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RESEARCH PAPER

Priming semantic structure in Brazilian Portuguese

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Abstract Structural priming, the tendency for speakers to reuse previously encountered sentence structures, provides some of the strongest evidence for the existence of abstract structural representations in language. In the present research, we investigate the priming of semantic structure in Brazilian Portuguese using the locative alternation: *A menina lustrou a mesa com o verniz* "The girl rubbed the table with the polish" vs. *A menina lustrou o verniz na mesa* "The girl rubbed the polish on the table." On the surface, both locative variants have the same syntactic structure: NP-V-NP-PP. However, location-theme locatives ("rub table with polish" describe a caused-change-of-state event, while theme-location locatives ("rub polish on table") describe a caused-change-of-location event. We find robust priming on the basis of these semantic differences. This work extends our knowledge by demonstrating that semantic structural priming is not isolated to languages like English (e.g., satellite-framed with strict word order and limited inflection) but is present in a language with very different typological characteristics (e.g., verb-framed and richly inflected with subject dropping).

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Introduction

Structural priming is the tendency for speakers to reuse previously encountered sentence structures (Bock 1986; for a meta-analysis and reviews, see Branigan 2007; Branigan and Pickering 2017; Mahowald et al. 2016; Pickering and Ferreira 2008; Tooley and Traxler 2010). For instance, Bock (1986) found that speakers were more likely to describe a picture using a double-object dative (e.g., *The man is reading the boy a story*) following another double-object dative (e.g., *A rock star sold an undercover agent some cocaine*) than following a prepositional-object dative (e.g., *A rock star sold some cocaine to an undercover agent*). Critically, this basic finding cannot be explained by the repetition of particular lexical items, verbal morphology, or metrical structure (Bock and Loebell 1990; Pickering and Branigan 1998). Instead, it reflects perseveration on the basis of the structure of the sentence itself. Accordingly, priming provides some of the strongest evidence for the existence of abstract structural representations in language (Branigan and Pickering 2017).

Most work on structural priming has focused on the priming of syntactic phrase structure (see, e.g.,

Branigan 2007; Branigan and Pickering 2017; Pickering and Ferreira 2008; Tooley and Traxler 2010). But there is substantial evidence that semantic structure can also be primed (e.g., Cai et al. 2012; Chang et al. 2003; Cho-Reyes et al. 2016; Griffin and Weinstein-Tull 2003; Hare and Goldberg 1999; Köhne et al. 2014; Pappert and Pechmann 2014; Salamoura and Williams 2007; Yi and Koenig 2016; Ziegler and Snedeker 2018; Ziegler et al. 2018b). For example, Chang et al. (2003) found that location-theme locatives (e.g., *The maid rubbed the table with polish*) led to a higher proportion of location-theme responses (e.g., *The farmer heaped the wagon with straw*) as compared to theme-location locatives (e.g., *The maid rubbed polish onto the table*). Both locative variants have the same surface syntax (both NP-V-NP-PP). Thus, on the basis of syntax alone, location-theme locatives should be no more likely to prime location-theme responses than theme-location responses. On the other hand, location-theme locatives do differ from theme-location locatives in meaning. If someone rubs the table with polish, for example, the entire table is understood as being covered in polish, whereas rubbing polish onto the table doesn't trigger the same entailment (Anderson 1971; Pinker 1989; Rappaport and Levin 1988). Accordingly, it's a contradiction to say *The maid rubbed the table with polish, but most of the table didn't get any polish on it* but not *The maid rubbed polish onto the table, but most of the table didn't get any polish on it* (adapted from Anderson 1971, p. 389). To capture these differences in meaning, some linguistic theories assign the two locative variants different semantic event structures: the [[X CAUSE [Z BE IN STATE]] WITH Y] structure for location-theme locatives and the [X CAUSE [Y BE AT Z]] structure for theme-location locatives (structures adapted from Rappaport and Levin 1988, p. 26).[1] Presumably it is these representations that drive priming in the Chang et al. (2003) study.

