that there were no correct or incorrect answers. The order of the conjunctions (Fig. 1) was counterbalanced.

Analysis We examined the drawings' spatial dimensions of *distance*, *containment* and *size*. *Distance* was defined as millimeters (mm) between objects' centers; *containment* codes whether objects were (or weren't) separated by one or more frames; *size* codes whether the objects had the same or a different size. Normalized distance scores (*z*-scores) were analyzed with linear mixed effect regression (LMER, lme4 package for R statistical software). Mixed-effects models are suitable for analyzing unbalanced data and capture participants' variation around multiple fixed effects similar to ANOVAs (Quené & van den Bergh, 2008). Our LMER modeled *distance* with conjunction as fixed effect, participant as random intercept, and the fixed effect as random slope.

For the analyses with *containment* and *size*, we calculated the percentage of representations that used these dimensions (e.g., *containment* was scored as present when an object was drawn with a frame around it, and *size* when differently-sized objects were used). A binomial test evaluated whether these percentages differed significantly from chance.

Results

Distance Figure 3 shows the normalized mean distances between objects by conjunction. A positive deviation from zero (the intercept and grand mean) indicates objects were drawn farther apart than the grand mean object distance; a negative deviation indicates they were closer together. Figure 3 illustrates that while objects were drawn farther apart than average for 'either… or' and 'or', they were drawn closer together for 'and'. Object distance for 'but' did not differ from average. The LMER[1] model confirmed a main effect of conjunction for *distance* (p<.001).

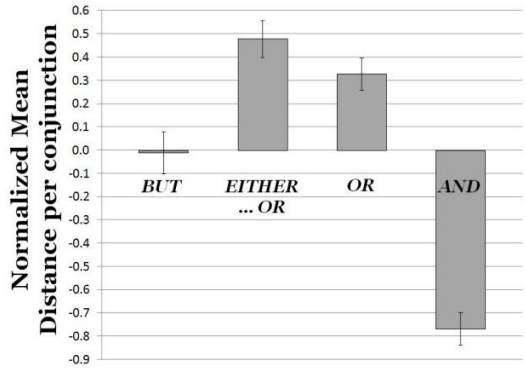

Figure 3: Normalized mean distances between objects for each conjunction. Error bars represent standard errors.

Post-hoc comparisons (Bonferroni corrected) confirmed shorter between-object distance for 'and' than any of the other conjunctions (ps<.001); objects for 'either…or' were significantly farther apart than those for 'but' (p=.01). The difference in distance between 'or' and 'but' did not reach significance (p=.24; uncorrected p=.037), and 'either…or' and 'or' did not differ (p=1).

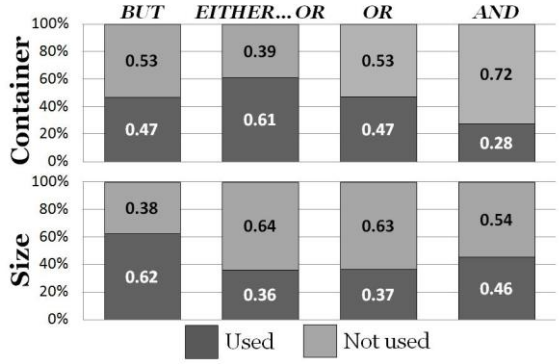

Figure 4: Participant percentage using *containment* (upper graph) and *size* (lower graph) for each of the conjunctions.

Containment & Size Figure 4 illustrates, for each conjunction, the percentage of participants who used frames around objects and different object sizes in their drawings. For 'but', the use of *containment* did not differ from chance (47%, p=.6). Instead, differently-sized objects distinguished the conjuncts (62%, p=.017). For 'either… or', *containment* (61%, p=.026), but not *size* (36%, p=.008) was used above chance. For 'or', the use of *containment* did not differ from chance (47%, p=.6), but differences in size were systematically avoided (37%, p=.012). Finally, drawings for 'and' avoided the use of *containment* (28%, p<.001) and used *size* at the level of chance (46%, p=.4).

Discussion

As predicted, different conjunctions were reliably associated with particular spatial dimensions. When two objects were conjoined by 'and', they were drawn close together and not separated by frames. By contrast, for 'or' and 'either…or' objects were drawn farther apart and separated by frames. Finally, depictions of 'but' relied on *size* to contrast the objects, but made no use of *containment* or *distance*. These conjunctions, therefore, elicited reliable spatial depictions in the absence of content words or linguistic context.

