Language and Cognition (2025), 17, e44, 1–17
doi:10.1017/langcog.2025.17

ARTICLE

Egocentric and allocentric memory recall strategies moderate transfer action sentence recognition

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(Received 13 May 2024; Revised 07 March 2025; Accepted 14 March 2025)

Abstract

Embodied cognition theory proposes that spatial cognition preferences facilitate the simulation of action language. Importantly, spatial cognition relies on either egocentric (body-dependent) or allocentric (body-independent) representations. Research demonstrates that spatial representation proclivity influences the simulation of non-transfer action sentences. However, the impact of individual spatial cognition preferences on transfer action sentence simulation remains unexplored. We administered an egocentric and allocentric memory task and an action sentence recognition task to 37 participants. We used an egocentric–allocentric recall strategy proclivity index to classify participants and employed this metric as a moderator between the transfer perspective (first-person perspective, 1PP vs. third-person perspective, 3PP) and the transfer type (concrete vs. abstract). We found that spatial preferences do not moderate 1PP transfer action sentence recognition. Importantly, we found that egocentric proclivity improves 3PP transfer action sentence recognition and that allocentric proclivity hampers 3PP transfer action sentence recognition. No moderation was found for the transfer type. The study suggests that recognition memory for sentences describing others' actions is related to body-dependent spatial representations, suggesting a possible link between spatial memory proclivity and action language simulation.

Keywords: action language; embodiment; individual preferences; spatial cognition; spatial navigation

C.R. and S.S. have contributed equally.

1. Introduction

Embodied cognition (EC) theories propose a fundamental shift away from cognitivist assumptions, arguing that the sensorimotor system plays a crucial role in cognitive representations. This reconceptualization of cognition has influenced research examining various cognitive domains, including memory and language (Borghi, 2024; Dove, 2023; Ianì, 2019). EC suggests that language comprehension engages sensorimotor information to mentally simulate sentence content (Glenberg & Gallese, 2012; Meteyard et al., 2012). This is especially evident with concrete action language (triggered by concrete verbs such as 'to kick'), although evidence also indicates that abstract action language (triggered by figurative verbs such as 'to plan') is grounded in the sensorimotor system (Ghandhari et al., 2020; Glenberg et al., 2008; Sakreida et al., 2013). Furthermore, language simulation processes have been documented in tasks examining embodiment through both 'online' (e.g., verification tasks) and 'offline' (e.g., recognition memory task) paradigms (e.g., Brunyé et al., 2009; 2016; Díez-Álamo et al., 2020; Ditman et al., 2010; Tuena, Di Lernia, Riva, et al., 2023; Tuena, Di Lernia, Rodella, et al., 2023). The fact that the body plays an important role in language comprehension is further demonstrated by the observation that individuals can simulate action language embodying the spatial perspectives (point of view) of the characters involved (Beveridge & Pickering, 2013; Meteyard et al., 2012; Zwaan, 2016). Indeed, growing evidence suggests a link between spatial cognition and language simulation (Beveridge & Pickering, 2013; Ibáñez et al., 2023; Majid et al., 2004; Vukovic & Shtyrov, 2017). The spatial grounding hypothesis (Beveridge & Pickering, 2013) states that for the action simulation to occur, readers must represent the spatial context (i.e., the spatial relationships among entities within a given text by means of a situation model; Zwaan & Radvansky, 1998) for the sentence. While agent-perspective simulations appear to be the most readily accessible, action simulations from other perspectives (e.g., patient or observer) are also possible. These non-agent simulations are facilitated by self-referential pronouns that occupy thematic roles other than the agent. This process is referred to as action perspective-taking. Additionally, this hypothesis highlights a second aspect: the spatial perspective (e.g., agent, patient or observer) from which the situational model incorporating the action is mentally represented. This latter process is designated as spatial perspective-taking.

A particular case of action sentences is when two characters are involved, one with the role of the agent and the other with the role of the patient/receiver (namely *transfer action sentence*s). These types of stimuli have been extensively investigated using the action-sentence compatibility effect (ACE) (e.g., Glenberg et al., 2008; Glenberg & Kaschak, 2002; Ibáñez et al., 2013; Papesh, 2015). The standard ACE paradigm requires participants to judge whether the sentences make sense by pressing a button located closer to or farther away from their body, relative to a starting position. These sentences could be both concrete (e.g., "*Courtney handed you the notebook*") and abstract (e.g., "*You confessed your secret to Dan*"). The key manipulation involves the compatibility between the action described in the sentence (away from or toward the participant's body) and the action required to respond (pushing a button far or close to the body). In a congruent condition, the physical action performed by the participant is compatible with the action described in the sentence. In the incongruent condition, the required physical action is incompatible with the action described in the sentence. Faster reaction times were observed in the

https://doi.org/10.1017/langcog.2025.17 Published online by Cambridge University Press

