The Source-Goal Asymmetry in Motion Events: Sources Are Robustly Encoded in Memory but Overlooked at Test

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Abstract

Previous research demonstrated an asymmetry between Sources and Goals in people's linguistic and non-linguistic encoding of motion events: when describing events such as a fairy going from a tree to a flower, people mention the Goal ("to a flower") more often than the Source ("from a tree") and are better at detecting Goal changes in a Same-different memory test. Many take these findings as evidence for a homology between linguistic and conceptual representations: an unmentioned event component is also conceptually less robust. Here, we show that the nonlinguistic Source-Goal asymmetry disappears when memory is probed with a Forced-choice task instead of a Same-different task. We argue that, despite frequent absence from linguistic descriptions, Sources are robust in event memory, but not attended to during Same-different tests due to people's task-relevance assumption. This result bears on the nature of the Source-Goal asymmetry and calls for a finer-grained account for language-cognition homology.

Keywords: Source-Goal Asymmetry; Goal bias; Event Cognition; Thematic Roles; Psycholinguistics

Introduction

The same event can be described in many different ways depending on the speaker's perspective. For example, a simple event such as a squirrel going from a mailbox to a trash can, can be described as "The squirrel went to the trash can" or "The squirrel came from the mailbox" or "The squirrel went from the mailbox to the trash can". Recent research has demonstrated an asymmetry between the origins (Source) and endpoints (Goal) of motion events: when people describe the aforementioned example event, they mentioned the Goal ("to the trash can") more often than the Source ("from the mailbox") (Lakusta & Landau, 2005, 2012; Papafragou, 2010; Regier & Zheng, 2007; Do, Papafragou & Trueswell, 2020). This asymmetry in language holds in production studies as well as natural corpora (Stefanowitsch & Rohlde, 2004), for adults as well as children (Papafragou, 2010; Lakusta & Landau, 2012; Lakusta, Muentener, Petrillo, Mullanaphy, & Muniz, 2016), in different subtypes of motion events (Lakusta & Landau, 2005, 2012) as well as in typologically (even modally) different languages (e.g., Regier & Zheng, 2007; Johanson, Semilis, & Papafragou 2019, Zheng & Goldin-Meadow, 2002).

A parallel asymmetry has been found in the non-linguistic representation of motion events. Researchers found that Goals are more accurately encoded in memory than Sources of motion events (e.g., Papafragou, 2010; Regier & Zheng, 2007; Regier, 1996; Do et al., 2020). Such an asymmetry has even been observed in prelinguistic children (Lakusta, Wagner, O'Hearn, & Landau, 2007; Lakusta & Carey, 2015; Lakusta & DiFabrizio, 2017).

The Source-Goal asymmetry in both linguistic and non-linguistic encoding of motion events has led to accounts positing that the asymmetry has cognitive roots (Regier, 1996; Regier & Zheng, 2007; Lakusta & Landau, 2005; 2012; Papafragou, 2010), and provides evidence for the language-cognition homology. However, we need to caution against taking these results as evidence for an overly simplistic account of homology - what's not mentioned in language is also not encoded conceptually, because the exact nature of the cognitive basis for Source-goal asymmetry remains less clear. Regier and Zheng (2007) proposed that the conceptual bias for Goal stems from people's attentional bias to the end-point. This account would predict an across-the-board weaker encoding of Source since it's less likely to be attended to. However, researchers have found that, in motion events where the moving Figure is inanimate, unintentional or non-agentive (Lakusta et al., 2007; Lakusta & Landau, 2012; Lakusta & Carey, 2015; Lakusta & DiFabrizio, 2017), although the linguistic asymmetry persists, the memory of Source and Goal is equivalent. The lack of a conceptual asymmetry in these cases challenges any account that attributes the advantage for Goal to its stable conceptual prominence due to how it is spatially and/or temporally situated within the event. It appears that the Goal bias is modulated by at least some inferences about intentionality and causality in motion events. The mismatch between linguistic and memorial encoding of Sources and Goals also provides evidence against a straightforward mapping between the two.

