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Motion verbs and memory for motion events

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ABSTRACT

Language is assumed to affect memory by offering an additional medium of encoding visual stimuli. Given that natural languages differ, cross-linguistic differences might impact memory processes. We investigate the role of motion verbs on memory for motion events in speakers of English, which preferentially encodes *manner* in motion verbs (e.g., *driving*), and Greek, which tends to encode *path* of motion in verbs (e.g., *entering*). Participants viewed a series of motion events and we later assessed their memory of the path and manner of the original events. There were no effects of language-specific biases on memory when participants watched events in silence; both English and Greek speakers remembered paths better than manners of motion. Moreover, even when motion verbs were available (either produced by or heard by the participants), they affected memory similarly regardless of the participants' language: path verbs attenuated memory for manners of motion, but the reverse did not occur. We conclude that overt language affects motion memory, but these effects interact with underlying, shared biases in how viewers represent motion events.

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Memory; motion events; motion verbs; path and manner; Greek

It is widely recognized that language plays a role in memory. Most of the available evidence for this conclusion comes from experimental paradigms in which people were given explicit linguistic cues when processing a visual stimulus. In an early study, participants saw ambiguous abstract drawings (e.g., a trapezoid shape) coupled with linguistic labels (e.g., *beehive* vs. *hat*). When later asked to draw the object they saw, the participants were more likely to produce a representation closer to the label they had heard than the figure they had actually seen (Carmichael, Hogan, & Walter, 1932). In more recent work, sentences containing spatial prepositions (e.g., "The block is on the building") paired with ambiguous spatial scenes (a block precariously balanced right on the edge of the top of a building) caused memory distortions: participants were more likely to remember seeing a more prototypical block-on-the-building picture later, with the block being further away from the edge (Feist & Gentner, 2007).

The effects of language on memory are not limited to vague, schematic or ambiguous visual stimuli, but extend to realistic scenes in photographs. In a classic series of papers, participants' memory for visual scenes was affected by misleading information that was presented verbally after the scenes (Loftus, 1975, 1979; Loftus & Palmer, 1974; Loftus, Miller, & Burns, 1978). In another study, the linguistic level used for categorizing an object in a visual scene (e.g., general: "This is a computer" vs. specific: "This is Peter's computer") affected subsequent memory performance, with changes to objects categorized at the specific level being detected faster than those categorized at the general level (Archambault, O'Donnell, & Schyns, 1999). Relatedly, overtly classifying objects at the basic level (e.g., "chair", "table") adversely affected recognition memory for the less typical members of a category (Lupyan, 2008). Other work suggests that implicit linguistic encoding of visual scenes can enhance memory accuracy for those scenes (Allport, Antonis, & Reynolds, 1972; Antes & Kristjanson, 1993; Loftus, 1972; Rowe & Rogers, 1975; Wolfe, Horowitz, & Michod, 2007). The effects of language on memory appear early in life: labels change infants' memory for individual objects (La Tourrette & Waxman, 2018), and overt linguistic

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descriptions referencing spatial configurations help older children bind and retain in memory features of the spatial display (Dessalegn & Landau, 2008, 2013).

Despite the ubiquity of these effects, the exact role that language plays in memory remains open. For instance, there are different possible ways to characterize the representational level at which the linguistic and visual levels of representation interact (depending on whether the linguistic stimuli are taken to transform the visual stimuli or come into play at some later processing stage; see Firestone & Scholl, 2016; McCloskey & Zaragosa, 1985; Paivio, 1971). More relevant for present purposes, there are different possible ways of generalizing these findings to situations in which people have to remember visual stimuli but are not engaged in linguistic processing (i.e., no labels are present). According to some commentators, language—even if not overtly engaged—is expected to deeply shape non-linguistic cognition, including perception and memory, because people need to encode their experience in a language-compatible format in case they need to talk about it later (Brown & Levinson, 1993; Levinson, 2003; Lucy, 1996; Majid, Bowerman, Kita, Haun, & Levinson, 2004; Pederson et al., 1998; Slobin 2003). Others have argued for an alternative view according to which language offers an additional, highly efficient but optional system of categorizing and encoding visual stimuli that does not alter, let alone determine, the underlying conceptual representations (Gleitman & Papafragou, 2005; Landau, Dessalegn, & Goldberg, 2010; Trueswell & Papafragou, 2010).

These issues acquire particular importance if one considers that natural languages differ in their lexical-semantic and morphosyntactic properties. Could such cross-linguistic differences impact memory processes, and if so, how? In the domain of space, perhaps the best-documented area of cross-linguistic variation, linguistic encoding preferences have often been shown to go hand in hand with performance on memory and other cognitive tasks (Bowerman, 1996; Levinson, 2003; Levinson & Wilkins, 2006). For instance, languages differ in the availability or use of frames of reference: English or Dutch use egocentric (*left-right*) terminology to encode small-scale arrays and Tzeltal Mayan uses allocentric (*north–south*) terminology. These patterns parallel patterns that emerge in spatial reasoning and spatial memory tasks in which participants need to silently represent, store and process spatial configurations (Brown & Levinson, 1993; Levinson & Wilkins, 2006; Majid et al., 2004; Pederson et al., 1998; cf. Haun, Call, Janzen, & Levinson, 2006; Haun, Rapold, Janzen, & Levinson, 2011). To take another example, languages differ in encoding spatial location: English distinguishes between the relations of containment (e.g., "putting an apple in a bowl") and support (e.g., "putting a cup on a table"), and Korean distinguishes instead between the relations of tight fit (e.g., "putting a hand in a glove") and loose fit (e.g., "putting an apple in a bowl"; Bowerman & Choi, 2001). Even though infants in both English- and Korean-speaking communities are able to distinguish between tight-fit/loose-fit relations in non-linguistic tasks (Casasola & Cohen, 2002; Hespos & Spelke, 2004; McDonough, Choi, & Mandler, 2003), adults attend to the tight-fit/loose-fit distinction only if their language encodes it (as is the case in Korean but not English; Hespos & Spelke, 2004; McDonough et al., 2003).