congruent compared to incongruent conditions for both concrete and abstract action sentences (e.g., Borreggine & Kaschak, 2006; Glenberg et al., 2008; Glenberg & Kaschak, 2002) or only for concrete action sentences (e.g., Diefenbach et al., 2013). Despite the interesting results, Papesh (2015) reported weak evidence for ACE in her review. More recently, using the ACE procedure, one study (Díez-Álamo et al., 2020) showed that sentences that describe concrete or abstract transfer toward the self are processed faster and remembered better than concrete and abstract transfer sentences describing motion away from the reader. The authors did not find the ACE and named the result the linguistic looming effect. These findings were replicated by a recent pre-registered multi-lab study on the ACE (Morey et al., 2022). This is somehow different from what Ditman et al. (2010) found for non-transfer (single-character) concrete action language. In this case, action language is remembered better when sentences depict an action from a 1PP (e.g., "*You slice the tomato*") than from a 3PP (e.g., "*He slices the tomato*"); this finding demonstrates that simulation could occur also during recognition memory tasks and in a similar way to the so-called enactment effect (see, Engelkamp, 1998). Conversely, Díez-Álamo et al. (2020) suggested that language-induced visual perceptual looming bias grabs attention and facilitates a quick adaptative response. However, according to the spatial grounding hypothesis, when a spatial context is unavailable for a transfer action sentence, the processes of action language simulation and perspective-taking may be impaired. (Beveridge & Pickering, 2013; Gianelli et al., 2011). Moreover, in a recent consensus paper, embodied cognition researchers proposed that when studying action language, it is crucial to evaluate individual preferences, particularly those related to spatial cognition, as they may influence simulation processes. (Ibáñez et al., 2023).

Spatial memory is a fundamental aspect of human spatial cognition (Burgess, 2008). In particular, spatial memory is the capacity to encode, store and remember the position and location of objects or places and includes orientation and distance (VandenBos, 2007). This information can be represented using two spatial frames of reference: egocentric and allocentric (Burgess, 2008). In the former, the environment is represented in a body-dependent way (e.g., "*to reach the church, go left at the bar*"), whereas in the latter, it is represented independently from our body and position (e.g., "*the church is close to the bar*"). These two representations can be used flexibly by switching from one to another (Ekstrom et al., 2014). In particular, research (Goeke et al., 2013; Gramann et al., 2005) showed that individuals have a preference for either an egocentric or allocentric frame of reference for solving spatial orientation tasks. In these tasks, participants watched on the computer screen short virtual paths (e.g., 12 seconds), without environmental landmarks, with different angle deviations from the fixed starting point. At the end of the path, participants were asked to indicate using arrows presented on the screen the heading direction of the initial position. Some arrows implied no rotation from the initial direction (i.e., participants kept the starting heading direction fixed during the path; allocentric preference), whereas other arrows denoted rotation from the starting direction (i.e., participants rotated the initial heading direction according to the path direction shown in the video; egocentric preference). Crucially, these tasks require 'online' spatial computations with an immediate retrieval of the navigated path and participants have no motor control over the navigated path (i.e., joypad/keyboard for navigation). However, egocentric and allocentric preferences are not used during 'online' spatial cognition; indeed, individuals could rely on egocentric or allocentric memory strategies also during spatial tasks that require information to be stored

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in memory (Chersi & Burgess, 2015). Using landmark-based virtual reality (VR) navigation tasks, it is possible to assess the ability to encode or recall object locations in an egocentric or allocentric representation by manipulating the virtual environmental cues (Burgess, 2008; Guderian et al., 2015). Environmental cues in navigation can be categorized into two types: boundaries and landmarks (Chersi & Burgess, 2015; Doeller et al., 2008; Schuck et al., 2015). Boundaries are extended obstacles, such as walls, that define the limits of an environment, whereas landmarks are discrete objects within the space, such as monuments, that serve as reference points. Boundary-based navigation is predominantly supported by the hippocampus and typically employs an allocentric strategy forming a cognitive map of the environment independent of one's position. Landmark-based navigation, on the other hand, predominantly engages the dorsal striatum and typically involves an egocentric strategy by encoding spatial information from the navigator's perspective with respect to discrete (also known as local) cues.

Regarding the interaction between action language simulation and spatial cognition, previous research has demonstrated that in non-transfer action sentences where participants act as agents, a first-person perspective (1PP; egocentric) is activated, while sentences featuring another person as the agent trigger a third-person perspective (3PP; allocentric) (Beveridge & Pickering, 2013; Brunyé et al., 2009; 2016). Crucially, spatial preferences might affect 'online' simulation processes. One study (Vukovic & Williams, 2015) explored the impact of egocentric/allocentric frames of reference proclivity on concrete (action) sentence simulation through an action sentence-picture verification task. Participants listened to 'You' ("*You are opening a bottle*" – the participant is the agent) and 'I' ("*I am opening a bottle*" – someone else is the agent) action concrete sentences and then were asked to match a photo of that action from the 1PP or the 3PP. By using a spatial orientation task (Gramann et al., 2005), the authors categorized participants as having an egocentric or allocentric proclivity. The first experiment reported in the study found that when listening to 'You' and 'I' sentences, participants with an egocentric preference were faster to verify 1PP photos compared to 3PP photos. No effect was found for allocentric participants. In the second experiment, the authors demonstrated that allocentric participants have differences in action sentence simulation when contextual information is manipulated (experimental instructions and stimuli; i.e., participants were asked to 'spy' a conversation of two individuals shown on the PC screen). In this case, allocentric participants had a faster response time to sentence-photo pairs from a 3PP perspective. Similarly to the first sentence-picture matching experiment procedure, a study (Vukovic & Shtyrov, 2017) used instead a continuous numeric index to rate spatial frames of reference preference computed from the same computerized orientation task (Gramann et al., 2005). They found that egocentric participants are facilitated when the sentences match the perspective of the photo shown (1PP and 3PP).