Following these endeavors, we aim to further understand the nature of the conceptual Source-Goal asymmetry in the current study. We approach this by closely examining the methods we use to probe conceptual representation. To the best of our knowledge, all previous work reporting a conceptual Source-Goal Asymmetry used memory of Source and Goal as a proxy of representational robustness and used a Same-different task as the probe (Papafragou, 2010; Regier & Zheng, 2007; Regier, 1996; Do et al., 2020; Lakusta et al., 2007). In the Same-different task, participants viewed a set of motion videos and later compared new videos presented to them at test to their memorial representation of the previous target event and made a decision (same or different). Indeed, a lower accuracy at detecting changes to Source could be taken as an indication of less robust representation of Source in their memory. However, another possibility is that, when searching for differences (especially in a limited decision time window), participants prioritized examining the Figure and the Goal, overlooking the possibility that Source could be where the difference lies. In this latter case, the worse performance at detecting Source changes does not necessarily reflect weaker Source representation in memory, but rather people's deprioritization of Source at test when viewing the probe, influenced by top-down mechanisms of attention selection. In the current study, we try to disentangle these two possibilities by comparing the memory of Source and Goal probed with two different tasks.

To do so, we turn to another widely used test format in studies of memory: the Forced-choice task. In a Forced-choice task, after participants have encoded items in memory, pairs of items - a target and a foil - appear at the same time during the memory test phase, and the participants are asked to select the target. Despite general agreement that the Same-different and Forced-choice tasks are comparable measures of recognition memory (Bayley, Wixted, Hopkins & Squire, 2002; Green & Moses, 1966; Macmillan & Creelman, 1994; Khoe, Kroll, Yonelinas, Dobbins & Knight, 2000; Kroll, Yonelinas, Dobbins & Frederick, 2002), the two measures differ, specifically in the attentional advantage that a high-salience event component would receive during the memory test phase. In the specific case of motion events, if the memory test phase used a Forced-choice task, two events that only differ in Source (or Goal) would be directly juxtaposed, and participants would have to select which one was the original target event. Therefore, participants could not fail to attend to Sources. If the previously observed conceptual Source-Goal asymmetry lies in the differential robustness of encoding Source and Goal into the memory of the event, one would expect that the asymmetry should surface in both the Same-different task and the Forced-choice task. However, if the asymmetry is due to the differential attention allocated to Source at test, the asymmetry might arise only or primarily in the Same-different task and not in the Forced-choice task.

We tested these predictions below. Specifically, we conducted two pairs of experiments where we compared the memory for Sources and Goals, probed with a Same-different task and a Forced-choice task, after participants passively viewed (Exp 1a & 1b) or viewed and described (Exp 2a & 2b) the same set of motion events.

Experiment 1a: Passive Viewing (Same-Different)

In Experiment 1a, we sought to replicate the Source-Goal asymmetry shown in prior work using a Same-different task (cf. Regier & Zheng, 2007; Lakusta & Landau, 2012; Papafragou, 2010; Do et al., 2020).

Methods

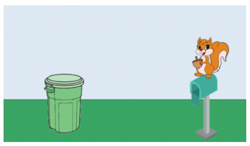
Participants Eighty-two native speakers of American English recruited on Prolific (www.prolific.co) participated for compensation at a rate of \$6.5/hour. The number of participants was determined based on a power analysis of previously reported effects in the literature.

Materials We created 16 critical video clips, each of which depicted an animate Figure moving from an inanimate Source landmark (i.e. the starting point of motion) to an inanimate Goal landmark (i.e. the end point of motion). The Figure, Source and Goal were all represented by clipart images (See Figure 1a for an example of a critical clip). The motion was achieved through Powerpoint Animation. Each clip lasts five seconds.

