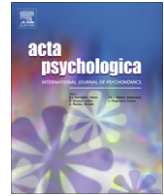




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## Egocentric-updating during navigation facilitates episodic memory retrieval

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### ABSTRACT

Influential models suggest that spatial processing is essential for episodic memory [O'Keefe, J., & Nadel, L. (1978). *The hippocampus as a cognitive map*. London: Oxford University Press]. However, although several types of spatial relations exist, such as allocentric (i.e. object-to-object relations), egocentric (i.e. static object-to-self relations) or egocentric updated on navigation information (i.e. self-to-environment relations in a dynamic way), usually only allocentric representations are described as potentially subserving episodic memory [Nadel, L., & Moscovitch, M. (1998). Hippocampal contributions to cortical plasticity. *Neuropharmacology*, 37(4–5), 431–439]. This study proposes to confront the allocentric representation hypothesis with an egocentric updated with self-motion representation hypothesis. In the present study, we explored retrieval performance in relation to these two types of spatial processing levels during learning. Episodic remembering has been assessed through Remember responses in a recall and in a recognition task, combined with a "Remember-Know-Guess" paradigm [Gardiner, J. M. (2001). Episodic memory and autooetic consciousness: A first-person approach. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 356(1413), 1351–1361] to assess the autooetic level of responses. Our results show that retrieval performance was significantly higher when encoding was performed in the egocentric-updated condition. Although egocentric updated with self-motion and allocentric representations are not mutually exclusive, these results suggest that egocentric updating processing facilitates remember responses more than allocentric processing. The results are discussed according to Burgess and colleagues' model of episodic memory [Burgess, N., Becker, S., King, J. A., & O'Keefe, J. (2001). Memory for events and their spatial context: models and experiments. *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences*, 356(1413), 1493–1503].

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### 1. Introduction

Data drawn from amnesic patients with hippocampal lesions and from the discovery of hippocampal "place cells", have led to the assumption that episodic memory and spatial processing are linked (Holdstock et al., 2000; King, Burgess, Hartley, Vargha-Khadem, & O'Keefe, 2002; O'Keefe & Dostrovsky, 1971; O'Keefe & Nadel, 1978; Spiers, Burgess, Hartley, Vargha-Khadem, & O'Keefe, 2001; Spiers et al., 2001). To date, however, little is known about how they are functionally related and more specifically which spatial processing underlies Episodic Memory.

Episodic memory was originally described as the memory for information located in time and space. This definition emphasized the access to "what", "when" and "where" information on the event. This definition of Episodic memory has greatly evolved since then. Tulving (2002) now considers that the subjective sense of re-experiencing an event, called autooetic consciousness, is the hall-

mark of episodic memory. Autooetic consciousness relies on the binding of the "what", "where", and "when" of the information learned (De Goede & Postma, 2008; Meiser, Sattler, & Weisser, 2008). To a larger extent, this ability allows one to mentally navigate backwards or project forward along something akin to a personal "movie" (Wheeler, Stuss, & Tulving, 1997).

Here, we distinguish three types of spatial representations, egocentric (i.e. code for static object-to-self relations), allocentric (i.e. code for static object-to-object relations) and egocentric updated with self-motion (i.e. code for self-to-environment relations in a dynamic fashion), that could be linked to long-term memory in different ways (for a recent review see Postma, Kessels, & van Asselen, 2008).

Due to permanent changes in the subjects' localisation and orientation, the static or iconic-egocentric representations (King, Burgess, Hartley, Vargha-Khadem, & O'Keefe, 2002), are generally seen as inefficient for long-term memory storage of an episode. In contrast, allocentric representations are considered more stable, independent of subject movement (Burgess, Becker, King, & O'Keefe, 2001). Nadel and Moscovitch (1998), and O'Keefe and Nadel