These effects of language on cognition, however, are malleable and context-sensitive. For instance, the choice of frame of reference in non-linguistic spatial tasks depends on task demands in ways that go well beyond the preferences of one's native language (Li & Gleitman, 2002). Furthermore, people can reason about spatial frames of reference that their language does not encode, thereby revealing a richness of cognitive resources that is not indexed by language (Le Guen, 2011; Li, Abarbanell, Gleitman, & Papafragou, 2011). Similarly, in the domain of spatial relations, newer tasks have shown that, despite earlier reports, both English- and Korean-speaking adults are sensitive to the non-linguistic distinction of tightness-of-fit (Norbury, Waxman, & Song, 2008). In addition, tight-fit relations are more salient than loose-fit relations for both groups (ibid.), pointing to the presence of a shared conceptual bias despite cross-linguistic differences (although see Yun & Choi, 2018 for a different perspective).

Taken as a whole, this literature suggests that language can be a tool for memory even when not explicitly invoked. Furthermore, such effects of language are flexible and do not seem to create deep and stable cognitive discontinuities among speakers of different languages. One limitation in the present state of the art though is that there is a gap between established paradigms in the study of

memory that have probed the role of language by using overt linguistic labels within a single language and cross-linguistic studies on memory that have typically conducted memory experiments in the absence of overt linguistic encoding. One way of bridging the two strands of literature would be to test memory for the same stimuli with and without labels across different languages. Such an approach would allow us to probe for the stability and nature of linguistic effects and could throw light on the question of whether identical linguistic stimuli would have a different role in promoting memory across languages depending on whether they are consistent with language-specific encoding preferences. Furthermore, it would be interesting to vary the source of the linguistic stimuli. Most prior studies on the role of overt language on memory relied on experimenter-provided labels (Archambault et al., 1999; Carmichael et al., 1932; Feist & Gentner, 2007). A more recent cross-linguistic study, however, found that participant-generated descriptions did not affect later spatial memory (Bosse & Papafragou, 2018), so the issue merits further investigation. The present study uses cross-linguistic evidence from the domain of motion to fill this gap.

Motion: A test case for the relation of language and memory

Languages differ in how they encode motion events (Talmy, 1975, 1985, 1991). While all languages have means to encode both the path of motion (i.e., the movement towards or from a point), and the manner of motion (i.e., the means through which motion is achieved, or its characteristic qualities), they differ systematically in how path and manner information are conflated in sentences. According to Talmy's typology, speakers of satellite-framed languages (e.g., English, German) tend to encode manner of motion information in the matrix verb (e.g., *drive*, *run*, *jump*) and path in adpositional phrases or particles ("satellites"; e.g., *into the cave*, *out*, etc.). Conversely, speakers of verb-framed languages (e.g., Greek, Spanish, Hebrew) prefer to encode the path of motion in the matrix verb (e.g., Greek: *beno* "enter", *kateveno* "descend", etc.) and manner in optional and often omitted gerunds, adpositional phrases, or adverbials (e.g., Greek: *odhigontas* "driving", *me to aftokinito* "with the car", etc.). This is not meant to imply that manner and path languages entirely lack certain kinds of verbs but rather that the most typical and unmarked way of describing motion events falls along the lines described here. This typological dichotomy affects how speakers describe motion events (Berthele, 2013, 2017; Bunger, Papafragou, & Trueswell, 2013; Bunger, Skordos, Trueswell, & Papafragou, 2016, under review; Durst-Andersen, Smith, & Thomsen, 2013; Gennari, Sloman, Malt, & Fitch, 2002; Georgakopoulos, Härtl, & Sioupi, 2019; Ji, Hendriks, & Hickmann, 2011; Montero-Melis & Bylund, 2017; Naigles, Eisenberg, Kako, Highter, & McGraw, 1998; Özçalışkan & Slobin, 1999, 2003), appears early in children's speech (Allen et al., 2007; Özyürek et al., 2008; Papafragou, Massey, & Gleitman, 2002, 2006; Slobin, 1996, 2003, 2004), and affects construals of novel motion predicates in both children and adults (Maguire et al., 2010; Naigles & Terrazas, 1998; Papafragou & Selimis, 2010; Skordos & Papafragou, 2014).

There is evidence that memory for motion is not affected by language-specific encoding effects. For instance, Papafragou et al. (2002) found that, even though children and adult speakers of English and Greek described motion events differently, they did not differ in the way they categorized or remembered these events (see also Gennari et al., 2002, for similar findings from an English-Spanish comparison). In an eye-tracking study in which English- and Greek-speaking adults had to silently study an unfolding event in preparation for a memory task, eyegaze patterns were identical across language groups, suggesting that event apprehension was not driven by viewers' native language (Papafragou, Hulbert, & Trueswell, 2008).

Nevertheless, language can be used as an additional, online system that optionally assists the encoding and remembering of motion information. In the eye-tracking study above (Papafragou et al., 2008), after event inspection was complete and people had additional time to attend to the event, people inspected path and manner regions in a way driven by their native language, arguably because they verbalized internally to help commit details of the motion event to memory (see also Bunger, Trueswell, & Papafragou, 2012). These effects disappeared when language use was blocked by a secondary task that involved verbal interference—and thus prevented participants from utilizing language as an

ancillary system for memory—but survived under non-verbal interference (Trueswell & Papafragou, 2010; cf. Athanasopoulos et al., 2015; Athanasopoulos & Bylund, 2013; Montero-Melis & Bylund, 2017). Even when participants covertly used language in preparation for a memory task, they did not show measurable gains in memory accuracy; furthermore, memory for manners and paths did not differ in English and Greek speakers (Papafragou et al., 2008; Trueswell & Papafragou, 2010).