The direction of the motion in the clips were left-right counterbalanced such that half of our clips showed a Figure moving from left to right and the other half showed a figure moving from right to left. We constructed two experimental lists to counterbalance Source and Goal landmarks such that objects which were the Sources in one list were the Goals in the other. We also created 12 filler motion events, which did not involve a Source/Goal path (e.g., A ghost moves around the moon).

To probe speakers' conceptual encoding of Sources and Goals in memory, we also constructed foil videos that involved either a Source Change or a Goal Change. Source and Goal changes were always within-category (e.g., the mailbox was changed to another mailbox, see comparison of Figure 1a and 1b).

Procedure Participants were directed to this online experiment via a URL link. First, in order to minimize the familiarity effect in the memory task, we familiarized participants with all the clipart images that would later appear in either the target video clips or the foil video clips in the memory task. These pictures were presented one at a time at the center of the screen and proceeded automatically every two seconds. Then, participants proceeded to the exposure phase, where they were asked to carefully view video clips and were told that we would ask them questions about these video clips later. The 28 clips were presented in a pseudo-random order. Each video clip disappeared after it played once. Meanwhile, participants heard a beep and automatically proceeded to the next trial 2.5s after the beep[1].



(Figure 1a) (Figure 1b)

Figure 1: (a) Sample first-frame of the event "the squirrel went from the mailbox to the trash can". (b) Sample first-frame of a test trial of this event involving Source change in the Same-different memory task.

The test phase immediately followed. During each test trial, participants were shown the Source Change/Goal Change variants of the critical videos. For each participant, half of the critical items had a Source Change and the other half had a Goal Change. For each critical event, each participant was either tested with a Source Change or a Goal Change. Which item was a Source or Goal change was counterbalanced across participants. Events were tested in a different pseudo-random order from the order in which they were viewed. Participants were instructed to click 'Yes' if the video clip shown here at test was 'exactly the same' as the clip that they had originally seen and click 'No' otherwise. For fillers, the memory phase displayed the "No Change" (original) version of the clips. Thus, correct responses on critical events were always 'No' and the correct response for filler events was always 'Yes'. (See Figure 2 for a sample trial). There was no time limit on participants' response, and the video was on a loop.

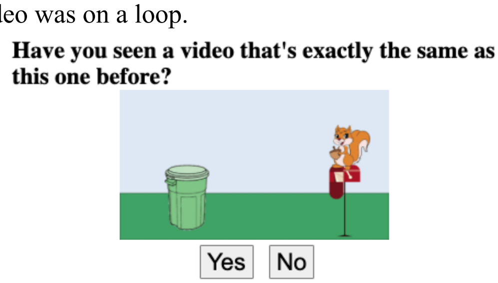


Figure 2: Sample Same-different test trial in Exp 1a.

Analysis In order to test whether Goal landmarks were remembered more accurately than the Source landmarks, we built a logistic mixed-effect model predicting whether the response on a critical trial was correct with a fixed effect of Change Type (Goal vs Source, sum coded) and by-subject and by-item random intercepts.[2] Participants who always selected "Yes" were excluded from analysis (n = 2).

Results and Discussion

In line with prior work in the literature, we found that participants were significantly more likely to detect a Goal change when probed with a Same-different task (β=0.335, SE=0.084, p<0.001) (See Figure 3 Left). Exp 1a thus fully replicated the Source-Goal asymmetry observed in prior work: Participants were more sensitive to Goal change than to Source change in the same motion event.

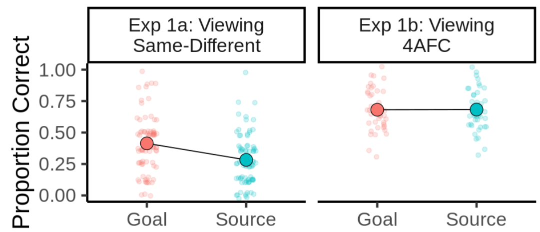


Figure 3: Participants' mean proportion of correct Goal and Source response at memory test in Exp 1a and 1b. In Exp 1a, correct response refers to successfully detecting the change of Goal/Source. In Exp 1b, correct response refers to selecting the event that contains the correct Goal/Source.