Thus, structural priming provides empirical evidence for a distinct level of semantic structure that maps to an independent syntactic representation (following, e.g., Baker 1988, 1997; Fillmore 1968; Goldberg 1995; Gruber 1965; Jackendoff 1972, 1990, 2002; Pinker 1989; Rappaport Hovav and Levin 1998, 2011). If this theory is correct, then we should also expect to see the same phenomena across languages. But while the priming of syntax has been studied in a wide variety of languages (including American Sign Language, Cantonese, Mandarin Chinese, Scottish Gaelic, Spanish, Swedish, etc.; Cai et al. 2011; Hall et al. 2015; Hartsuiker et al. 2004; Kantola and van Gompel 2011; Kutasi et al. 2018), there is a relative dearth of work on the priming of semantic structure outside of English. The work that addresses this gap most directly is studies of the dative alternation. Because the dative alternation is absent in many languages, most of this work has been in Germanic languages (Cho-Reyes et al. 2016; Griffin and Weinstein-Tull 2003; Hare and Goldberg 1999; Köhne et al. 2014; Pappert and Pechmann 2014; Ziegler and Snedeker 2018; Ziegler et al. 2018b), although Greek and Mandarin Chinese are notable exceptions (Cai et al. 2012; Salamoura and Williams 2007).[2] Critically, the work on datives is ambiguous with respect to the representation(s) being primed. Double-object and prepositional-object datives differ from each other on three levels: surface syntax (NP-V-NP-NP vs. NP-V-NP-PP), event structure ([X CAUSE [Z HAVE Y]] vs. [X CAUSE [Y BE AT Z]]), and syntax-animacy mappings (animate-inanimate vs. inanimate-animate). We know that all three of these levels can be primed (for evidence that animacy can be primed, see Bock et al. 1992; Gámez and Vasilyeva 2015; Ziegler and Snedeker 2018). Thus, dative-to-dative priming alone typically cannot isolate the effect of semantic structure from that of syntax or animacy.

Locatives get around both of these constraints, allowing us to test a more diverse set of languages with greater theoretical clarity. But to date, locative priming has only been studied in English (e.g., Chang et al. 2003; Yi and Koenig 2016; Ziegler and Snedeker 2018). In this work, we aim to extend locative priming (and semantic structural priming more generally) to a

[1] These differences are also frequently attributed to different orderings of thematic role representations (i.e., location before theme vs. theme before location). For present purposes, the two accounts make the same predictions. But we have argued elsewhere that event structures better capture the full range of priming facts than thematic role mappings (Ziegler et al. 2018b).

[2] While Salamoura and Williams (2007, Exp. 3) also studied "locatives," these were standard transitive sentences with a locative prepositional phrase (e.g., *The president kept the gold medal in the drawer*; see also Bock and Loebell 1990; Potter and Lombardi 1998; Ziegler and Snedeker 2018) and not the alternating change-of-location verbs we are interested in here (following, e.g., Levin 1993; Pinker 1989).

typologically distinct language—namely, Brazilian Portuguese. Romance languages like Brazilian Portuguese differ from Germanic languages in their verb argument realization properties in a number of ways. Specifically:

1. Romance languages are typically verb-framed with respect to the realization of path and manner components in language (e.g., *entrar no quarto correndo* "to enter the room running"), while Germanic languages are typically satellite-framed (e.g., "to run into the room"; Levin and Rappaport Hovav 2019; Talmy 1985, 2000),
2. Romance languages generally lack resultative constructions (e.g., *to hammer the metal flat*), verb-particle constructions involving pure manner verbs (e.g., *to dance the night away*), and double-object datives (e.g., *to give the dog a bone*; Baker 1988; Gonçalves 2015; Larson 1988; Levin and Rappaport Hovav 2019; Mateu 2012; Mateu & Rigau 2010; Snyder 2001, 2012; Talmy 1991, 2000; though cf. Abreu Gomes 2003), and
3. Romance languages exhibit a highly skewed (and less productive) frequency distribution of locative sentences, with theme-location locatives occurring systematically less frequently than location-theme locatives, arguably due to their status as verb-rather than satellite-framed (Lewandowski 2014; Mateu 2017).

These differences have been tied to fundamentally distinct verb lexicalization patterns for Romance and Germanic languages (e.g., Beavers et al. 2010; Mateu 2012; Mateu and Rigau 2010; Snyder 2001, 2012; for discussion and review, see Levin and Rappaport Hovav 2019), a point to which we will return in the general discussion. For these reasons, Brazilian Portuguese is a good candidate for extending the empirical coverage of locative priming to a more typologically diverse set of languages.

Despite this typological distinction, locatives in Brazilian Portuguese (1, 2) behave similarly to their counterparts in English (Negrão and Viotti 2006). Specifically, Brazilian Portuguese locatives have a location-theme variant (1a) and a theme-location variant (2a), both of which, like English, have the same surface syntactic structure (1b, 2b). However, location-theme and theme-location locatives in Brazilian Portuguese also differ in their semantic structures (1c, 2c), such that location-theme locatives entail a state change in their direct object (1c) but theme-location locatives do not (2c).

(1) a. *A menina* *lustrou* *a mesa* *com o verniz.* =location-theme
the girl rubbed the table with the polish
"The girl rubbed the table with the polish."
b. NP V NP PP
c. [[X CAUSE [Z BE IN STATE]] WITH Y]

(2) a. *A menina* *lustrou* *o verniz* *na mesa.* =theme-location
the girl rubbed the polish on.the table
"The girl rubbed the polish on the table."
b. NP V NP PP
c. [X CAUSE [Y BE AT Z]]

Accordingly, on the basis of these semantic differences, we expect to find more location-theme productions following location-theme primes than following theme-location primes, consistent with the findings in English (Chang et al. 2003; Yi and Koenig 2016; Ziegler and Snedeker 2018).