But do these results reflect spontaneous associations between conjunctions and space, or task-induced strategic reflection? To rule out that participants interpreted all four conjunctions and planned their sketches, perhaps to contrast them, we conducted a self-paced rating study based on the results of Experiment 1. In the rating study, participants only saw one conjunction-schema pair at a time. If sketches served to contrast the conjunctions, then use of space should disappear, or at least be greatly diminished in the rating task when only one pair is rated at a given time.

Experiment 2: Rating study

Each conjunction ('and', 'or', 'but', 'either…or') was paired with each of eight spatial schemas, designed to contrast three spatial dimensions: *distance*, *containment*, and *size* (Figure 5). These conjunction-schema pairs were randomly presented, so that participants could not predict the ensuing schema-conjunction pair. If the use of spatial information was not strategic, then ratings of how well a given depiction illustrates the meaning of a conjunction should replicate findings from Experiment 1. Specifically, we predict higher ratings for 'either… or', and 'or' when paired with schemas representing *far* (vs. *close*) distance and separated *containers* (vs. *objects-contained*). By contrast, ratings for 'and' should be higher with schemas representing *close* (vs. *far*) distance and *objects-contained* (vs. *separated containers*). Finally, we predict no differences for 'but' on *distance*- or *containment*-related schema ratings, but higher than average ratings for *size*-related schemas.

Method

Participants A further twenty-four native German speakers completed Experiment 2. They all gave informed consent and received monetary compensation for their participation.

Materials Figure 5 shows the schematic depictions. Seven visual schemas covered the three dimensions analyzed in

[1] We report p-values calculated using a MCMC simulation (R code: pvals.fnc) for a mixed-effects model without random correlations. The R code is: lmer (distance ~ conjunction + (1|participant) + (0+conjunction | participant), data).

Experiment 1 (i.e., *distance*, *containment*, *size*, Fig. 5, A-G); an eighth schema served as a baseline (Fig. 5 H). Each schema was presented on the computer screen with each one of the four conjunctions from Experiment 1.

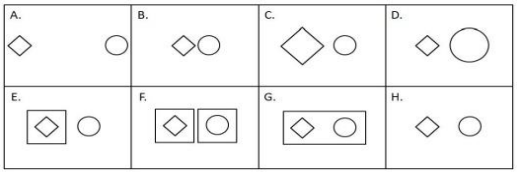

Figure 5: Depictions for the spatial schemas: *far* (A); *close* (B); *big* (C), *small* (D), *one-container* (E); *two-containers* (F); *objects-contained* (G); and *baseline* (H).

Design and procedure A within-subjects design, had schema (eight schemas; Fig. 5) and conjunction ('and', 'or', 'but', 'either…or') as factors. Participants rated each possible pairing on how well a schema depicted a conjunction using a 7-point scale (1=very bad to 7=very good). Items were presented one at a time on a computer monitor, and participants responded self paced. Experiment Builder v10.6 software (SR Research) recorded responses and randomized trial order.

Analysis For each conjunction, we normalized participants' raw ratings relative to their rating of the baseline schema H by subtracting their baseline rating from their other ratings[2]. Thus, within a conjunction, schemas that were judged more acceptable than baseline received a positive score, but a negative score if they were less acceptable than baseline.

Schema ratings were split into three subsets, based on the three spatial dimensions analyzed in Experiment 1. The *distance* subset included ratings for *far* and *close* schemas; the *containment* subset included ratings for *one-container*, *two-containers* and *objects-contained* schemas; and the *size* subset included ratings for *big* and *small* schemas. Each set of normalized ratings was then analyzed separately using an LMER model, with schema and conjunction as fixed effects, participant as random intercept, and the main effects and interaction of the fixed effects as random slopes. Planned dependent *t*-tests (Bonferroni corrected) compared ratings for each schema within conjunctions.

Results

Distance The LMER showed neither main effects of schema nor conjunction (*ps*>.29). However, as predicted, schema and conjunction interacted (*p*=.011), with higher ratings for the *far* schema for 'and', but the *close* schema for 'either…or' and 'or' (Fig. 6).

Planned pairwise comparisons assessed the effect for each conjunction. For 'but', ratings did not differ for the *far* and *close* schemas (*p*=.92). For both 'either… or' and 'or', by contrast, the *far* schema received higher ratings (*p*<.001 and *p*=.018, respectively). The pattern reversed for 'and', for which the *close* schema was reliably preferred (*p*<.001).