Experiment 1b: Passive Viewing (Forced-Choice)

Experiment 1b was exactly the same as Exp 1a, except that we probed the memory of the landmarks with a Forced-choice task.

Methods

Participants Forty native speakers of American English recruited on Prolific participated for compensation at a rate of $6.5/hour.

Procedure The only difference between Exp 1a and 1b was in the memory test. This time, on each trial, participants chose which video they had seen from 4 options: the target, a foil that only differed in the Source, a foil that only differed in the Goal and a foil that differed in both (See Figure 4 for an example sample memory test trial). Foil clipart images were the same ones used in Exp 1a.

Analysis In order to analyze the memory data in a comparable way to Experiment 1a, we coded each Forced-choice memory test trial for whether the event

[1] This transition duration is chosen because it corresponds to response time of typing in sentence descriptions of these events in Experiment 2a & 2b.

[2] When deciding the random-effect structure of the model, we always started out with a maximal model (including by-subject and by-item random slopes of Change Type, in this case) and only simplified the structure when non-convergence and singularity were encountered and no non-intrusive method could resolve these issues. We report the final random-effect structure.

chosen by the participant contained the correct Goal (0 vs 1) and/or the correct Source (0 vs 1) respectively. Then, we built the same logistic mixed-effect model as Experiment 1a, predicting correct response with Change Type (Goal vs Source, sum coded) as a fixed effect and by-subject and by-item random intercepts.

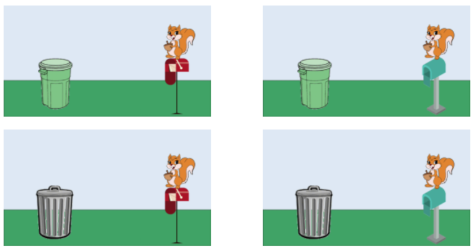


Figure 4: Sample Forced-choice test trial in Exp 1b.

Results and Discussion

Contrary to Exp 1a, the Goal bias disappeared when probed with a Forced-choice task (p=0. 671) (See Figure 3 Right). Thus it seems that - despite the failure to recover Source information in a Same-different task, Source information is not lost from the event representation.

Experiment 2a: Production (Same-Different)

In previous literature, it has been reported that the Source-Goal asymmetry persists even when participants describe the motion events, and not simply view them passively (e.g., Do et al., 2020). To make sure that the difference we observed in the previous pair of experiments still holds in a variety of contexts, Experiment 2a and 2b probed the memory of Source and Goal using a Same-different vs. Forced-choice task after participants provided a linguistic description of motion events.

Methods

Participants Eighty-three native speakers of American English recruited from the University of Pennsylvania subject pool and Prolific participated in the experiment[3]. The University subjects received course credit, and the Prolific subjects were compensated at a rate of $6.5/hour.

Procedures In Exp 2a, instead of passively viewing the events, participants typed in the description in a text box cued by a beep after the video played once and disappeared. The rest of the experiment was identical to Exp 1a.

Analysis We built a logistic mixed-effects model to analyze the linguistic description data. We predicted landmark mention with Role type (Goal vs Source) as a fixed effect and included by-subject and by-item random intercepts as well as random slopes of Role type.

The memory data were analyzed with a logistic mixed-effects model similar to the one in Experiment 1a. However, in order to look at how participants' description of these events interacted with memory, we added Source Mention (Mentioned vs Not mentioned, sum coded) and its interaction with Change Type as fixed effects and by-subject and by-item random intercepts. Five participants were excluded for always selecting "Yes".

Results and Discussion

Language Production We replicated the Goal bias in language observed in prior work: participants were more likely to mention the Goal than the Source in their descriptions of the events (β=1.091, SE=0.085, p<0.001) (Figure 5 Top-Left).