Other studies have challenged the conclusion that motion cognition is unaffected by language-specific encoding patterns. Kersten and colleagues (Kersten et al., 2010) report that monolingual English speakers performed better than English/Spanish bilinguals tested in Spanish when they had to categorize a number of novel bug-like creatures based on their manners of motion, while the two groups performed equally well when they had to categorize the same novel creatures based on their paths of motion. This held both when the novel creatures were identified with linguistic labels corresponding to names, and when they were identified with numbers. Since this study did not attempt to block use of language, however, it is possible that participants were employing language covertly during the task. Consistent with this possibility, in a further experiment, the behaviour of English/Spanish bilinguals varied depending on the language they were tested in: when tested in Spanish, they were less likely than English speakers to use manner as a criterion for categorization, but when tested in English, they performed similarly to the monolingual English speakers. The fact that the language of testing has such a strong effect on these bilinguals demonstrates that these are not in fact effects of language on non-linguistic cognition, but essentially effects of language on language: in all likelihood, participants verbalized and therefore conceptualized and later categorized events in a way that was compatible with the language of testing (similar observations apply to the recognition memory study reported in Filipović, 2011). The role of language on motion cognition remains an active area of investigation and debate (cf. Flecken, Athanasopoulos, Kuipers, & Thierry, 2015; Gerwien & von Stutterheim, 2018).

Against this background, the present study revisited the role of language on memory in the domain of motion events. A first goal was to probe the relation between language and recognition memory in adult speakers of different languages (English vs. Greek) in the absence of any linguistic cues. A second goal was to see whether the overt presence of path or manner verbs would affect memory and would do so in similar ways cross-linguistically. A third goal was to assess whether any effects of overt motion verbs would generalize across tasks.

Specifically, in a series of three experiments using the same stimuli and general procedure as prior studies (Trueswell & Papafragou, 2010; Bunger et al., 2012), we showed English- and Greek-speaking adults motion events with manner (e.g., driving) and path (e.g., entering) components and asked them to (a) watch each motion event silently and try to remember it (Experiment 1), (b) spontaneously produce a verb while watching the motion event (Experiment 2), or (c) comprehend and maintain in memory a motion verb provided by the experimenter while watching the event (Experiment 3). In all three cases, we later assessed participants' memory of the path and manner components of the original events. To approximate everyday situations in which people use or interpret language as they process incoming visual stimuli, in Experiments 2 and 3 we did not inform participants that a memory task would follow.

Of interest was whether, as past work had suggested (e.g., Trueswell & Papafragou, 2010), English and Greek speakers would represent and retain motion events in similar ways if they did not have to speak or understand language during exposure to the events (Experiment 1). Of greater interest was whether English and Greek speakers' recognition memory for motion events would be differentially affected by the use of specific path or manner verbs during exposure (Experiments 2 and 3). One possibility, inspired by within-language work on the role of words on memory (Carmichael et al., 1932; Dessalegn & Landau, 2008, 2013; Feist & Gentner, 2007; La Tourrette & Waxman, 2018; Loftus, 1979; Lupyan, 2008), was that memory for paths would be worse if event apprehension was accompanied by manner verbs (and vice versa for memory for manners), regardless of the participants' native language. Alternatively, the impact of motion verbs on recognition memory might depend on whether the verbs fit language-specific lexicalization patterns. If so, the same linguistic stimulus could

produce different effects on memory of the same visual event for speakers of different languages. In the simplest instantiation of this hypothesis, verbs whose meaning (path vs. manner) aligns with the dimension that tends to be lexicalized most strongly in motion verbs within each language should have the strongest influence on memory since lexicalization represents habitually attended semantic dimensions (cf. Oh, 2003; as well as Pederson et al., 1998, for such a perspective). On this view, manner verbs should be more likely to decrease memory for paths in English compared to Greek speakers (and vice versa for path verbs).[1]

Finally, of interest was whether any potential effects of verbs on motion memory would depend on the way verbs were introduced: spontaneously generated by the participants (Experiment 2) vs. provided by the experimenter (Experiment 3) as participants viewed the events. Notice that production and comprehension are inherently asymmetrical. When speakers produce a verb to describe a motion event, they have to select from among multiple dimensions of the event the one that they will encode. By contrast, when listeners hear a verb and have to process it while watching an entity in motion, they need to recover what the speaker intended to convey and hence might attend to the motion through the zoom lens of that verb. In the present context, since the verbs are intentionally introduced by the experimenter, participants might consider them especially relevant for processing later visual stimuli. Given these differences between tasks, it is possible that presenting participants with verbs (as in Experiment 3) might interfere more intensely with motion event apprehension and later memory compared to asking participants themselves to produce verbs (as in Experiment 2). In support of this possibility, most prior studies reporting influences of overt language on memory have used experimenter-provided labels (Archambault et al., 1999; Carmichael et al., 1932; Feist & Gentner, 2007). The role of participant-generated descriptions on later spatial memory has been studied less and has mainly produced negative results (Bosse & Papafragou, 2018; Gennari et al., 2002; Papafragou et al., 2002).

Experiment 1: Event memory without linguistic cues

Participants

The sample consisted of 32 adult native English speakers and 30 adult native Greek speakers. The English-speaking participants were students at either the University of Delaware or the University of Pennsylvania and received course credit for their participation. The Greek-speaking participants were students at either the University of Athens or the Technological Educational Institute of Peloponnese in Greece and received either course credit or monetary compensation for participating. All participants provided written consent before being tested.

Materials

Stimuli were 24 short videos of animated clip art drawings. Target trials included 12 motion events in which a human or animal agent moved with the assistance of an instrument to reach a landmark representing a path endpoint. Still frames from the beginning, middle, and end of one of the target events can be seen in Figure 1: in the clip that these images are taken from, the alien driving a car moved across the scene space from right to left, ending in the mouth of the cave. Distinct visual elements represented the manner and

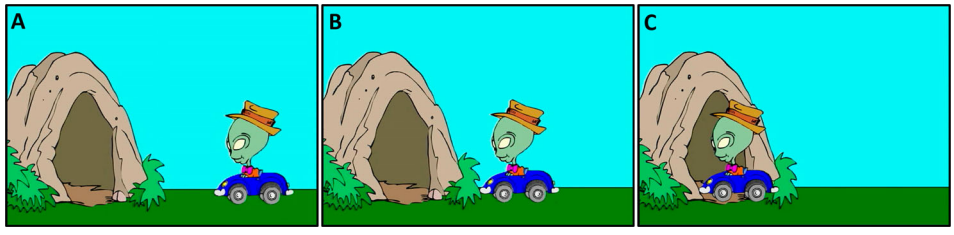

Figure 1. Still frames taken from the start (A) midpoint (B) and endpoint (C) of a motion event. In this example, an alien (agent) driving a car (manner) moves across the screen and into the mouth of a cave (path). [To view this figure in colour, please see the online version of this journal.]

path components in each event. The manner of motion was represented by an instrument or vehicle (e.g., driving a car, riding a motorcycle) and the agent rode on or in this instrument toward a static landmark that determined the actual path (e.g., into a cave, to a carwash).