To examine the intricate interaction between transfer sentences and frames of reference proclivity, a cross-cultural study (Tuena et al., 2023) examined Italian and American English participants. Cultural background can influence the use of spatial frames of reference at the population level. North Americans predominantly favor an allocentric frame of reference orientation, whereas Europeans demonstrate no specific preference (Goeke et al., 2015). In Tuena and colleagues' study, participants read concrete transfer sentences in which they could be either the agent or the patient. They were then asked to verify whether a photo from a first-person perspective (1PP)

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or third-person perspective (3PP) matched the previously shown sentence. The researchers found no differences between the two samples, suggesting shared embodied mechanisms: when readers were the patients in action sentences, they demonstrated faster response times in the photo-matching task. This suggests that participants simulated the agent's action (performed by another person) while maintaining the patient's point of view (their own) from a third-person perspective. Consequently, action and spatial perspective sentence simulation may operate independently in the context of concrete transfer action sentence phrases. Crucially, participants demonstrated faster responses when they were the agents of the action sentence and the picture depicted the action from their first-person perspective (1PP), suggesting that action and spatial perspective-taking converge with the participant's perspective in these conditions.

In summary, for non-transfer action sentences (Vukovic & Shtyrov, 2017; Vukovic & Williams, 2015), egocentric participants simulate pictures more rapidly from a first-person perspective (1PP) compared to a third-person perspective (3PP) when acting as agents. Conversely, allocentric participants simulate others' actions more quickly from a 3PP compared to 1PP, but only when contextual information is manipulated. However, these patterns shift with transfer sentences, as readers may adopt varying action and spatial perspectives. The findings from Tuena et al. (2023) challenge the spatial grounding hypothesis (Beveridge & Pickering, 2013): regardless of spatial cultural bias, action perspective-taking consistently occurs from the agent's perspective (whether the participant or another person), while spatial perspective-taking remains fixed to the reader's (participant's) viewpoint, which can be either 1PP or 3PP.

From the studies mentioned above, it is still unclear how spatial cognition preferences and language simulation are bound and possibly affected by contextual aspects, like the type of spatial task (e.g., online vs. memory).

In the present study, we investigated whether participants' predisposition toward egocentric or allocentric memory modulates their recognition of transfer action sentences (both concrete and abstract) from different perspectives. To pursue these aims, we employed a VR spatial memory task to generate an egocentric–allocentric recall strategy proclivity index to predict action sentence recognition performance.

Regardless of the type (concrete or abstract) of transfer, we speculate that participants with an egocentric recall preference will have better recognition of 1PP sentences, conversely, participants with an allocentric recall preference will have better 3PP sentences recognition.

2. Methods

2.1. Participants

We recruited 37 Italian young adults for this study (M_{age} = 24.05, SD_{age} = 2.57; $M_{education}$ = 15.56, $SD_{education}$ = 2.32; males = 18; right-handed = 31). Participants were recruited at psychology courses at the Catholic University of Milan. Inclusion criteria were: speaking Italian as a native language and age 18–30 years. Exclusion criteria were self-reported history of memory and/or language disorders. We computed the sample size by considering that all the participants were allocated to each level of the independent variables of the sentence recognition task and the number of stimuli used (stimuli-within-condition design). With a medium Cohen's *d* of 0.5, a

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power of 0.8, and 80 target stimuli, the power analysis for a mixed-effects model (Westfall et al., 2014) required a minimum of 26 participants. Moreover, considering that our design included a third continuous predictor in the linear model, at least 10 observations were added (VanVoorhis & Morgan, 2007). The study was approved by the Ethics Committee of the Catholic University of Milan. Participants gave their written consent to participate.

2.2. Egocentric and allocentric spatial memory task

We employed a VR landmark-based navigation task to test participants' egocentric and allocentric spatial memory strategies, as in a similar study (Guderian et al., 2015). The virtual environment consisted of a circular arena surrounded by a wall, with an obelisk inside the arena and some fixed distal cues (i.e., mountains and clouds) visible throughout the experiment to provide orientation. In the encoding phase, participants navigated the virtual arena (50 virtual meters in diameter) using arrow keys and a mouse. They had to collect eight objects and memorize their locations in the arena. The eight objects (supra-span performance; Jeneson & Squire, 2011; Spinnler & Tognoni, 1987) were balanced for living and non-living categories. The objects had predetermined locations and appeared one at a time in random order across the trials. The participants had to navigate to the exact item location to collect the item and see the following. Once they reached it, the object disappeared, and the participant had to find the next one. Object locations could be encoded in this phase using the boundaries of the arena (i.e., wall – allocentric cue) and a local landmark (i.e., obelisk – egocentric cue). Figure 1 shows the environment at encoding. Each object was collected four times in random order.