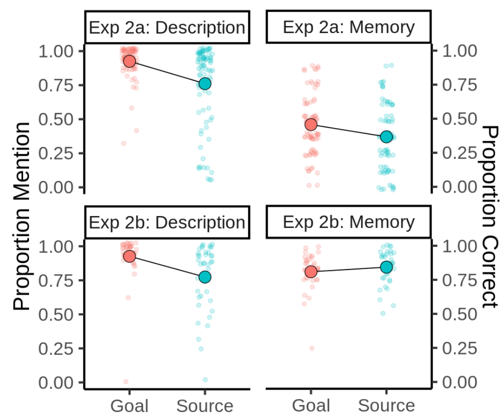


Figure 5: Participants' mean proportion of mentioning Goal/Source in their linguistic description and mean proportion of correct Goal/Source response at memory test in Exp 2a and 2b.

Memory for Sources and Goals As shown in Figure 5 (Top-Right), just like in Experiment 1a, there was a main effect of Change Type: participants were more likely to detect Goal changes than Source changes (β=0.274, SE=0.083, p<0.001).

Additionally, there was a main effect of Source Mention: participants were more accurate on events for which their description earlier included Source (β = 0.287, SE = 0.104, p = 0.006). In Figure 6, we plotted participants' memory data by whether they mentioned Source before during description of these events to illustrate this effect. As can be seen from the linguistic data (Figure 5 Top-Left), Goal was almost always mentioned (95% of the trials), whereas Source was mentioned less (77% of the trials). Therefore, trials with Source mention were mostly trials that elicited both Source and Goal mentions[4]. It is thus not surprising

[3] To ensure that we recruited participants with comparable demographic distributions from the two platforms, we screened for monolingual English speakers aged between 18 and 26 who indicated student status on Prolific for all of the experiments.

[4] Only 27 trials (2% of total) elicited Source-only description.

that we see slightly better memory performance on these trials because these were trials of participants who were generally paying more attention or trials that had more perceptually salient Goals and (particularly) Sources.

However, importantly, the interaction between Source Mention and Change Type was not significant (p=0.571). That is to say, the discrepancy between memory of Source and Goal probed by a Same-different task was not modulated by whether Source was mentioned in the description (Figure 6). Regardless of the type of descriptions they gave, participants showed a Goal bias in memory when probed with a Same-different task.

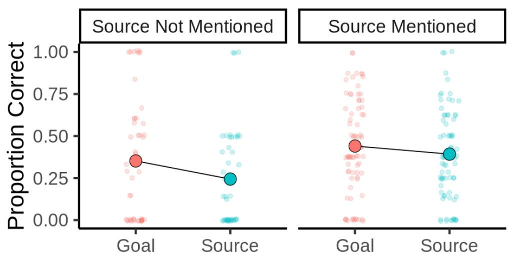


Figure 6: Participants' proportion of correct Goal/Source response at memory test on trials that elicited Source mention during description vs trials that did not in Exp 2a.

Experiment 2b:Production (Forced-Choice)

Methods

Participants Forty native speakers of American English recruited from the same University subject pool as Exp 2a participated for course credit.

Procedures The only difference between Exp 2a and 2b is that a Forced-choice task was used to test memory instead of the Same-different task.

Results and Discussion

Language Production We analyzed the language production data with the same method as Exp 2a. As shown in Figure 5 (Bottom-Left), the pattern was identical to Exp 2a: participants were significantly more likely to include Goals than Sources in their descriptions of the motion events (β=0.980, SE=0.115, p<0.001).