A comprehensive list of the 12 target events is in the Appendix. Two versions of each target clip were put together for the memory task (target-change events). In the Manner-change version (Figure 2(A)), the instrument or vehicle used by the agent to reach the endpoint was replaced by another instrument or vehicle (e.g., the alien's car was replaced by an airplane). In the Path-change version (Figure 2(B)), the landmark defining the path changed such that the corresponding relation between the agent and the landmark also changed (e.g., the alien drove *to* a rock, instead of driving *into* a cave). Independent testing was conducted to assess the degree of visual difference in Manner- vs. Path-change versions of each target video. English speaking adults (n = 10) viewed pairs of videos consisting of a target event and one changed version (a total of 24 pairs of videos) and had to rate on a 5-point Likert scale (1 = not very different; 5 = very different) how visually different the pairs were. Their ratings revealed no significant difference for Manner vs. Path changes (average ratings for Manner-change vs. target: 2.81 and Path-change vs. target: 2.97; t-test on item means: $t(11) = 0.6$, $p = 0.56$).

Filler trials included 12 videos that featured animate agents and inanimate objects in events that did not include specified endpoints (e.g., throwing a basketball in the air). In both test and filler trials, movement lasted for 3 sec, at which point an audio stimulus (beep) was heard. Apart from the audio stimulus, the videos featured no sound. After movement ended and the audio stimulus sounded, the final frame of each video remained on screen for an additional time of 2 sec.

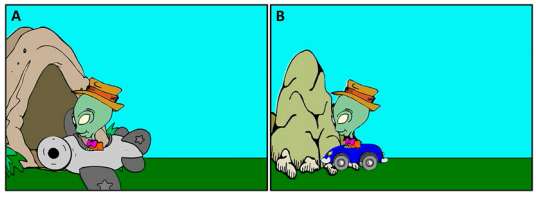

Figure 2. Still frames taken from the endpoint of target events showing changes to the Manner (A) and Path (B) components of the event depicted in Figure 1. Frame A depicts a Manner change with the alien moving into the mouth of a cave flying an airplane instead of driving a car. Frame B depicts a Path change with the alien driving to a rock instead of driving into the mouth of a cave. [To view this figure in colour, please see the online version of this journal.]

Procedure and experimental design

Participants were tested in a quiet room at their respective university campuses. Testing was conducted by an experimenter who carried out all conversations in the participants' native language. Participants were told that they would be viewing short animated clips of a man or an animal doing something. They were also told that they had to remember the clips as best as they could because at the end of the set they would see another set of animated clips and they would have to indicate whether they were the same or different from the ones they saw before. Participants were discouraged from overtly encoding the event linguistically: participants who began to give descriptions or otherwise talk were asked to "watch quietly". The stimuli were presented as follows: During the initial inspection phase, participants viewed a set of 24 animated clips consisting of 12 target and 12 filler items. Once the presentation of this set was concluded, they were told that the Memory test would start and that they had to say "whether each clip is the same or different" from the one they saw before. They then proceeded immediately to the memory test phase in which they viewed a second set of 24 animated clips consisting of 12 target-change events and 12 fillers.

Participants viewed one of two batteries of stimuli. In each battery the 24 clips of the inspection phase were shown in a fixed random order, followed by the 24 clips of the memory task phase in the same fixed random order. Filler events shown during the memory task phase were identical to the filler events that participants saw in the inspection phase, while target-change events were always different. The twelve target-change events were evenly divided into Manner changes and Path changes and distributed among the batteries. This meant that the 6 Manner target-change events in battery one were Path changes in battery two, and vice versa. The presentation of events in the memory task phase was paced by the experimenter so that participants would move on to the next event in the battery as soon as they provided a judgment for the previous

one. Between all clips during both the inspection and the memory task phase, participants viewed a white screen with a black plus sign just above its centre. Participants' responses in the memory task were recorded on an answer sheet and later transcribed and coded.

Results

Participants' accuracy during the memory task phase was assessed by comparing Same/Different judgments with the actual changes to target stimuli in each battery. Following Barr, Levy, Scheepers, and Tily (2013), here and in all subsequent experiments we used multilevel mixed logit modelling for confirmatory analyses with the maximal model structure permitted by our design and sum coding of variables for contrasts. In cases where the maximal model failed to converge, we first used an optimizer (bobyqa) to increase the maximum number of iterations to 100.000 and if that failed started trimming random effects by removing those with the smaller variance first. To run the analyses, we used R version 3.6.1 (R Core Team, 2019) and the lme4 package version 1.1-21. Table 1 summarizes the data.

We analysed the data using multilevel logistic modelling of accuracy in detecting changes of Manners and Paths by using binary accuracy values (correct = 1, incorrect = 0) for each subject-item pair. Language (English, Greek), Type of Change (Manner, Path) and the interaction between Language and Type of Change were entered into the model as first-level fixed factors. Random factors included the intercept and slope for Subjects as well as the intercept for Events (=Items). This model revealed effects of Language, with Greek speakers being overall less accurate than English speakers, and Type of Change, with changes to Manners being more difficult to detect than changes to Path (Table 2).

Discussion

In Experiment 1, English speakers performed somewhat better than Greek speakers in remembering motion events. This could be due to the English-speaking participants' greater familiarity with similar testing procedures, or to other reasons related to the populations we tested. The participants' native language did not differentially affect memory for path vs. manner of motion, in accordance with prior findings not favouring relativistic views on the relation between language (motion verbs) and memory (Papafragou et al., 2002; Trueswell & Papafragou, 2010, among others).