Critically, we see no obvious reasons to believe that locative priming in Brazilian Portuguese should be fundamentally different from English due to these typological differences in how post-verbal arguments are expressed. Nor will testing locatives in this language distinguish between two alternate theories of priming. But if we wish to ensure that we are building our understanding of semantic structural priming on a robust foundation, studying locatives in Brazilian Portuguese is a reasonable next step.

Methods

This study was preregistered on the Open Science Framework (OSF) prior to data collection: http://doi.org/10.17605/OSF.IO/9FHW2.

Participants

52 native speakers of Brazilian Portuguese recruited online (10 via Amazon Mechanical Turk, 42 via an advertisement on social media) participated in the experiment (32 female, 20 male; mean age 32, SD 7,

range 25–59, 16 unreported). All participants provided written consent prior to participating.

Materials

The study consisted of 8 critical trials interspersed with 8 filler trials, for a total of 16 trials. All trials included a single prime sentence, presented verbally as an audio clip, followed by a target animation, to be described by participants. Each prime sentence was paired with two cartoon still images. The images depicted two separate events, one consistent with the prime sentence and one distractor (a different event with the same agent). Primes and targets contained one of eight alternating Brazilian Portuguese locative verbs (*acertar* "hit," *besuntar* "smear," *borrifar* "spray," *embrulhar* "wrap," *enrolar* "roll," *esfregar* "rub," *lustrar* "polish," *rabiscar* "scribble") in either the location-theme (1a) or theme-location (2a) variant. Filler trials contained direct objects with either one or two noun phrases (e.g., one: *A menina bebeu o leite* "The girl drank the milk"; two: *A mulher quebrou o prato e a jarra* "The woman broke the plate and the jar"). All materials had one of four agents (boy, girl, man, woman), in equal proportions across items. In no case did verbs or nouns repeat within a trial. Sentences were prerecorded by an adult male native Brazilian Portuguese speaker (second author). (For a full list of all prime and target materials, see Appendices A and B.)

We created four counterbalanced lists (two sets of counterbalanced lists with different pairings of items and conditions). Within each list, half of the primes appeared in the location-theme variant, and the other half appeared in the theme-location variant. Across lists, each prime sentence occurred an equal number of times in both variants. Prime sentences were randomly paired with target animations across participants, within the constraint that no content words (verbs or nouns) repeat within a trial. All lists began with a filler trial before the first critical trial, and alternated between filler and critical trials thereafter. Within this constraint, the orders of critical and filler trials were randomized, separately, across participants.

Procedure

The study was administered online using psiTurk (Gureckis et al. 2016). For prime trials, participants listened to the prerecorded sentences while viewing the cartoon images on a screen (Fig. 1). Participants were instructed to select which of the two images matched the sentence being played (the position of the image depicting the prime sentence was randomly determined). Participants were perfectly accurate (100%) on this task.

On target trials, participants were shown a 3-s cartoon animation of an event, along with a word to be used to describe that event. This word was our target locative verb, and was presented to increase the likelihood that participants would use the intended constructions. The target verb was displayed in capital letters above the animation (see Fig. 1). Participants' responses were recorded for later coding.

Design

The independent variable was prime type (location-theme vs. theme-location), and the dependent measure was the number of location-theme locatives produced by participants (coded as 1, with theme-location locatives coded as 0) out of all locative (location-theme + theme-location) responses. In presenting the production cell means (for descriptive purposes), we have aggregated over both participants and items (location-theme/location-theme + theme-location).

Coding

Participants' recorded responses were coded as "location-theme," "theme-location," or "other." Location-themes were sentences with a post-verbal DESTINATION followed by the prepositions *com* or *de* and a THEME. Theme-locations were sentences with a post-verbal THEME followed by a locational preposition and a DESTINATION. Here we accepted the prepositions *em* "in/on," *num*(*a*) "in/on," and *sobre* "on/over." All other forms were counted as other, including any responses that omitted an argument altogether or that included prepositions that were ambiguous or inconsistent with the expected thematic role (e.g., *besuntar o bolo de chocolate* "to smear the cake with chocolate" vs. "to smear the chocolate cake"). Responses in which participants used a different verb than we expected were included in the analysis so long as the verb produced was also an alternating locative verb and different from the prime verb. In total, 317 of the 406 target descriptions produced were locative