Memory for Sources and Goals We analyzed the memory data with the same method as Exp 2a. In the final model, we included by-subject and by-item random intercepts as well as by-subject and by-item random slopes of Change Type. As shown in Figure 5 (Bottom-Right), contrary to Exp 2a, there was no effect of Change Type (p=0.892). The memory of Source and Goal were equivalent when probed by the Forced-choice task. There was still a main effect of Source Mention: participants were more accurate on events in which they mentioned the Source during description (β=0.419, SE=0.102, p<0.001). However, crucially, this time the interaction between Change Type and Source Mention was significant (β=-0.200, SE=0.093, p=0.031). As shown in Figure 7 as well as suggested by post hoc comparisons achieved with R emmeans package, the interaction was driven by the drastically different performance on Source: in cases where Source was mentioned (alone or along the Goal), the memory of Source was in turn better (β= 1.238, SE=0.267, p<.0001). In other words, memory probed with the Forced-choice task seemed to more straightforwardly map onto the description patterns: the event component that received higher attention at encoding, thus selected for mention, was also more robust in memory. We will return to the implications of this result in the general discussion.

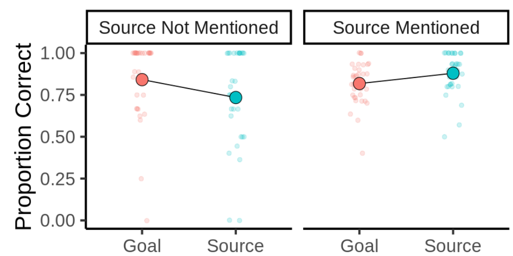


Figure 7: Participants' proportion of correct Goal/Source responses at memory test on trials that elicited Source mention during description vs. trials that did not in Exp 2b.

Levels of Performance Across Paradigms and Exps In line with previous research comparing memory paradigms, participants' performance in the Forced-choice task was overall better than in the Same-different task in terms of the proportion of correct responses before any conversion (cf. Green & Moses, 1966; Deffenbacher, Leu & Brown, 1981; Macmillan & Creelman, 1994). Furthermore, our participants' performance in the Same-different task (Exp 1a, 2a) was lower than what was reported in previous studies; we attribute this drop in overall accuracy to our open-ended instructions about the memory test (e.g., we did not give examples of what a change to the event might look like), as well as the fact that stimuli were presented in a different random order between memory exposure and test. One might wonder whether either or both of these facts affected our main conclusion. For instance, could the lack of a Source-Goal asymmetry in the Forced-choice task be due to ceiling effects?

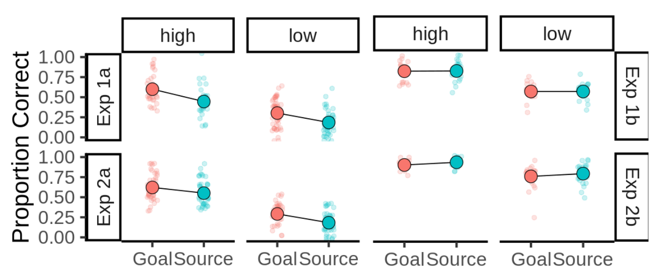


Figure 8: High- versus low-accuracy participants' mean proportion of correct Goal/Source response at memory test in Exp 1a, 1b, 2a and 2b.

To address this concern, we split the participants in all four experiments into high and low accuracy groups based on whether their overall memory accuracy was above or below median respectively. As shown in Figure 8, and contrary to this alternative explanation, the Goal bias was attested in both better-performing and worse-performing participants when a Same-different task was used, and not attested in either group when a Forced-choice task was used.

General Discussion

Prior work has shown that Sources and Goals of motion events are not mentioned equally frequently when people describe motion or remembered equally accurately when memory of motion is probed with a Same-different task (Papafragou, 2010; Regier & Zheng, 2007; Regier, 1996; Do et al., 2020). Many commentators have taken this asymmetry as an indication that the human mind represents Sources of motion in a less robust way: just like Sources are less likely to be selected for mention, they are less likely to enter the conceptual representation of the event. The results of our experiments offer a different account: while confirming that Sources, unlike Goals, are frequently absent from people's linguistic description of motion events (Exp 2a, 2b), our data show that Sources nonetheless enjoyed equally robust representation in the memory of the event as revealed by specific testing conditions. Specifically, the previously observed memory bias only appeared in a Same-different task (Exp 1a, 2a), where participants could prioritize where to look for potential differences themselves, but not in a Forced-choice task (Exp 1b, 2b), where participants' attention was explicitly equally directed to contrasts of Sources and Goals. These patterns held both after participants passively viewed motion events and after they provided linguistic descriptions of the events.