During the recall phase, either the wall or the obelisk was removed in random order across recall trials. This forced the use of an allocentric (i.e., obelisk removed) or egocentric (i.e., wall removed) strategy during spatial memory recall (Chersi & Burgess, 2015). At each trial, participants were shown each item one at a time at the bottom of the PC screen and had to navigate to the location where the item had previously been collected. Once there, they had to press the spacebar if they were satisfied with the remembered location. Each object was tested four times for 32 recall trials (16 trials for each allocentric and egocentric recall strategy). The response variable was the Euclidean distance between the recalled and actual location of each object trial at recall (distance expressed as virtual meters of the virtual environment between the recalled and the actual location at encoding). The task was created with Unity software.

2.3. Transfer sentence recognition memory task

We developed a sentence recognition memory task with Gorilla software (Anwyl-Irvine et al., 2020) with the old-new paradigm (Squire et al., 2007). A set of 160 sentences was created involving two characters (the pronoun 'You'/the participant and Gianni or Maria). We used 'You' sentences because this yielded the most consistent results in studies on sentence simulation (Brunyé et al., 2009; 2016; Ditman et al., 2010; Vukovic & Williams, 2015). The set of stimuli was divided into four action sentence conditions: 1PP concrete transfer sentences (e.g., "*You shoot the rubber band at Gianni*"), 3PP concrete transfer sentences (e.g., "*Maria shoots the*

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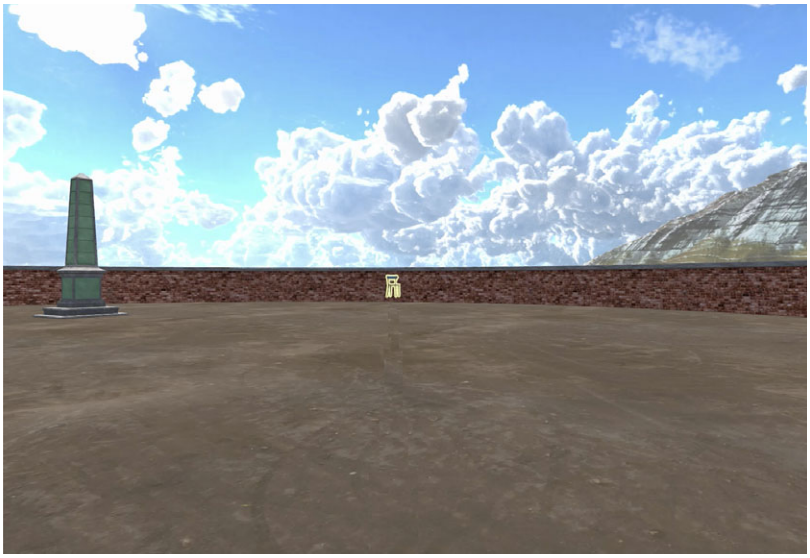

Figure 1. Virtual environment of the arena.
Note: During the encoding phase, both a local landmark (obelisk – egocentric) and a boundary (wall – allocentric) were used to encode the item location. During the recall phase, either the local landmark or the wall was shown to assess egocentric or allocentric memory recall.

rubber band at you"), 1PP abstract transfer sentences (e.g., "*You give some time to Maria*"); and lastly, 3PP abstract transfer sentences (e.g., "*Maria gives some time to you*"). In the 1PP, the reader is the agent, while in 3PP, the reader is the grammatical patient (receiver). Forty action sentences were taken from a previous study (Tuena et al., 2023), while the remaining were created *ad hoc.*

As in Díez-Álamo et al. (2020), we created a main list of 80 sentences (20 sentences for each condition) and then we created a reversed list (i.e., the sentence "*You shoot the rubber band at Gianni*" in the main list was reversed to "*Gianni shoots the rubber band at you*"). Following the procedure of Díez-Álamo and colleagues, participants in the encoding phase learned the sentences of the main list (*old* items) during the recognition phase, the sentences of the reversed list were shown as *new* items in addition to old items. We counterbalanced this aspect across participants so that the participant that learned "*You shoot the rubber band at Gianni*" had as a new item "*Gianni shoots the rubber band at you*," the following participant had as target "*Gianni shoots the rubber band at you*" and as new item "*You shoot the rubber band at Gianni.*" The participants should discriminate the correct agent/patient for the old from the new sentences. Stimuli were also balanced by gender (Maria/Gianni) so that half of the concrete and abstract sentences involved a male and half a female. Additionally, we analyzed the sentence lengths (letters plus spaces) for old stimuli, comparing concrete and abstract sentences between first-person singular (1PP) and third-person singular (3PP) perspectives in both main and reversed lists. For concrete sentences in the main lists, the comparison between 1PP and 3PP yielded $t_{37} = 1.88$, $p = 0.068$. For abstract sentences in the main lists, the 1PP versus 3PP comparison

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resulted in $t_{37} = 1.70$, $p = 0.099$. In the reversed lists, the 1PP-3PP comparison for concrete sentences showed $t_{37} = 1.98$, $p = 0.057$, while for abstract sentences, it resulted in $t_{37} = 1.37$, $p = 0.180$. None of these comparisons revealed statistically significant differences in sentence length between 1PP and 3PP perspectives. In addition, sentence lengths (letters plus spaces) for old stimuli were not statistically different for concrete and abstract sentences, in the main (concrete, $t_{37} = 1.88$, $p = 0.068$; abstract, $t_{37} = 1.70$, $p = 0.099$) and reversed (concrete, $t_{37} = 1.98$, $p = 0.057$; abstract, $t_{37} = 1.37$, $p = 0.180$) lists, between 1PP and 3PP.