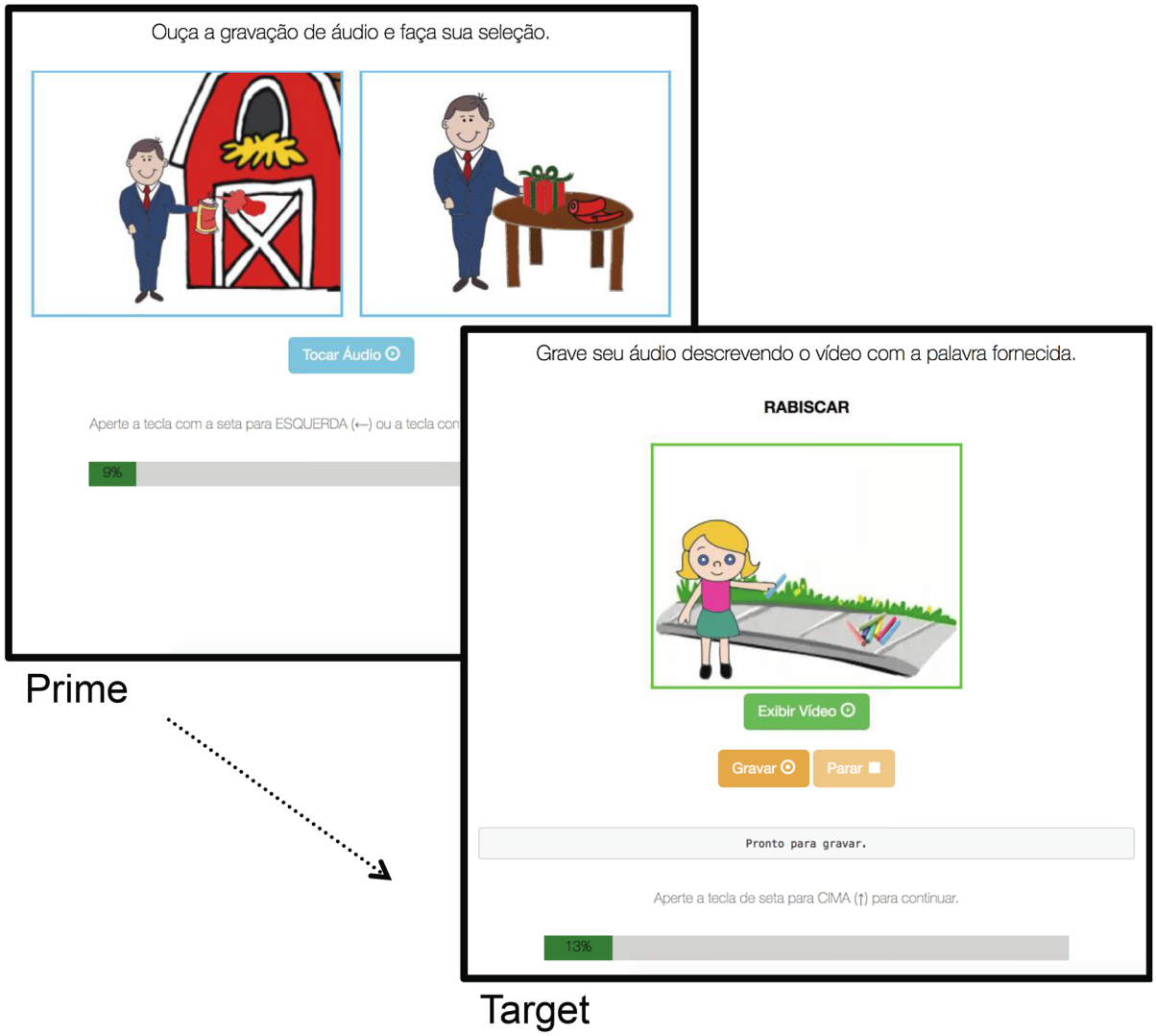

Fig. 1 Procedure and example materials

(78.1%) constructions and thus entered into the analysis, with no differences in the number of excluded trials by prime type (21.2% location-theme loss, 22.7% theme-location loss). Fifteen percent of the target responses were independently coded by a second coder. Intercoder reliability was overall very high (95%, Cohen's $\kappa = 0.90$).

Data analysis

Participants' productions were analyzed using a logistic mixed-effects model (Baayen et al. 2008; Jaeger 2008) in the lme4 package in R (Bates 2010), with prime type as a fixed effect. We started with the maximal random effects structure appropriate for this experimental design (Barr et al. 2013). However, this model failed to converge. The final model included random intercepts for participant and item (target verb) and a random slope for prime type within participants. The fixed effect (prime type) was effect coded (location-theme as 1, theme-location as -1). Confidence intervals were computed by running the confint function on the glmer model in the R stats package. Model goodness-of-fit (R^2) was calculated on the correlation between fitted and observed values.