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(1978) proposed that the hippocampus would be able to bind all the neocortical representations related to an episode by providing a spatial scaffold for the episode. This theory posits that episodic memory relies on spatial knowledge acquired as a map, thus on relations existing between objects (i.e. allocentric representations). As previously mentioned numerous studies have reported a coincidence of impairments in topographical and episodic memory following hippocampal lesions (Burgess, 2006; Holdstock et al., 2000; Hort et al., 2007; King, Burgess, Hartley, Vargha-Khadem, & O'Keefe, 2002; Spiers, Burgess, Hartley, Vargha-Khadem, & O'Keefe, 2001; Spiers et al., 2001). Although, to our knowledge only two studies have clearly focused their interest on allocentric and egocentric deficits in relation with episodic memory impairments after hippocampal lesions (Holdstock et al., 2000; King, Burgess, Hartley, Vargha-Khadem, & O'Keefe, 2002). These experiments opposed iconic-egocentric (i.e. visual pattern matching tasks) to a shifted-view condition, and supported the idea that iconic-egocentric representation cannot be proposed to functionally underlie episodic memory. As acknowledged by its authors, the shifted-view condition might have been concurrently solved using an allocentric processing or an egocentric-updated processing.

In fact, spatial memory cannot be reduced to only allocentric and iconic-egocentric representations (Avraamides & Kelly, 2008; van Asselen et al., 2006; Waller, Lipka, & Richardson, 2008). Behavioural, electrophysiological and fMRI data suggest that it could be useful to consider another type of representation involved in navigation (Burgess & O'Keefe, 1996; Farrell & Robertson, 1998; Maguire et al., 2003; Mellet et al., 2000; Nardini, Burgess, Breckenridge, & Atkinson, 2006; Wang & Spelke, 2000; Whishaw, McKenna, & Maaswinkel, 1997). This egocentric updated with self-motion representation would be automatically constructed from both ideothetic (i.e. sensorial information extracted from stable stimuli) and allotethic information (i.e. sensorial information acquired through self-movement). This representation would remain egocentric in the sense that it uses a coordinate system centred on the observer. Nevertheless, it would encode self-to-environment relations in a dynamic fashion due to continuous vestibular, proprioceptive, and visual flow inputs, during navigation.

Moreover, although episodic information of an event can be simultaneously represented in an allocentric and an egocentric way, allocentric representations alone cannot account for self-centred visuo-spatial re-experiencing, in a direct way (Burgess, Becker, King, & O'Keefe, 2001). A translation from the allocentric reference frame to an egocentric reference frame would be necessary. Crawley and French (2005) explored the link between points of view and autothetic consciousness by using the "Remember-Know-Guess paradigm" (RKG) (Gardiner, 2001; Gardiner, Ramponi, & Richardson-Klavehn, 1998). They observed that Remembered (R) information induced viewer-centred recall, whereas Known (K) information was independent of viewer perspective, like allocentric relations. R information refer to event retrieved through an "autothetic consciousness" of the original event, a central feature of episodic memory. Instead, K information induce no re-experiencing of the event and are related to the semantic memory. In a similar vein, congruent body posture has been observed to facilitate access to and retention of remote episodic memories (Dijkstra, Kaschak, & Zwaan, 2007). Thus, episodic memory appears to be linked with viewer-centred recall.

We acknowledge that egocentric-updated information could simply reflect the possible translation of allocentric information representations into egocentric iconic ones. Nonetheless, we wondered if a memory of allocentric processing alone could account for episodic memories or if egocentric-updated processing performed during learning is crucial for re-instantiating an episodic memory. Indeed, if iconic-egocentric representations do not underlie long-term memory, it remains unclear in the literature which of these

last two spatial representations, allocentric or egocentric updated with self-motion, plays a more important role for long-term episodic memory. The aim of this experimental study is to directly compare these two types of spatial representation by testing whether egocentric-updated processing helps subsequent episodic remembrance more than allocentric processing alone.