To reduce the effort to learn 80 sentences in only one block and then recognize 160 items, we divided the recognition task into two identical parts. In this way, in the first block, participants learned 40 target items and recognized 80 (old + new) sentences; then, a second block was presented, where the remaining 40 target sentences were learned, followed by the recognition part. To reduce any potential order-of-presentation effect, the four blocks order was counterbalanced across participants (sentence length lists at encoding: $p = 0.526$). In this way, old-new (1PP vs. 3PP) items and presentation blocks were counterbalanced during the task, yielding four possible lists to be administered. See Supplementary Material 1 for an example of one of the four lists presented and its English translation.

In the encoding phase, sentences were presented at the center of the screen for 5 seconds, followed by a 500ms fixation cross. In the recognition phase, the old-new sentences were presented at the center of the screen with no time limit to respond, once responded a 500ms fixation cross appeared. To respond, the participants used the mouse by clicking the two relevant (old-new) screen sections placed in the middle of the bottom part of the PC screen.

2.4. Procedure

The participants were welcomed in a quiet room at the Catholic University of Milan and read and signed the consent form. The PC for this study was a VR-ready Dell G5 15.6inch. Before the tasks, participants were required to provide some demographic information (age, sex, education and handedness). Then, the participants were invited to take a seat 50cm from the PC screen. The spatial memory and the sentence recognition tasks were administered in a counterbalanced order across participants.

The instructions for the intentional spatial memory task at encoding were: "*Now you will be in a circular virtual arena and your task is to collect some objects and memorize their locations because you will then be asked to remember them later. You will see one object at a time. You will see each object four times in the same position so that you can remember better its location. To help you to memorize the location you can use the obelisk, the wall, the mountain range, and the fixed clouds as references. You can navigate within the arena with the arrow keys and the mouse. To collect the object, go exactly over it. It will disappear and you will be presented with the next one.*" After this phase, the recall instructions were read "*You will be asked to put each object in the position where you collected it. However, in random order, either the obelisk or the wall will be removed. Once you are in the location you think is correct, press the space bar to release the object and proceed with the next one. You will be asked to replace each object several times regardless of the correctness of your answer.*"

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The intentional sentence recognition memory task was divided into two blocks (encoding block one and recognition block one, encoding block two and recognition block two). Instructions were displayed before each encoding and recognition phase. Then, the encoding instructions of the first block appeared. "*Now you will see some sentences. Your job is to read the sentences carefully and memorize them because you will then be asked to remember them later. Stay focused because the phrases will only be shown for a few seconds on the screen and will change automatically.*" The instructions of the recognition phase were "*Now you will see some sentences. Your task is to evaluate, using the appropriate buttons on the screen, if the sentence is NEW or OLD. Press OLD with the mouse if you believe that you have seen the sentence among those you memorized a little while ago. Press NEW if you think you have not seen it among those shown before.*"

2.5. Statistical analyses

R studio (v. 3.6.3) was used to perform the analyses. The design is a full within-subjects design (Transfer Type, 2 levels: abstract vs. concrete; Transfer Perspective, 2 levels: 1PP vs. 3PP) with a continuous moderator (egocentric–allocentric Proclivity index). The egocentric–allocentric Proclivity index was computed as the delta between the average recall error allocentric strategy minus the average recall error egocentric strategy (i.e., the negative index represents greater accuracy for the allocentric strategy and a positive one greater accuracy for the egocentric strategy). We also computed an accuracy-weighted Proclivity index, which is the aforementioned delta multiplied by the sum of the average allocentric and egocentric error. The former is a measure of preference and the latter is an index of preference weighted by accuracy.

The dependent variable was a-prime (A'). A' is a non-parametric measure of the signal-detection theory in the case of non-normal distributions of hit and false alarm rates (Pastore et al., 2003). An A' equal to 0.5 represents chance responses and an A' of 1 is the best signal-noise discrimination performance. A' computation requires collapsing each trial (sentence ID) to compute the average hit and false alarm rate (*psycho* package in R).