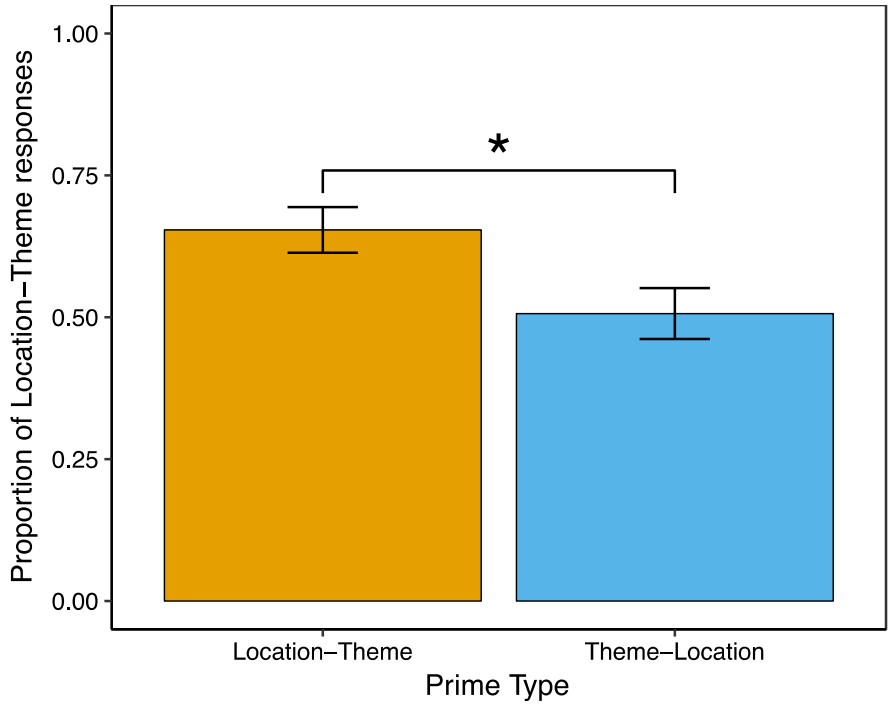

Fig. 2 Overall proportions of location-theme locatives by prime type. Error bars reflect by-subject standard errors

Results

As expected, participants produced significantly more location-theme locatives following location-theme primes than following theme-location primes (65% vs. 51%), $\beta = 0.50$(SE = .18), $z = 2.81$, $p = 0.005$, 95% CI [0.15, 0.90], $R^2 = 0.58$ (Fig. 2).[3] This effect was present both in the sample recruited from Amazon Mechanical Turk (N = 10) and in the sample recruited from social media (N = 42; see Table 1).

Table 1 Priming magnitudes by participant population

Participants	Priming (%)
All participants (N = 52)	15
Participants from social media (N = 42)	16
Participants from Amazon Mechanical Turk (N = 10)	10

Discussion

To date, semantic structural priming has only been studied in English and related languages (e.g., Chang et al. 2003; Cho-Reyes et al. 2016; Hare and Goldberg 1999; Köhne et al. 2014; Pappert and Pechmann 2014; Yi and Koenig 2016; Ziegler and Snedeker 2018; Ziegler et al. 2018b; see also Cai et al. 2012; Salamoura and Williams 2007). Outside English, this work has only looked at the dative alternation. Here we found evidence for priming among locatives in a typologically distinct language, Brazilian Portuguese, in accordance with the English results (e.g., Chang et al. 2003; Yi and Koenig 2016; Ziegler and Snedeker 2018). Because the syntactic structures for both locative types are the same in Brazilian Portuguese, as in English, this situates priming at the level of semantic structure (cf. the ambiguity of dative priming). These results therefore demonstrate that semantic structure contributes to priming in similar ways across a diverse set of languages.

In the remainder of this discussion, we will consider, in turn, (1) the possible influence of closed-class lexical overlap on our results, (2) how our results contribute to research on structural priming

[3] Note that this is consistent with the skewed frequency distribution of locative sentences reported for romance languages in the literature (e.g., Lewandowski 2014; Mateu 2017): participants produced *theme-location* locatives 35% of the time when unprimed (inverse of 65%) and only 49% when primed (inverse of 51%).

in Brazilian Portuguese, and (3) the relationship between typological variation and semantic structural priming in Romance vs. Germanic languages.

Contribution of closed-class lexical overlap

We now consider the degree to which repetition of closed-class lexical items may have influenced these results. Although there were never any content words (nouns or verbs) that repeated within a trial, it was frequently the case that prime sentences and target productions included the exact same prepositions. Specifically, the location-theme locative materials we constructed always used the preposition *com* "with," while our theme-location locatives always used the preposition *em* "in/on" (in *em* + *a* = *na* "in/on the" or *em* + *o* = *no* "in/on the"), and participants overwhelmingly used these same prepositions in their productions (except for in 3% of all cases). Thus, it is possible that the priming we observed is due entirely to the priming of specific prepositions. We cannot directly test this possibility using the current dataset. Critically, however, this confound is also present in English locative-to-locative priming studies as well: while theme-location locatives *can* occur with a variety of different prepositions (e.g., *around*, *in*[*to*], *on*[*to*], *over*), location-theme locatives almost exclusively use the preposition *with*. To the best of our knowledge, there have been no attempts to date to rule this confound out, although Chang et al. (2003) report similar levels of priming from theme-location locatives to other theme-location locatives as from location-theme locatives to other location-theme locatives [8% vs. 7%, respectively (standard coding)].