To investigate this issue, we designed two experimental conditions emphasizing either object-to-object processing (i.e. allocentric) or dynamic self-to-environment processing (i.e. egocentric-updated) by changing the spatial context-task performed during incidental encoding of items into long-term memory. Free recall, and recognition of item names were then measured 4 h later. This global memory performance emphasized only the "what" component of episodic memories. To strictly assess episodic memory, a "Remember-Know-Guess" paradigm was used to insure that the measured effects were associated with autothetic consciousness (i.e. R responses). An additional source-monitoring task was proposed after the recognition task. By evaluating memories of the stimuli encoding context, this task provides further corroboration on the effects measured through R responses. In the present study, we attempted to disentangle two hypotheses describing the link between episodic memory and spatial processing. The first hypothesis that we will call the allocentric hypothesis, supposes that allocentric representations are sufficient and essential for episodic memory (Nadel & Moscovitch, 1998). The allocentric hypothesis presumes that learning words while emphasizing allocentric representation rather than egocentric updated with self-motion representation facilitates retrieval performance, especially when related to autothetic consciousness (i.e. R responses). The second hypothesis, that we will call the egocentric-updated hypothesis, predicts the opposite pattern of results (i.e. retrieval facilitation in the egocentric-updated condition, especially for R responses). This hypothesis does not exclude a potential functional implication of the allocentric representation within the Episodic Memory.

## 2. Materials and methods

In the first part of the following procedure, participants learnt to spatially process the environment layout then they spatially processed the layout when it included test pictures (which were here learnt incidentally). In the second part, 4 h later, they were unexpectedly tested on recall and recognition for the pictures alone (and not on any of the spatial relations that appeared to be the test in the first part).

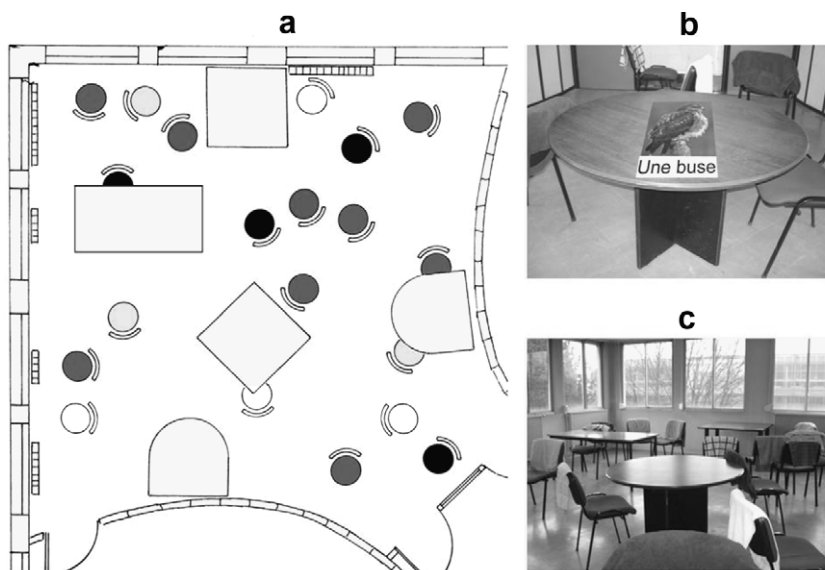
### 2.1. Participants

Twenty-two undergraduate and graduate students in psychology (1 male and 21 females), aged from 18 to 37 years (mean age of 22 years and 2 months) participated in the experiment for course credit. They all gave written informed consent to the experiment.

### 2.2. Stimuli

To capture the true dynamism of navigation while maintaining an appropriate degree of experimental control, participants accessed the environment via pre-processed data, instead of interacting freely with a real environment (see Fig. 1a).

The items-to-be-remembered consisted of 28 names and pictures of birds, matched with 28 other bird names for the recognition task. These items were embedded in "close viewpoint object" images by placing them on a goal object (see Fig. 1b). "Contextual snapshots" were taken from a more distant viewpoint, to provide contextual information on the "goal object" (see Fig. 1c).



**Fig. 1.** (a) A detailed map of the controlled environment layout. The colours of towels placed on chairs are represented by different shades of grey. (b) Examples of snapshots presented on the probe screen during the learning phase and a close view snapshot of a “goal object” with an example of verbal item (i.e. a buzzard) embedded on the object. (c) A “contextual snapshot” presenting a sample of the environment.