Based on these results, we argue that, contrary to common belief, the cognitive bias against Source (and in favor of Goal) does not lie in encoding: when given specific visual alternatives (like in Exp 1b & 2b), people are as likely to recognize the correct Source as they are to recognize the correct Goal. The Source information is well encoded and not lost in representation. Rather, the disadvantage of Sources likely results from what happens at test: people overlook the Source (but not the Goal) in the Same-different test. What can account for such a bias at test? A first possibility is that this effect is due to a low-order attentional bias favoring the endpoint of the motion trajectory (Regier & Zheng, 2007). However, this would mean that, during both encoding and test, participants are subject to the same attentional bias against Source. Since the account predicts that Source was hurt at encoding, it should be less accurately remembered regardless of the memory probe. However, this contradicts with the fact that the non-linguistic encoding of Source was not hurt when probed with a Forced-choice task (Exp 1b & 2b).

A second, and we think more likely, possibility is that the attentional bias against Sources at test stems from an assumption that people carry into the test - specifically, that Source is not what they are going to be tested on. This is reminiscent of the recent finding that pragmatic factors such as informativity modulate the linguistic Goal bias (Do et al., 2020): speakers leave Sources out of their descriptions because they believe it is not necessary to mention them to their interlocutors (unlike Goals). In a Same-different test, people did not prioritize to consider the possibility that the Source would be the critical element when every aspect of the event could potentially differ from the original and lead to a "different" decision. In other words, this attentional bias is a result of a top-down computation of what is likely to be relevant in the current cognitive task.

The analysis of how linguistic description and memory interact in Exp 2a and 2b further supports our task-relevance account of the Source-Goal asymmetry. In Exp 2a, under a Same-different test, a Goal bias in memory appeared regardless of the type of description participants had provided for the event earlier. In other words, even when people mentioned Sources in description earlier, they still tended to overlook Sources at test in the Same-different task. However, in Exp 2b, the encoding advantage of those Sources that are mentioned in linguistic description surfaced in the Forced-choice memory task. In some sense, the Forced-choice task is a more sensitive probe to the underlying motion event representation per se: the Same-different task introduces an additional, less constrained attention selection process during the test simply because of the multiplicity of factors that can make two events "the same" or "different".

In future work, we hope to further investigate the task-relevance account by testing several concrete predictions that it makes. First, it straightforwardly predicts that the shorter time participants have to decide, and the more complex the scene, the more likely they are going to overlook the Source in a Same-different task. Second, explicit manipulations of the task-relevance of Sources should modulate the memory of Sources in the Same-different task as well.

To conclude, our results show that, different from common belief, Sources in motion events are just as well encoded in memory as Goals, but overlooked at test. What is selected for mention in a linguistic description of an event does not exhaust what is conceptually encoded. Thus, the linguistic Source-Goal asymmetry cannot be fully rooted in a cognitive asymmetry: what sometimes appears to be a conceptual disadvantage of Sources might instead be influenced by pragmatic (task-relevant) factors that are malleable and flexible. Our results challenge the presence of a strict homology between linguistic and non-linguistic encoding of events and call for a finer-grained account of how these two processes interact across contexts and tasks.

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References

Bayley, P. J., Wixted, J. T., Hopkins, R. O., & Squire, L. R. (2008). Yes/no recognition, forced-choice recognition, and the human hippocampus. *Journal of Cognitive Neuroscience*, 20(3), 505-512.

Deffenbacher, K. A., Leu, J. R., & Brown, E. L. (1981). Memory for faces: Testing method, encoding strategy, and confidence. *American Journal of Psychology,* 94, 13–26.