When we move beyond the locative alternation, the picture is equally unclear. For example, Bock (1989) found that *for*-datives (e.g., *The secretary is baking a cake for her boss*) were just as good at eliciting *to*-dative descriptions (e.g., *The girl is handing the paintbrush to the man on the ladder*) as other *to*-dative primes (e.g., *The secretary is taking a cake to her boss*; see also Chang et al. 2003; Ziegler and Snedeker 2018). On the other hand, Ziegler et al. (2018a) observed priming between intransitive locatives (e.g., *The 747 might land by the airport control tower*) and passives (e.g., *The 747 was radioed by the airport control tower*) only when the preposition *by* was repeated from prime to target (e.g., *by the airport control tower*) but not when it was not (e.g., *The 747 might land near the airport control tower*). This begs the question: if priming is sometimes mediated by closed-class lexical overlap, how can we predict when such mediation will occur and when it will not? And critically, how does this affect our interpretation of the present findings? As we discuss below (Sect. 4.2), active-passive priming and the priming of verb-phrase alternations appear to be systematically different. It could be that prepositions contribute to priming of the active-passive alternation, but we know of no evidence that they contribute to priming in verb-phrase alternations (e.g., locatives, datives). Clearly, more data would be useful, but we don't think lexically-mediated priming contributed here.

One way to directly test for the influence of closed-class lexical overlap on locative priming, at least in Brazilian Portuguese, would be to construct locative materials using other prepositions and see whether they still prime the more common use cases (or vice versa, given a large enough data set). For example, in addition to *em* "in/on," theme-location locatives in Brazilian Portuguese also allow the preposition *num*(*a*) "in/on." Likewise, location-theme locatives are also acceptable with the preposition *de* "of" in place of *com* "with" (Negrão and Viotti 2006), although some researchers have noted a slight semantic difference between the two at least in Spanish (see, e.g., Lewandowski 2014). Unfortunately, neither *de* "of" nor *num*(*a*) "in/on" occurred sufficiently frequently in our own data (4 and 3 occurrences, respectively) to investigate this possibility. A final alternative would be to prime locatives between languages (say, Brazilian Portuguese and English) in a bilingual population. We leave resolution of this question to future research.

Structural priming in Brazilian Portuguese

These results contribute to a growing body of structural priming research in Brazilian Portuguese. To date, there have been only a handful of priming studies in Brazilian Portuguese and all of them have used the active-passive alternation (Felicio 2018; Kramer 2016; Kuerten et al. 2016; Teixeira 2016; see also Santos 2017, for an investigation of cross-linguistic priming between Brazilian Portuguese and French). However, the active-passive alternation has a distinct status in many theories of argument realization relative to alternations like the locative and dative

that occur within the verb phrase (e.g., Bresnan 1982; Culicover and Jackendoff 2005; Goldberg 1995; Perlmutter and Postal 1983). The two syntactic realizations of both locatives and datives are believed to differ from one another on the basis of their underlying event structures (e.g., Anderson, 1971; Goldberg 1995; Pinker 1989; Rappaport and Levin 1988). The active-passive alternation, on the other hand, is typically assumed to result from a single semantic representation rather than two (e.g., Baker 1988; Bresnan 1982; Chomsky 1965; Katz and Postal 1964; though cf. Pinker 1989; for discussion, see Culicover and Jackendoff 2005). Thus, the difference between actives and passives is in their information structure, and not in their semantics. In particular, passive sentences serve to allow the argument which normally would be the object in an active sentence to be more topical, or the argument which would normally be the subject argument in an active sentence to be omitted. Accordingly, while the two syntactic realizations of locatives and datives reflect differences in underlying event representation, passivization imposes on a given event structure, once selected, a different surface ordering of its arguments and therefore a different discourse function without necessitating a change in meaning.[4] Consistent with this analysis, constructions like the locative and dative can serve as possible inputs to passivization (e.g., *The table was rubbed with polish*, *Polish was rubbed onto the table*, etc.).