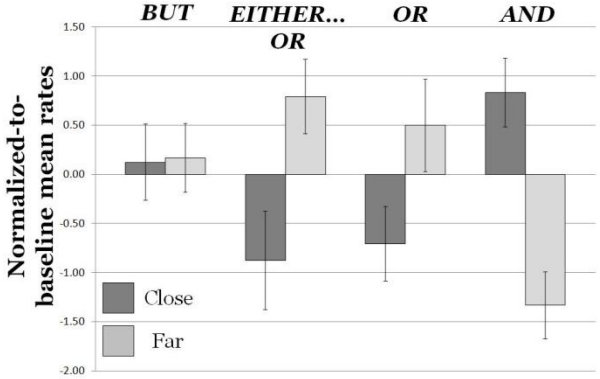

Figure 6: Normalized-to-baseline mean rate for *far* and *close* schemas for all conjunctions. Error bars represent standard errors.

Containment LMER analyses showed a reliable main effect of conjunction (*p*=.002) but not of schema (*p*=.3); schema and conjunction interacted, as predicted (*p*<.001, Fig. 7).

Planned pairwise comparisons examined *containment* preferences for each conjunction. For 'either… or', the *two-containers* schema—which maximally separates the two objects—was rated higher than both the *objects-contained* and the *one-container* schemas (both *p*<.001). Similarly, for 'or', the *two-container* schema was significantly preferred over the *one-container* schema (*p*=.002), and was marginally preferred over the *objects-contained* schema (*p*=.08; uncorrected *p*=.027). By contrast, for 'and', the *objects-contained* schema—which groups both objects together—received the highest ratings among the containment-related schemas. The *one-container* schema was significantly disliked, compared to both the *objects-contained* and the *two-container* schemas (both *p*<.001, *ps* for the other comparisons, *n.s.*).

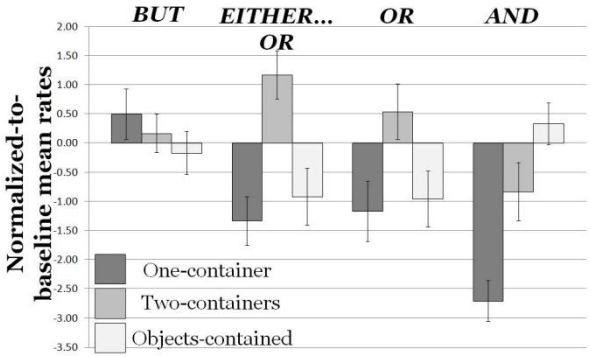

Figure 7: Normalized-to-baseline mean rate for *one-container*, *two-container* and *objects-contained* schemas. Error bars represent standard errors.

Size The LMER showed a main effect of conjunction (*p*=.002). Schemas that highlighted differences in *size* were rated highly for 'but', nevertheless, dispreferred for all other conjunctions (Fig. 8, other *ps n.s.*).

[2] For instance, if the *and* + *baseline* schema was rated as a 4, and *and* + *objects-contained* was rated a 6, the normalized rating for *and* + *objects-contained* was 6 - 4 = 2.

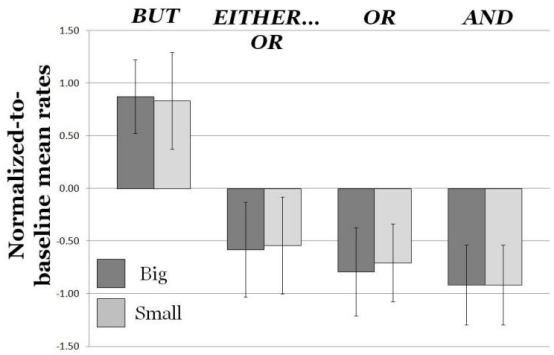

Figure 8: Normalized-to-baseline mean rate for *big* and *small* schemas for all conjunctions. Error bars represent standard errors.

Discussion

Experiment 2 confirmed that participants exhibit systematic preferences for spatial representations of conjunctions. Both 'either…or' and 'or' were rated higher with larger distances between objects, while 'and' was rater higher for shorter object distances. These conjunctions were also contrasted by the ratings for *containment*: the *two-container* schema was preferred for both 'either…or' and 'or', while the top-rated schema for 'and' contained both objects in a single frame. Finally, schemas that depicted size differences were reliably preferred for 'but', and rejected for all other conjunctions.