In fact, path changes were easier to detect than manner changes regardless of the participants' linguistic background. This finding is reminiscent of past memory studies on motion events: in one of these studies that included 4- to 7-year-olds, 9- to 12-year-olds and adults (Papafragou et al., 2002), the ability to detect manner changes was low in young children and developed with age, but the ability to detect path changes stayed constant across age groups (see also Bunger et al., 2012). The present finding is also consistent with work showing that infants, after watching a series of motion events, can extract the invariable path component of motion before they can do so for manner (Pruden, Hirsh-Pasek, Maguire, & Meyer, 2004; Pulverman, Sootsman, Golinkoff, & Hirsh-Pasek, 2003) and prefer to interpret novel motion verbs as path-denoting before they acquire the lexicalization patterns of their language around age of 3 years (Maguire et al., 2010). In addition to this, non-literal uses of motion verbs, i.e., those involving metaphor and fictive motion, by very young children acquiring Greek and English initially occur with path rather than manner verbs in both languages (Selimis & Katis, 2010). All of these strands of work suggest that path of motion might be more central to motion events compared to manner of motion.

Table 1. Proportion accuracy and standard errors in detecting changes to Manner and Path event components in Experiment 1.

	Manner change	Path change
English	0.75 (±0.031)	0.86 (±0.025)
Greek	0.66 (±0.037)	0.77 (± 0.031)

Table 2. Fixed effects from maximal multilevel logistic model of accuracy in detecting changes to Manner and Path components.

Effect	Estimate	Std. error	Z-value	Pr(>|z|)	
(Intercept)	1.4605	0.2116	6.901	5.18E-12	***
Language (ref: Greek)	−0.6797	0.3306	−2.056	0.03978	*
Type of Change (ref: Manner)	−0.6563	0.2256	−2.909	0.00363	**
Language (ref: Greek) by Type of Change (ref: Manner)	0.2127	0.3958	0.537	0.591	n.s.

*Significant at $p < 0.05$,**significant at $p < 0.01$, ***significant at $p < 0.001$. Code used in R: <- glmer (accuracy ~ Language * Change + (1 + Change| Subject) + (1|Event), data = EXP1, family = "binomial").

Experiment 2: Verb production and event memory

Participants

The sample consisted of 43 adult native English speakers and 35 adult native Greek speakers. The English-speaking participants were students at either the University of Delaware or the University of Pennsylvania and received course credit for their participation. The Greek-speaking participants were students at the University of Athens, the Technological Educational Institute of Peloponnese in Greece or the University of Delaware. They received monetary compensation or course credit for participating. All participants provided written consent before being tested.

Materials

The stimuli were identical to those used for Experiment 1.

Procedure and experimental design

The procedure was similar to that in Experiment 1 with the following difference: Participants were once again told that they would be viewing "short animated clips" of "a man or an animal doing something". It was explained to them that once each event concluded, an audio prompt (beep) would be heard. They were told that they had to produce a single verb in their native language describing the event they just viewed when they heard the audio prompt. Participants were not informed that a memory task would follow. The verbs produced by participants were recorded in an answer sheet and were later transcribed and coded.

Results

Beginning with participants' verb productions, verbs that referred to the agent's manner of motion (e.g., *fly*/Greek: *petai*) were coded as Manner verbs, and those that referred to the relationship between the agent's motion and the path endpoint (e.g., *enter*/Greek: *beni*) were coded as Path verbs. Cases in which participants produced a verb that could not be classified as either Manner or Path, produced both a Manner and a Path verb, produced nothing, or used another term entirely were coded as "Other". These cases constituted 61 tokens out of a total of 1235 and were excluded from analyses. A summary of Manner and Path verb uses is given in Table 3.

We analysed the verb production data using multilevel logistic modelling of verb production by using binary values (Path = 1, Manner = 0) for each subject-item pair. Language (English, Greek) was entered into the model as a first-level fixed factor, with Subjects and Events as random intercepts. This model revealed an effect of Language. As shown in Table 4, Greek speakers were more likely to produce Path verbs than English speakers.

The participants' accuracy in detecting changes to the Manner and Path components of the motion events is shown in Table 5.

We analysed the data using multilevel logistic modelling of accuracy in detecting changes of Manners and Paths, by using binary accuracy values (correct = 1, incorrect = 0) for each subject-item pair. Language (English, Greek), Type of Verb Produced (Manner, Path), Type of Change (Manner, Path) and all interactions were entered into the model as first-level fixed factors, with a random intercept and slope for Subjects and a random intercept for Events. This model revealed an effect of Language, with Greek speakers being less accurate overall at detecting changes to motion event components (Manner, Path); an effect of Type of Change, with changes to Manners of motion being more difficult to detect than changes to Paths; and finally a Type of Verb Produced by Type of Change interaction: Changes to Manner were more difficult to detect when participants produced Path verbs, regardless of their language background, but the reverse did not hold. Moreover, the three-way interaction between Language, Type of Change and Type of Verb produced was not significant (Table 6).

Table 3. Proportion of type of verb produced (Manner, Path) and standard errors during the inspection phase in Experiment 2.

	Manner verb	Path verb
English	0.81 (±0.01)	0.19 (±0.01)
Greek	0.59 (±0.02)	0.41 (±0.02)

Table 4. Fixed effects from maximal multilevel logistic model of production of path verbs.

Effect	Estimate	Std. error	z-Value	Pr(>|z|)
(Intercept)	−1.4011	0.3343	−4.192	2.77E-05***
Language (ref: Greek)	1.5107	0.2626	5.752	8.80E-09***

*Significant at $p < 0.05$,**significant at $p < 0.01$, ***significant at $p < 0.001$. Code used in R: <- glmer (accuracy ~ Language * Change + (1 + Change| Subject) + (1|Event), data = EXP1, family = "binomial").

Table 5. Proportion accuracy and standard errors in detecting changes to Manner and Path event components in Experiment 2.

	Manner verb produced		Path verb produced	
	Manner changes	Path changes	Manner changes	Path changes
English	0.82 (±0.02)	0.80 (±0.02)	0.73 (±0.05)	0.87 (±0.05)
Greek	0.69 (±0.03)	0.67 (±0.03)	0.59 (±0.04)	0.84 (±0.04)

Table 6. Fixed effects from maximal multilevel linear model of accuracy in detecting changes to manner and path components.