We used the linear mixed-effects model ANOVA (Luke, 2017) and Bonferroni corrected simple slope post-hoc tests (Lenth, 2022). Participants were put as a random effect with random intercept to account for inter-individual variability, whereas for RT also sentence ID was also added as a random effect. R formulas were lmer(A' ~ type×perspective×Proclivity index+(1|ID), REML = T, control = lmerControl(optimizer = "bobyqa")). Assumptions for the linear method were met by looking at diagnostic plots. Regarding pre-processing of the data, we checked regardless of the experimental conditions any random guessing patterns of A' and old-new response bias (A' = 0, bias = 1; one participant removed). Analyses were carried out on 36/37 participants. Then, we used the interquartile range detection method to identify abnormal trials on sentence (377/5920) and spatial (41/1216) memory tasks and outliers were replaced as missing responses, which can be handled by the linear mixed-effects model (Brown, 2021). Effect size (η^2_p) was interpreted according to small = 0.01, medium = 0.06, and large = 0.14 (Richardson, 2011). The alpha level was set to 0.05 for all analyses. Data are fully available at OSF (https://osf.io/yvhra/). The study was not pre-registered.

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3. Results

The average hit rate of the sentence recognition task, regardless of the conditions, was 64.02 (*SD* = 17.36). Participants were better at recalling item spatial locations during the allocentric (wall) compared to the egocentric (obelisk) condition, the average egocentric error (expressed as virtual meters) was 12.56 (*SD* = 4.49) and the average allocentric error was 11.21 (*SD* = 4.54) and this difference was significant ($p < 0.001$). Concerning the spatial task, we did not find any main effect of testing effect across trials ($p = 0.28$) or testing effect interaction with egocentric and allocentric conditions ($p = 0.76$). Additionally, any main block order effect ($p = 0.08$) or block order effect interaction with egocentric and allocentric conditions ($p = 0.21$) was found. See Table 1 for a detailed summary of the transfer sentence recognition task.

3.1. Egocentric–allocentric proclivity and recognition accuracy

To study the impact of egocentric and allocentric recall strategy proclivity on transfer action sentence recognition, we used a within-subjects linear mixed-effects ANOVA with Proclivity index as moderator and Transfer Perspective and Transfer Type as categorical variables.

Concerning the main effects, we did not find any significant results (Transfer Perspective, $p = 0.070$; Transfer Type, $p = 0.172$; P, $p = 0.175$). These two-term interactions were not significant (Transfer Perspective by Transfer Type, $p = 0.331$; P by Transfer Type, $p = 0.594$). The three-term interaction was not significant (Proclivity index by Transfer Perspective by Transfer Type, $p = 0.592$).

Importantly, we found a two-term significant Proclivity index by Transfer Perspective interaction ($F_1 = 24.19$, $p < 0.001$, $\eta^2_p = 0.19$, 95%CI [0.09, 1.00]). Simple slope analysis showed that A' changed as a function of the Proclivity index trend for 3PP sentences ($\beta = 0.04$, SE = 0.01, $p = 0.009$) but not for 1PP ($p = 1$). A positive Proclivity index (egocentric proclivity) predicts higher A' scores for 3PP sentences, whereas a negative Proclivity (allocentric proclivity) predicts lower A' for 3PP sentences; furthermore, the contrast between the slopes was significant (est. diff. = −0.04, SE = 0.01, $p < 0.001$), indicating different patterns of sentence recognition as a function of spatial frame of reference proclivity and transfer perspective. Conversely, no impact emerged of Proclivity index on 1PP phrase recognition. Figure 2 shows the

Table 1. Transfer sentence recognition task performance

Transfer type	Abstract		Concrete	
Transfer perspective	1PP	3PP	1PP	3PP
A′	0.76 (0.69, 0.86)	0.73 (0.50, 0.84)	0.72 (0.63, 0.88)	0.81 (0.61, 0.88)
RT	2489.50 (1835.13, 3621.52)	2446.35 (1833.35, 3630.15)	2485.85 (1745.15, 3800.63)	2380.30 (1780.30, 3576.75)
Responses				
Hit	455 (34%)	448 (33%)	471 (35%)	470 (35%)
CR	404 (30%)	455 (34%)	410 (30%)	424 (32%)
FA	216 (16%)	242 (18%)	222 (16%)	210 (16%)
Miss	251 (19%)	213 (16%)	253 (19%)	239 (18%)

Note: Median and inter-quartile range are reported. CR: correct rejection; FA: false alarms; RT: reaction times; A′: A prime; 1PP: first-person perspective; 3PP: third-person perspective.

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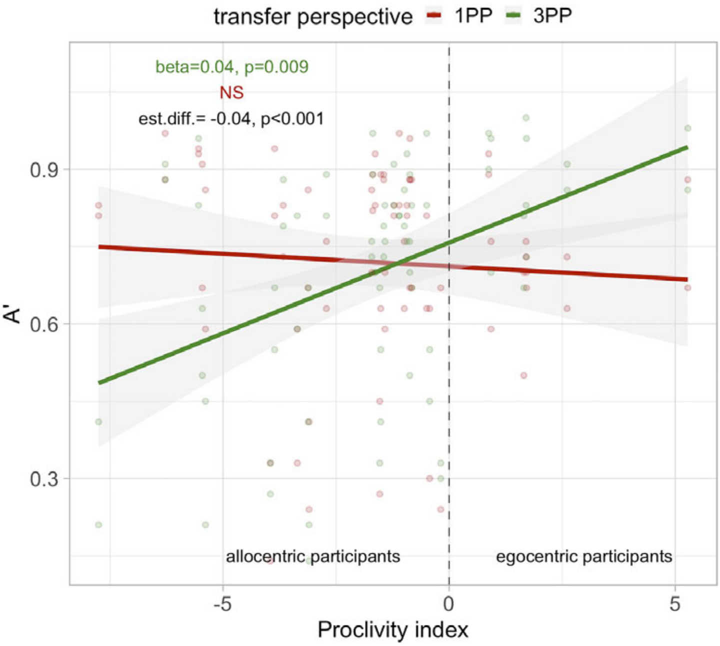