General Discussion

Although previously suggested in the literature (e.g., Glenberg, 2010; Langacker, 2008), until now there was no experimental evidence that space might play a role in the representation of function words such as conjunctions. In two experiments, conjunctions were systematically associated with schematic spatial information, both when participants produced and when they rated spatial representations in the context of conjunctions.

We have framed these results in terms of semantics, and we believe they can shed light on the comprehension of conjunctions in natural language. But they may also tell us something about norms of visual representations or the communicative use of space. Logic and mathematics are rife with spatial diagrams used to represent and reason about logical relations, including *and* and *or* diagrams that are strikingly similar to the spatial representations in the current studies (Fig. 9; Guaquinto, 2007). Similarly, Langacker's *Cognitive Grammar* (2008) relies on spatial diagrams to represent relations between grammar and conceptualization. Sketches and diagrams, after all, are powerful tools for representing abstract concepts (Tversky, 2011).

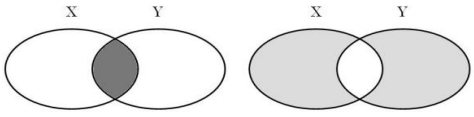

Figure 9: Venn diagrams use spatial containment to depict logical relations: *and* (left) and *or* (right). *And* is depicted by a compact area, while *or* involves two separated areas.

If conjunctions are associated with spatial representations, then this may even account for some of the varied senses of *and* and *or* that have been discussed in the literature (e.g. Culicover & Jackendoff, 1997). For instance, since time is also associated with spatial representations (e.g. Santiago et al., 2007), an implicit schematic spatial representation of the conjuncts could perhaps also induce a temporal ordering.

Where does this leave the relation between lexical semantics and logic? Perhaps closer than ever. In their book on the conceptualization of mathematics, Lakoff and Núñez (2000) suggest that "much of what is often called logical inference is in fact spatial inference mapped onto an abstract logic domain" (p.43). If so, then reasoning about logical relations, such as *and* and *or*, may rely on "metaphoric" representations of *containment* and *distance* (see, e.g., Boot & Pecher, 2011; Guerra & Knoeferle, 2012). If both the semantics of conjunctions and formal logic turn out to rely on space, then natural language semantics may be closer to formal logic than recently supposed—if we're willing to accept an appropriately naturalized version of formal logic, and an appropriately embodied version of lexical semantics.

Indeed, a question that remains unaddressed is whether schematic spatial information plays a spontaneous role in the real-time comprehension of conjunctions, when space is not an explicit part of the task. Suggestively, this is the case for *content* words. Richardson and colleagues (2001) used two offline norming studies to elicit schematic spatial representations associated with both concrete and abstract verbs (e.g. *give*, *respect*). They later found that these spatial schemas systematically influenced real-time comprehension of the associated verbs (Richardson et al, 2003), suggesting that the schemas elicited by the offline tasks were active during online language processing. We hypothesize that similar spatial processing may occur during the processing of conjunctions—that is, that the online comprehension of conjunctions may also involve schematic spatial representations of the kind examined here. Such online measures are necessary before we can draw definite conclusions about the semantics of conjunctions.

We do know, however, that conjunctions such as *either…or* modulate online sentence comprehension (e.g. Frazier, Munn & Clifton, 2000 for *and*-coordinations). In a reading study, Staub & Clifton (2006) examined the effect of the presence or absence of the word *either* on reading times for the second conjunct of *or*-coordinated structures (both for noun phrases and independent clauses). They found that the presence of *either* facilitated the reading of the content that followed the word *or*. These findings showed that conjunctions (*and*, *either… or*) can influence online sentence interpretation. Future studies should investigate whether these online effects extend to influences on spatial processing.

Conclusion

We have shown that different conjunctions are distinctively associated with spatial dimensions of *distance*, *containment*, and *size*. In both a drawing and a rating task, people

associated ‘and’ with closeness and containment; ‘or’ and ‘either…or’ with distance and separation; and ‘but’ with contrasting size. Future work will investigate whether these schematic spatial properties are activated during online comprehension, and determine their functional contribution. Nevertheless, the present experiments highlight the use of space to distinguish abstract grammatical relations, suggesting the meaning of different function words can be expressed through distinct visual spatial representations.

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