Effect	Estimate	Std. error	z-Value	Pr(>|z|)	
(Intercept)	1.3955	0.20596	6.775	1.24E-11	***
Language, Greek	−0.7573	0.28525	−2.655	0.00793	**
Type of Change, Manner	−0.60957	0.20851	−2.924	0.00346	**
Type of Verb Produced, Path	0.08025	0.21105	0.38	0.70375	n.s.
Language, Greek by Type of Change, Manner	−0.15209	0.38489	−0.395	0.69274	n.s.
Language, Greek by Type of Verb Produced, Path	0.41121	0.40185	1.023	0.30617	n.s.
Type of Change, Manner by Type of Verb Produced, Path	−1.61893	0.37694	−4.295	1.75E-05	**
Language, Greek by Type of Change, Manner by Type of Verb Produced, Path	−0.06863	0.74947	−0.092	0.92704	n.s.

**Significant at $p < 0.01$, ***significant at $p < 0.001$. Code used in R: <- glmer (accuracy ~ Language * Change * Production + (1 + Change |Subject) + (1| Event), data = EXP2, family = "binomial", control = glmerControl (optimizer = "bobyqa", optCtrl = list (maxfun = 100,000))).

Discussion

In Experiment 2 we asked English and Greek speakers to describe a series of motion events using single verbs and later tested their recognition of path and manner aspects of the original motion events. There were several main findings. First, English and Greek speakers differed in the kind of verb they produced to describe motion: in accordance with well-known language-specific lexicalization biases, Greek speakers were more likely to produce path verbs compared to English speakers (see Papafragou et al., 2002, 2006 among many others). Second, as in our first experiment, English speakers performed better in the memory task compared to Greek speakers. Third, as before, detecting changes to manners of motion proved overall more difficult than detecting changes to paths of motion. Fourth, and importantly, spontaneously produced path verbs attenuated later memory for manners of motion, while manner verbs did not seem to have a similar effect on memory for paths of motion. Interestingly, these effects held regardless of the native language (and lexicalization biases) of the speakers.

Why should motion verbs affect memory only in a subset of the above manipulations? We hypothesize that this is largely a result of the fact that manners typically constitute more peripheral aspects of motion events compared to paths. Manners tended to be harder than paths to remember in general in both this experiment and in Experiment 1 and are considered less salient and important components of motion compared to paths, especially for telic events (Bunger et al., 2012; Papafragou et al., 2002, 2006; Pruden et al., 2004; Pulverman et al., 2003). As a result, the ability to retain manner details of a motion event (e.g., whether the event involved skating vs. skiing, or driving vs. flying) might be more vulnerable and malleable by linguistic cues compared to the ability to remember path aspects of the event (e.g., whether the event involved entering or reaching a reference point).

Experiment 3: Verb comprehension and event memory

Participants

The sample consisted of 71 adult native English speakers and 56 adult native Greek speakers. The English-speaking participants were students at either the University of Delaware or the University of Pennsylvania and received course credit for their participation. The Greek-speaking participants were students at either the University of Ioannina or the Technological Educational Institute of Peloponnese in Greece. They received either monetary compensation or course credit for participating. All participants provided written consent before being tested. None of them had participated in our earlier studies.

Materials

The stimuli were identical to those used in Experiments 1 and 2.

Procedure and experimental design

The procedure was similar to that in Experiment 1 with the following differences: Participants from each language group were divided between two conditions, the Manner condition (English n = 41, Greek n = 21) and the Path condition (English n = 30, Greek

n = 35). During the initial inspection phase, participants were told that they would be given a verb before each event and that they would have to repeat the verb after hearing the audio stimulus (beep). Verbs were verbally provided by the experimenter during the black screen that appeared before the motion event. In the Manner condition, participants were provided with semantically equivalent manner-encoding verbs in their native language (e.g., *fly/petai*) and in the Path condition they were provided with semantically equivalent path-encoding verbs (e.g., *enter/beni*). The verbs provided were sourced from those produced by English and Greek-speaking participants in Experiment 2 to describe the corresponding events. The verbs in Greek had 3rd person singular present morphology (there is no morphologically unmarked infinitive form). A full list of the verbs used can be seen in the Appendix. Participants were not informed that a memory task would follow.

Results

Table 7 summarizes memory accuracy. As in previous experiments, we analysed the data using multilevel logistic modelling of accuracy in detecting changes of Manners and Paths by using binary accuracy values (correct = 1, incorrect = 0) for each subject-item pair. Language (English, Greek), Type of Verb Provided (Manner, Path), Type of Change (Manner, Path) and all interactions were entered into the model as first-level fixed factors, with a random intercept and slope for Subjects and a random intercept for Events. This model revealed an effect of Language, with Greek speakers being less accurate overall at detecting changes to motion event components (Manner, Path); an effect of Type of Change, with changes to Manners of motion being more difficult to detect than changes to Paths; and finally, a Type of Verb Provided by Type of Change interaction: Changes to Manner were more difficult to detect when participants were provided with Path verbs, regardless of their language background (Table 8).

Table 7. Proportion accuracy in detecting changes to manner and path event components in Experiment 3.

	Manner verb provided		Path verb provided	
	Manner change	Path change	Manner change	Path change
English	0.67 (±0.03)	0.72 (±0.03)	0.63 (±0.03)	0.80 (±0.03)
Greek	0.60 (±0.04)	0.67 (±0.04)	0.49 (±0.03)	0.71 (±0.03)

Discussion

In Experiment 3, we provided participants with path and manner verbs that could function as labels for dynamically unfolding motion events and that had to be maintained in memory as the events developed. Depending on the participants' language background (English vs. Greek), these verbs either aligned or conflicted with language-specific (manner-oriented vs. path-oriented) verb lexicalization biases. Furthermore, the verbs either aligned or conflicted with the motion event component that would later change during the memory task. We found that the presence of verbs made a difference for speakers of both languages, but only in one combination of verb and event change: when given a path verb, both Greek and English speakers became significantly less accurate in noticing manner changes. Thus motion verbs can affect recognition memory, but the way they do so depends on whether they interfere with more central (path) or more peripheral (manner) components of motion events. Path as a central component of motion events seems to be quite resilient to manner verb intrusions. Conversely, path verbs attenuate memory for manners regardless of the participants' native language (and verb lexicalization biases).