Figure 2. Main results of the experiment.
Note: Negative Proclivity index values represent participants with better accuracy in the allocentric than the egocentric recall strategy condition, positive Proclivity index values represent participants with better accuracy during the egocentric than the allocentric recall strategy condition. A': A prime; 1PP: first-person perspective; 3PP: third-person perspective transfer.

Proclivity index results. No other significant result was found. The results were replicated using the accuracy-weighted Proclivity index.

4. Discussion

This study aimed to investigate whether individual preferences for egocentric and allocentric spatial memory influenced action language memory, particularly focusing on the recognition of concrete and abstract transfer sentences where either the participant or another person serves as the agent. Participants' spatial memory performance was assessed using a task that involved both egocentric and allocentric recall strategies. Using a continuous index (Proclivity index, a delta between egocentric and allocentric average performance), participants were evaluated as being more accurate with the egocentric strategy compared to the allocentric one or *vice versa.* Memory for transfer action sentences was evaluated with an old-new recognition paradigm using a signal detection parameter.

First, we did not find any impact of proclivity on 1PP phrases for either egocentric or allocentric participants. Second, we found that the greater the egocentric proclivity in the participants, the greater the recognition accuracy for 3PP sentences, regardless of the transfer type. Consequently, the greater the allocentric proclivity, the lower the

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recognition accuracy for 3PP sentences, regardless of the transfer type. Lastly, the results did not show any differences in transfer type.

According to our predictions, we expected better recognition for 1PP sentences for egocentric participants and better recognition for 3PP sentences for allocentric participants. In contrast, we found that egocentric preference facilitates 3PP sentence recognition compared to an allocentric preference while neither egocentric nor allocentric proclivity had an impact on 1PP sentence recognition. Lastly, we did not predict differences concerning the type of action sentence (abstract vs. concrete); this hypothesis was confirmed instead.

Regarding the first finding, a previous study (Tuena et al., 2023) showed that when two-character sentences depict a concrete transfer and point of view of the reader as the agent, simulation is facilitated and occurs in a 'default' manner with transfer action sentence-picture verification task (see, also Brunyé et al., 2009, 2016). Such facilitation also arises for recognition memory with concrete sentences without transfer (Ditman et al., 2010). This might explain why no impact of egocentric or allocentric preference for 1PP sentences was found: additional support of spatial cognition processes is not required during 1PP sentence simulation. Nonetheless, a study (Vukovic & Williams, 2015) showed that egocentric participants simulate faster transfer action sentence-picture pairs where the participant is the agent, rather than when the agent is someone else. Yet in their study, the authors used a dichotomous proclivity classification rather than a continuous index, sentences without transfer, and a spatial orientation rather than a spatial memory task. These differences might account for dissimilar results. However, consistent with this study, we found no effect of allocentric proclivity on 1PP sentences. While our data did not reveal a significant relationship between egocentric–allocentric proclivity and 1PP transfer sentence simulation from memory, further research would be needed to draw definitive conclusions about the absence of such effects. Our findings suggest the possibility that 1PP transfer sentence simulation from memory may operate independently of egocentric–allocentric proclivity, though this interpretation should be considered preliminary

Regarding the second finding, we found that spatial memory preferences and ability come into play when non-self-related simulation processes are required. Tuena et al. (2023) found that the participant can simulate concrete transfer phrases when (s)he is not the agent of the action while retaining the spatial perspective of the patient (the participant's point of view); however, the simulation of the action occurs at higher processing cost (slower reaction times) for the individual compared to a 'default' 1PP transfer action sentence-picture matching condition. This is also in line with a study (Vukovic & Shtyrov, 2017) that showed that the greater the egocentric index, the greater the magnitude of the transfer action sentence-picture verification of concrete sentences.

Our results suggest that egocentric ability is a key process to simulate from memory sentences when the agent is someone else. Indeed, egocentric spatial representations are rooted in the sensorimotor states of the body (Chersi & Burgess, 2015). This is in line with studies on spatial perspective taking that suggest that to assume someone else's perspective, an *egocentric translocation* of our body coordinates is required (Vogeley et al., 2004; Vogeley & Fink, 2003). Assuming the perspective of someone else should not be defined as a pure allocentric process, rather it requires egocentric mechanisms, such that the translation from 1PP to 3PP encompasses an egocentric to allocentric switch first and then an allocentric to