Not surprisingly, the active-passive alternation also behaves in a fundamentally different way in priming studies. As we mentioned above, priming involving the active-passive alternation is sensitive to closed-class lexical overlap, while the priming of verb-phrase alternations is not (e.g., Bock 1989; Chang et al. 2003; Ziegler and Snedeker 2018; Ziegler et al. 2018a). There is also a difference in the degree to which these alternations are sensitive to priming on the basis of semantic overlap. Both the locative and the dative constructions show priming on the basis of semantic structure (see, e.g., Cai et al. 2012; Chang et al. 2003; Cho-Reyes et al. 2016; Hare and Goldberg 1999; Köhne et al. 2014; Pappert and Pechmann 2014; Salamoura and Williams 2007; Yi and Koenig 2016; Ziegler and Snedeker 2018; Ziegler et al. 2018b). In contrast, passive priming does not appear to be influenced by semantic structure (e.g., Bock and Loebell 1990; Messenger et al. 2012; Ziegler et al. 2018a). Indeed, Bock and Loebell (1990, Exp. 2) found that priming for passives was just as great after intransitive sentences with locative prepositional (*by*-)phrases (e.g., *The construction worker was digging by the bulldozer*) as it was after true passives (e.g., *The construction worker was hit by the bulldozer*; see also Ziegler et al. 2018a), suggesting that the thematic roles of the arguments is irrelevant for priming of this kind. This is readily explained if we assume that the active-passive alternation does not involve a semantic difference and thus both forms have the same event structure (e.g., [X ACT Z]). On this analysis, a passive prime cannot lead to more passive over active productions than an active prime on the basis of semantic structure alone; thus, it can only prime due to shared syntax or shared lexical content. Since these features are parallel in passives and intransitive locatives, we expect them to act as equivalent primes (for further discussion, see Ziegler et al. 2018b).

Critically, we contribute the first evidence of priming in Brazilian Portuguese that involves an alternation within the verb phrase or of semantic structural priming.

Typological variation and the priming of semantic structure

One major assumption of most theories of semantic representation is that there is a limited number of conceptual components (e.g., MANNER, PATH, CAUSE, BE AT, HAVE) that all languages use to create sentence meanings (for discussion, see Levin and Rappaport Hovav 2019). Languages differ, however, in how these components are expressed in surface syntax, giving rise to distinct lexicalization patterns (e.g., Talmy 1985, 2000). For example, to express motion events, Romance languages like Brazilian Portuguese typically encode path information in the verb and manner information in the satellite, while Germanic languages like English tend to encode manner information in the verb and path information in the satellite

[4] Passives and actives famously *can* differ in meaning (e.g., *Two languages are known by every linguist* vs. *Every linguist knows two languages*). However, such differences appear to stem from differences in scopal preference based on the differences in information structure (e.g., Goldberg 2006, ch. 8). Specifically, the more topical argument tends to have wider scope.

(Levin and Rappaport Hovav 2019; Talmy 1985, 2000).[5] Languages like English also make free use of verbal particles that express results of action (e.g., *toss out*, *eat up*, *run over*), allowing more event components to be crammed into the verb phrase, while languages like Brazilian Portuguese are more restrictive in their use of resultative constructions (Levin and Rappaport Hovav 2019; Mateu 2012; Mateu and Rigau 2010; Snyder 2001, 2012; Talmy 1991, 2000). Finally, Romance languages generally lack the dative alternation (see, e.g., Baker 1988; Gonçalves 2015; Larson 1988; though cf. Abreu Gomes 2003).

Some researchers have argued that these differences are a consequence of parametric variation in the types of syntactic argument realization operations available to languages (e.g., Mateu 2012; Mateu and Rigau 2010; Snyder 2001, 2012; though cf. Beavers et al. 2010). According to Mateu (2012) and Mateu and Rigau (2010), for instance, languages have at their disposal two operations for argument realization. One operation, which is assumed to be available to all languages, is called *incorporation*. Incorporation can be thought of as satisfying the standard selectional restrictions of a verb. For example, path verbs lexically entail a path and can therefore express caused or directed motion by incorporating (selecting for) an optional directional complement (e.g., *entrar no quarto* "to enter into the room"). In English, this directional complement can be null (e.g., *to enter* ∅ *the room*). Motion verbs, on the other hand, do not lexically entail a path and therefore cannot incorporate a directional complement to express caused or directed motion (but they can incorporate non-directional modifier adjuncts; e.g., *correr no quarto* "to run in the room"). Thus, in languages that only have incorporation, verb phrases like *to run into the room* are disallowed. This explains why Brazilian Portuguese and other Romance languages tend to encode path but not manner in the verb.

The second operation, called *conflation*, is only available in some languages. Conflation enhances the basic argument structure of a verb by adding an additional argument-taking head to it, thereby creating a "compound verb." In English and related languages, for instance, a motion verb can conflate with a null verbal head that itself selects for a directional complement, which can then be incorporated into the resulting compound verb (e.g., *to run into the room*). In contrast, in Brazilian Portuguese and other Romance languages, conflation is not available. Thus, motion verbs in these languages cannot take directional complements. Consequently, *correr no quarto* can only mean "run in the room" and not "run into the room." This explains why Germanic languages but not Romance languages permit resultative and verb-particle constructions.