Table 8. Fixed effects from maximal multilevel linear model of accuracy in detecting changes to manner and path components.

Effect	Estimate	Std. error	z-Value	Pr(>|z|)	
(Intercept)	0.89508	0.24055	3.721	0.0002	***
Language (ref: Greek)	−0.5703	0.21666	−2.632	0.00848	**
Type of Change (ref: Manner)	−0.8059	0.14864	−5.422	5.91E-08	***
Type of Verb Provided (ref: Path)	0.06007	0.21616	0.278	0.78108	n.s
Language (ref: Greek) by Type of Change (ref: Manner)	0.02754	0.28708	0.096	0.92359	n.s
Language (ref: Greek) by Type of Verb Provided (ref: Path)	−0.3361	0.43185	−0.778	0.43635	n.s
Type of Change (ref: Manner) by Type of Verb Provided (ref: Path)	−0.8323	0.2824	−2.947	0.00321	**
Language, Greek, by Type of Change, Manner by Type of Verb provided, Path	−0.0708	0.5697	−0.124	0.90107	n.s

**Significant at $p < 0.01$, ***significant at $p < 0.001$. Code used in R: <- glmer (accuracy ~ Language * Change * VerbProv + (1 + Change |Subject) + (1| Event), data = EXP3, family = "binomial", control = glmerControl (optimizer = "bobyqa", optCtrl = list (maxfun = 100,000))).

It is worth considering an alternative account according to which the effect of path verbs on memory for manner across Experiments 2 and 3 is not related to an asymmetry between path and manner but might occur for different reasons in the two languages in our sample. On this account, in English speakers, path verbs might result in worse memory for manners because they violate the typical (manner) verb lexicalization pattern. In Greek speakers, however, path verbs might result at a cost for manner memory because such verbs draw attention away from manner information, which is not typically encoded in other elements of the sentence (although it can be if the speaker chooses to do so). On this account, manner verbs do not lead to worse memory for paths in speakers of English because this group could be used to distributing attention across both manner (in verbs) and path (in adpositional or other phrases) in their typical use of language. However, this account does not explain why manner verbs do not lead to worse memory for paths in speakers of Greek: this would mirror the cost observed in English for violating a verb lexicalization bias. Furthermore, by not linking the results from Experiments 2 and 3 to those of Experiment 1, this account does not integrate the fact that, across language populations, path information was remembered better than manner information when no verb is present. We conclude that this alternative account is unlikely to explain the patterns in our data.

General discussion

In this study, we explored the impact of cross-linguistic differences on memory with a focus on the domain of motion. In three experiments, we asked whether preferences for conflating path/manner information in motion verbs in English and Greek might affect memory for paths and manners of motion in speakers of the two languages even when no language was overtly used as participants experienced the events (Experiment 1). We also investigated the effects that overtly introduced motion verbs, whether produced spontaneously by participants (Experiment 2) or given by the experimenter (Experiment 3), had on participants' memory for motion events.

We found that native language biases to encode manner or path did not affect memory for motion in the absence of linguistic encoding during event apprehension (Experiment 1). Similarly, native language lexicalization biases did not affect motion memory under conditions in which participants were asked to provide (Experiment 2) or were given (Experiment 3) a single verb as they watched motion events. In all three experiments, we found that—regardless of the participants' native language—motion paths were easier to commit to memory than motion manners, presumably because they were more central to the representation of motion itself—its "core schema" in Talmy's (1991) words. Most importantly, path verbs negatively affected memory for manners of motion (but the reverse did not happen)—again presumably because manners of motion were more peripheral to motion representation and hence more vulnerable to linguistic intrusions. This effect of path verbs on memory emerged regardless of whether path verbs were produced (Experiment 2) or simply heard and understood by participants (Experiment 3).

Our findings have important implications for theories about the interaction between language and memory. As we discussed in the Introduction, one prominent position in the literature is that language is always engaged when people perceive, reason about and commit to memory details about the world, including aspects of space and motion. According to this position, the by-default engagement of language has profound effects on non-linguistic memory and cognition by forcing non-linguistic perception and memory to conform to a language-compatible format, thus ensuring that what is actually perceived is shaped by what can be later talked about (Brown & Levinson, 1993; Levinson, 2003; Lucy, 1996; Majid et al., 2004; Pederson et al., 1998; Slobin, 2003). Our findings provide evidence against this position. No interactions between native language and type of change were observed in Experiment 1, despite the fact that we explicitly informed participants that a memory task would follow and did not restrict their ability to use language covertly (for instance, we did not use a verbal shadowing task); thus participants had both reason and ample opportunity to covertly use language to encode the motion events for later recall. An even stronger demonstration of this absence of language-specific effects was found in Experiment 2: even when people were asked to simply observe and describe motion using a single verb, their native language did not affect their recollection of the events, despite the fact that their

linguistic descriptions clearly matched language-specific lexicalization biases (with English speakers producing more manner verbs than Greek speakers). These findings show that aspects of visual memory are largely independent of native language.

This observation echoes other recent experimental investigations that have examined the potential influence of cross-linguistic differences on memory. For instance, German encodes the axial position of an inanimate figure object that is supported by a ground object (in sentences of the type "The book is standing/lying on the chair") but English does not (*The book is on the chair*). Nevertheless, when German and English speakers were tested on their ability to detect changes in the axial position of objects during recognition memory tasks, they performed similarly: even when participants were asked to describe the spatial scenes as they initially viewed them, later memory performance did not differ between the two language groups (Bosse & Papafragou, 2018; cf. Flecken & van Bergen, 2019). Similar results characterize the more abstract domain of evidentiality (i.e., the linguistic encoding of information source). English does not encode source of information grammatically, but Turkish marks the source of information with obligatory morphemes on past-tense verbs: a direct morpheme indicates direct (often visual) evidence for an event and an indirect morpheme indicates hearsay or inference from a clue. Ünal, Pinto, Bunger, and Papafragou (2016) asked whether the availability of these obligatory grammatical evidential morphemes would affect people's notoriously unreliable memories of how they experienced an event (documented previously in English speakers; Durso & Johnson, 1980; Fazio & Marsh, 2010). Ünal and colleagues showed English and Turkish speakers photographs in which events could be inferred from visual clues (e.g., bubbles travelling through the air next to a girl). In a later recognition task, participants were shown versions of the photographs where the same events could be *seen* (e.g., the girl blowing bubbles). English and Turkish speakers were very similar in the number and types of memory errors they made: specifically, both groups about 30% of the time reported having seen an event that they had only inferred from clues. Thus, the availability of an obligatory grammatical distinction did not protect Turkish speakers from a prevalent sort of memory error.