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egocentric (new egocentric 3PP) switch (Vogeley et al., 2004; Vogeley & Fink, 2003). Consequently, egocentric memory appears to be a crucial aspect to simulate sentences when the reader is not the agent of an action sentence and participants simulate sensorimotor states of someone else (see Tuena et al., 2023). However, our results are not in line with a previous study (Vukovic & Williams, 2015) that showed that allocentric participants do not show any facilitation or inhibition of action language simulation. On the contrary, we showed that allocentric participants are not facilitated in 3PP sentence simulation. An allocentric representation that is not body-based cannot help with sentence simulation of someone else's actions. Moreover, we did not provide allocentric participants with specific task instructions to manipulate their spatial model of the phrase (Vukovic & Williams, 2015) but rather just asked them to remember and then recognize the stimuli presented. We extended previous research by demonstrating that participants who prefer to use an egocentric memory strategy are more accurate (compared to allocentric participants) in recognizing 3PP transfer sentences. In other words, simulation (Ditman et al., 2010) of 3PP transfer sentences from memory is facilitated in individuals that have an egocentric memory strategy preference.

Lastly, we found no difference in recognition performance based on spatial frame of reference proclivity, regardless of the type of transfer. This finding is in line with strong embodiment positions that state that sensorimotor states support both concrete and abstract language representations (Glenberg et al., 2008; Meteyard et al., 2012; Sakreida et al., 2013). We extended previous findings by showing that egocentric–allocentric proclivity has no impact on concrete and abstract two-character sentences when simulated from memory.

A significant departure from previous literature (Tuena et al., 2023; Vukovic & Shtyrov, 2017; Vukovic & Williams, 2015) is the use of a VR spatial memory task and a sentence recognition memory task (rather than an 'online' verification task) with transfer sentences to further investigate action language and spatial cognition preferences. A second key aspect is the use of VR, this is a promising technology that can be used to study spatial cognition mechanisms in a standardized way while retaining realism depending on technological features and task characteristics. In contrast to standard cognitive task stimuli (e.g., pre-recorded videos), VR can provide combined visual and bodily (e.g., motor commands) information close to real-world spatial cognition even when used in its 2D (e.g., PC monitor and joystick) setup (Chen et al., 2013; Tuena et al., 2021). Conversely, pre-recorded videos used in previous research on this topic (e.g., Vukovic & Shtyrov, 2017; Vukovic & Williams, 2015), while retaining visual information and optic flow, do not allow the participants to actively control navigation with motor commands and route decision-making, which is what happens as we navigate. Such aspects make VR navigation closer to cognitive processes that occur during real-world navigation (Tuena et al., 2019).

It is important to note that embodied language is influenced by both contextual and individual differences (Ibáñez et al., 2023). We demonstrated that spatial memory preferences affect simulation from memory of both abstract and concrete transfer sentences involving an agent and a patient. Careful consideration of metrics, sentence types, characters in the sentence, individual preferences, and task procedure/instructions is mandatory in the context of embodied language.

However, we must acknowledge some limitations of our study. First, we did not control for the action or spatial perspective from which the participants encoded and/or recognized the transfer action sentences; therefore, it was not possible to draw

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any conclusions regarding the spatial grounding hypothesis. Second, overall recognition accuracy is not high, probably due to the intrinsic task difficulty that might have affected our results. Third, our study focused on young adults, employing an age range (18–30) commonly used in spatial navigation studies using the same VR landmark-based navigation task (Doeller et al., 2008) and in studies comparing allocentric and egocentric abilities across age groups (e.g., Rosenbaum et al., 2012). Therefore, we acknowledge that our results cannot be generalized to other age groups, given the well-known differences between young and older adults in spatial performance (Lester et al., 2017). Future research should investigate how individual spatial cognition preferences influence transfer action sentence simulation across different age groups.

To conclude, this study suggests that recognition memory performance for transfer action sentences with a third-person agent is associated with participants' egocentric spatial memory abilities. The observed pattern aligns with perspectives on sensorimotor simulation from memory, though the precise mechanisms require further investigation. While these findings contribute to our understanding of how individual differences in spatial cognition may relate to sentence processing and sensorimotor representations, further research is needed to establish direct connections to action language simulation processes.

Supplementary material. The supplementary material for this article can be found at http://doi.org/10.1017/langcog.2025.17.

Data availability statement. Data are fully available at OSF https://osf.io/yvhra/

Author contribution. Conceptualization: C.T., S.S.; Writing – first draft: C.T.; Editing: C.T., S.S., C.R., D.D.L.; Data collection: C.T.; Task: C.T.; Study method: C.T., C.R.; Statistical analyses: C.T.; Supervision: G.R., S.S., C.R. All the authors approved the final version of this manuscript.

Acknowledgments. The work was partially supported by the Italian Ministry of Health.

Funding statement. This work was financed by the Italian Ministry of Education, University, and Research (MIUR) through PRIN-2017 "INSPECT" (Project 2017JPMW4F).

Competing interests. The authors declare none

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Cite this article: Tuena, C., Di Lernia, D., Riva, G., Repetto, C., & Serino, S. (2025). Egocentric and allocentric memory recall strategies moderate transfer action sentence recognition, *Language and Cognition*, 17, e44, 1–17. https://doi.org/10.1017/langcog.2025.17