This difference also accounts for why Germanic languages exhibit the dative alternation and why Romance languages do not, which is perhaps one reason why semantic structural priming has not been observed in Brazilian Portuguese until now. Specifically, the prepositional-object construction consists of a motion verb conflated with a path-taking null verbal head, thereby licensing the directional *to*-complement (e.g., *to give a bone to the dog*). For the double-object construction, the directional complement has a null head (e.g., *to give the dog* ∅ *a bone*). Germanic languages have conflation available to them and thus permit these constructions. However, conflation is not available in Romance languages, and thus these constructions do not exist. While Romance languages do appear to exhibit a counterpart to the English prepositional-object construction (e.g. *dar um osso ao cachorro* "to give a bone to the dog"), it has been argued that the preposition used for such cases (i.e., *a*) denotes location and not direction (for discussion, see Beavers et al. 2010). Thus, this construction could be characterized as a motion verb with an incorporated non-directional modifier adjunct.

Conclusion

We contribute the first evidence of semantic structural priming in Brazilian Portuguese. This finding demonstrates that the conceptual components which build sentence meanings are both present and similarly active in a wide range of typologically distinct languages (e.g., Brazilian Portuguese, Chinese, English, German). Exploring when and how the linguistic system's many levels of representation contribute to priming across the world's languages can put tangible constraints on theory, highlighting those aspects of structure which are universal and those which are

[5] Still other languages, like Chinese, have serial verb constructions that encode both manner and path in separate verbs (see, e.g., Levin and Rappaport Hovav 2019).

language-specific; a full theory of language will need to be held accountable for both. Thus, cross-linguistic work is invaluable to our understanding of the human language faculty at large.

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

Appendix A: Prime sentences

Verb	Location-theme	Theme-location
acertar "hit"	*A mulher acertou a rede com a raquete*	*A mulher acertou a raquete na rede*
	"The woman hit the net with the racquet"	"The woman hit the racquet on the net"
besuntar "smear"	*O homem besuntou o pão com a manteiga de amendoim*	*O homem besuntou a manteiga de amendoim no pão*
	"The man smeared the bread with the peanut butter"	"The man smeared the peanut butter on the bread"
borrifar "spray"	*O menino borrifou a planta com a água*	*O menino borrifou a água na planta*
	"The boy sprayed the plant with the water"	"The boy sprayed the water on the plant"
embrulhar "wrap"	*O homem embrulhou o presente com o papel de seda*	*O homem embrulhou o papel de seda no presente*
	"The man wrapped the present with the tissue paper"	"The man wrapped the tissue paper on the present"
enrolar "roll"	*A mulher enrolou a pizza com o papel filme*	*A mulher enrolou o papel filme na pizza*
	"The woman rolled the pizza with the plastic wrap"	"The woman rolled the plastic wrap on the pizza"
esfregar "rub"	*O menino esfregou o cabelo dele com o xampu*	*O menino esfregou o xampu no cabelo dele*
	"The boy rubbed his hair with the shampoo"	"The boy rubbed the shampoo on his hair"
lustrar "polish"	*A menina lustrou a mesa com o verniz*	*A menina lustrou o verniz na mesa*
rabiscar "scribble"	*A menina rabiscou o caderno com a canetinha*	*A menina rabiscou a canetinha no caderno*
	"The girl scribbled the notebook with the marker"	"The girl scribbled the marker on the notebook"

Appendix B: Target animations

Verb	Description
acertar "hit"	O menino acertando a trave com a bola/a bola na trave
	"The boy hitting the goal post with the ball/the ball on the goal post"
besuntar "smear"	A mulher besuntando o bolo com a cobertura/a cobertura no bolo
	"The woman smearing the cake with the frosting/the frosting on the cake"
borrifar "spray"	A menina borrifando o pescoço com o perfume/o perfume no pescoço
	"The girl spraying the neck with the perfume/the perfume on the neck"
embrulhar "wrap"	O homem embrulhando a caneca com o jornal/o jornal na caneca
	"The man wrapping the mug with the newspaper/the newspaper on the mug"
enrolar "roll"	A mulher enrolando o braço da criança com a faixa/a faixa no braço da criança
	"The woman rolling the arm with the bandage/the bandage on the arm"
esfregar "rub"	O homem esfregando as mãos com o sabão/o sabão nas mãos
	"The man rubbing the hands with the soap/the soap on the hands"
lustrar "polish"	O menino lustrando o sapato com a cêra/a cêra no sapato
	"The boy polishing the shoe with the wax/the wax on the shoe"
rabiscar "scribble"	A menina rabiscando o passeio com o giz/o giz no passeio
	"The girl scribbling the sidewalk with the chalk/the chalk on the sidewalk"

Appendix C: Supplementary material

The data associated with this article can be found at https://www.doi.org/10.17605/OSF.IO/MK2ES.

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