Even though language does not seem to have a lasting or pervasive effect on visual memory, the findings of both Experiments 2 and 3 strongly suggest that linguistic labels made available as people process events can affect what is remembered and can exert their influence in similar ways across different linguistic communities. These results comport with and extend the literature on the effects of language on memory that has so far relied exclusively on evidence from English-speaking adults (Carmichael et al., 1932; Dessalegn & Landau, 2008, 2013; Feist & Gentner, 2007; La Tourrette & Waxman, 2018; Loftus, 1979; Lupyan, 2008). Furthermore, these results suggest that linguistic processes engaged during production or comprehension offer an additional, optional system for categorizing and encoding visual stimuli online without altering or determining the underlying conceptual representations (Gleitman & Papafragou, 2005; Landau et al., 2010; Trueswell & Papafragou, 2010).

A particularly important aspect of our findings is that these online effects of language interact with non-linguistic biases of event conceptualization: what people remembered in Experiments 2 and 3 depended on the interrelation between the semantics of the specific motion verbs and prior conceptual biases that determined the salience of individual event components. Peripheral components of motion events such as manners of motion appear to be vulnerable to the availability of path verbs. Central components, however, such as paths of motion appear to be impervious to linguistic intrusions from manner verbs. These effects occur regardless of participants' native language, thereby revealing commonalities in the way that a linguistic stimulus can affect spatial memory across linguistic communities.

The present work leaves open a number of further directions. First, Experiments 2 and 3 focused on the role of language during event inspection. It would have been interesting to also examine potential effects of language during the memory test phase (i.e., when participants are asked to recognize an event as old or new). In other domains such as number, linguistic effects on non-linguistic representations emerge during initial inspection of the stimuli but not at test (Frank, Fedorenko, Lai, Saxe, & Gibson, 2012). It is an open question whether access to language during the test phase affected the memory results.

Second (and related to the above), even though in this case recognition memory was *impaired* by language, it is possible that in other contexts language can have a beneficial effect. For instance, as we discussed in the Introduction, there is evidence that language can lead to both memory distortion (Carmichael et al., 1932; Feist & Gentner, 2007; Loftus, 1979; Lupyan, 2008) and memory facilitation (Allport et al., 1972; Antes & Kristjanson, 1993; Archambault et al., 1999; Loftus, 1972; Rowe & Rogers, 1975; Wolfe et al., 2007). The above findings can be reconciled if one considers that language, whether overt or covert, might either help strengthen non-linguistic perceptual memory or distort it by pulling it closer to a category mean and abstracting away perceptual details that might be important. For example, if viewers label a particular vase in a display, they might later be better at remembering that they saw a vase (as opposed to a jug), but they might be worse at remembering its other characteristics (colour, height, decoration). The above observations strongly predict that language should make between-category changes easier to detect but within-category changes more difficult (cf. Lupyan, 2008, for the additional role of typicality).

Finally, the present experiments have focused on the role of verbs in memory for motion. However, motion and space meanings are often encoded in prepositions and other linguistic devices that are also characterized by cross-language variability (Bowerman, 1996; Bowerman & Choi, 2001; Gentner & Bowerman, 2009; but cf. Landau, Johannes, Skordos, & Papafragou, 2017, for cross-linguistic similarities). A more complete synthesis of how linguistic patterns might influence memory should consider the broader array of linguistic options available to speakers to encode dimensions of their spatial experience.

Note

1. On a different instantiation of this hypothesis, single verbs should exert their influence on memory not only as a function of whether they encode path or manner but also as a result of how representative they are of motion encoding in the language. On this version, for instance, manner verbs should be *less* likely to decrease memory for visual paths in English compared to Greek speakers because in satellite-framed but not verb-framed languages use of manner verbs typically goes hand in hand with path information encoded in adpositional phrases ("crawl into the tent"). We will not discuss this possibility further because it does not connect well with prior literature on lexical effects on memory. However, the data from the present experiments bear on this hypothesis too, and the conclusions we will draw about whether lexicalization differences affect memory apply to this version as well.

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Appendix

Comprehensive list of events for all Experiments as well as verbs provided for each event in Experiment 3.

Events	English Manner Verbs	English Path Verbs	Greek Manner Verbs	Greek Path Verbs
An alien drives a car into the mouth of a cave	drive	enter	odigi	beni
A man in a hot air balloon lands on top of a building	fly	land	petai	prosgionete
A man in a sailboat lands on an island	sail	enter	istioploi	prosarazi
A man paddles a canoe to a dock	paddle	reach	kopilati	fthani
A woman on a magic carpet lands on the moon	fly	land	petai	prosgionete
A man drives a motorcycle into a carwash	drive	enter	odigi	beni
A man parachutes from the sky and lands on a tree	float	land	eorite	prosgionete
A man lands an airplane on a platform	fly	land	petai	prosgionete
A boy roller skates into a soccer net	skate	reach	kani patinaz	fthani
A girl rides a scooter into the mouth of a cave	roll	enter	rolari	beni
A duck ice skates toward a fishing hut	skate	enter	kani patinaz	beni
A man skis through a finish line	ski	reach	kani ski	fthani

*Significant at $p < 0.05$,**significant at $p < 0.01$, ***significant at $p < 0.001$. Code used in R: <- glmer (accuracy ~ Language * Change + (1 + Change|Subject) + (1|Event), data = EXP1, family = "binomial").