Do, M. L., Papafragou, A., & Trueswell, J. (2020). Cognitive and pragmatic factors in language production: Evidence from source-goal motion events. *Cognition*, 205, 104447.

Green, D. M., & Moses, F. L. (1966). On the equivalence of two recognition measures of short-term memory. *Psychological Bulletin*, 66(3), 228.

Johanson, M., Selimis, S., & Papafragou, A. (2019). The Source-Goal asymmetry in spatial language: Language general vs. language-specific aspects. *Language, Cognition and Neuroscience.*

Khoe, W., Kroll, N. E., Yonelinas, A. P., Dobbins, I. G., & Knight, R. T. (2000). The contribution of recollection and familiarity to yes–no and forced-choice recognition tests in healthy subjects and amnesics. Neuropsychologia, 38(10), 1333-1341.

Kroll, N. E., Yonelinas, A. P., Dobbins, I. G., & Frederick, C. M. (2002). Separating sensitivity from response bias: Implications of comparisons of yes-no and forced-choice tests for models and measures of recognition memory. *Journal of Experimental Psychology: General*, 131(2), 241.

Lakusta, L., & Carey, S. (2015). Twelve-month-old infants' encoding of goal and source paths in 'agentive' and 'nonagentive' motion events. *Language Learning and Development,* 11, 152–175.

Lakusta, L., & DiFrabrizio, S. (2017). And, the Winner Is…A Visual Preference for Endpoints over Starting Points in Infants' Motion Event Representations. *Infancy*, 23, 323–343.

Lakusta, L., & Landau, B. (2005). Starting at the end: The importance of goals in spatial language. *Cognition*, 96, 1–33.

Lakusta, L., & Landau, B. (2012). Language and Memory for Motion Events: Origins of the Asymmetry Between Source and Goal Paths. *Cognitive Science*, 36, 517–544.

Lakusta, L., Muentener, P., Petrillo, L., Mullanaphy, N., & Muniz, L. (2016). Does Making Something Move Matter? Representations of Goals and Sources in Motion Events With Causal Sources. *Cognitive Science*, 41, 1–13.

Lakusta, L., Spinelli, D., & Garcia, K. (2017). The relationship between pre-verbal event representations and semantic structures: The case of goal and source paths. *Cognition*, 164, 174-187.

Lakusta, L., Wagner, L., O'Hearn, K., & Landau, B. (2007). Conceptual foundations of spatial language: Evidence for a goal bias in infants. *Language Learning and Development*, 3, 179–197.

Macmillan, N. A., & Creelman, C. D. (1994). *Detection theory: A user's guide.* Psychology press.

Melcher, D., & Piazza, M. (2011). The role of attentional priority and saliency in determining capacity limits in enumeration and visual working memory. *PloS one*, 6(12), e29296.

Papafragou, A. (2010). Source-goal asymmetries in motion representation: Implications for language production and comprehension. *Cognitive Science*, 34, 1064–1092.

Regier, T. (1996). *The human semantic potential: Spatial language and constrained connectionism.* Cambridge, MA: MIT Press.

Regier, T., & Zheng, M. (2007). Attention to endpoints: A cross-linguistic constraint on spatial meaning. *Cognitive Science*, 31, 705–719.

Rohde, H., Kehler, A. and Elman, J. (2006). Event Structure and Discourse Coherence Biases in Pronoun Interpretation. *Proceedings of the Annual Meeting of the Cognitive Science Society*, 28, 697-702.

Stefanowitsch, A., & Rohlde, A. (2004). The goal bias in the encoding of motion events. In G. Radden & K.-U. Panther (Eds.), *Studies in linguistic motivation.* Berlin: Mouton de Gruyter

Zheng, M. & Goldin-Meadow, S. (2002). Thought before language: how deaf and hearing children express motion events across cultures. *Cognition*, 85, 145-175.