210 Thirty-three 20 s-long 1st-person perspective movies were cre- 244  
 211 ated including views of short navigation routes in the environ- 245  
 212 ment. Neither the movies nor the contextual snapshots contain 246  
 213 the **material-to-be-remembered**. 247

214 **2.3. Procedure**

215 Each participant followed a procedure composed of three 244  
 216 phases: training, study, and four-hours-delayed-test. From pilot 245  
 217 studies, we designed two spatial tasks of equivalent complexity. 246  
 218 Each task, which we will call “frame **task**”, is intended to maximize 247  
 219 one or the other type of spatial processing during learning of the 248  
 220 item-to-be-remembered. Processing conditions (i.e. Allocentric 249  
 221 **vs.** Egocentric-updated) were manipulated during the study phase 250  
 222 in a “within-subject” design. 251

223 **2.4. Training phase**

224 Participants were familiarised with five trials of each spatial 252  
 225 frame task, without presentation of any items-to-be-remembered. 253

226 **2.5. Allocentric frame task**

227 To emphasize object-to-object processing, participants had to 254  
 228 locate and establish relative positions between two objects by 255  
 229 employing relative distance and direction terms. 256

230 An object static image is presented, and designated by the 257  
 231 experimenter as the spatial goal object which will have to be 258  
 232 reached during the probe screen presentation (see Fig. 2). Then, 259  
 233 the probe screen (which will be used to present the **item-to-be-** 260  
 234 **remembered** in the study phase) is presented during 15000 ms. 261  
 235 In this condition, the probe screen is composed of four snapshots: 262  
 236 A close-up view of the goal object, a close-up view of an object des- 263  
 237 ignated as the source object, and two contextual snapshots. Each of 264  
 238 the close-up view is designated as the source object or the goal ob- 265  
 239 ject. Each of the contextual snapshots is designated as the context 266  
 240 image (of the goal or of the source). The task was to indicate the 267  
 241 position of the goal object relative to the source object. Crucially 268  
 242 here, to enhance object-to-object processing and the use of map- 269  
 243 like representations, no images contained enough information to 270

244 solve the task via a direct visual strategy. Participants gave verbal 245  
 246 categorical information on the relationships such as “on the left”, 247  
 247 “to the top”, **and** “far from”. They sketched with a pointer on the 248  
 248 source image the directional vector toward the goal object (see 249  
 249 Fig. 2). 250

251 **2.6. Egocentric-updated frame task**

252 To emphasize self-to-environment processing, participants had 253  
 253 to situate them in the environment according to a route movie and 254  
 254 complete a pseudo-navigation between two locations. 255

256 A 1st-person-perspective movie is presented (see Fig. 2). Movies 257  
 257 were always circuitous so that there was a shortcut that differed 258  
 258 from the path taken in the movie. On the final view of the movie, 259  
 259 the object presented is designated by the experimenter as the spa- 260  
 260 tial goal object which will have to be reached during the probe 261  
 261 screen presentation. Then, the probe screen (which will be used 262  
 262 to present the **item-to-be-remembered** in the study phase) is pre- 263  
 263 sented during 15000 ms. In this condition, the probe screen is com- 264  
 264 posed of two snapshots: a close-up view of the goal object 265  
 265 (corresponding to the final view in the movie) and the initial snap- 266  
 266 shot of the movie. The close-up view is designated as the goal ob- 267  
 267 ject. The initial snapshot of the movie is designated as the source 268  
 268 view. This initial snapshot is a large view of the environment, thus 269  
 269 it contains contextual information on the room. The task was to 270  
 270 mentally produce shortcut navigation, from the initial view of 271  
 271 the movie (i.e. the source view) to the final view of the movie 272  
 272 (i.e. the goal object). Participants were asked to produce a self- 273  
 273 centred navigation from the initial point of view of the movie to 274  
 274 the final point of view of the movie. To assess task execution, parti- 275  
 275 cipients gave verbal categorical information on their navigation, such 276  
 276 as “I turn left”, “I walk straight”. They were free to sketch out their 277  
 277 path while imagining it (see Fig. 2). 278  
 278

279 **2.7. Study phase**

280 Fourteen items-to-be-remembered were presented in each con- 281  
 281 textual spatial task condition. It is crucial for the experiment that 282  
 282 the first static images and videos do not contain the pictures or 283  
 283 names of the birds (which are to-be-remembered). They only gave 284  
 284

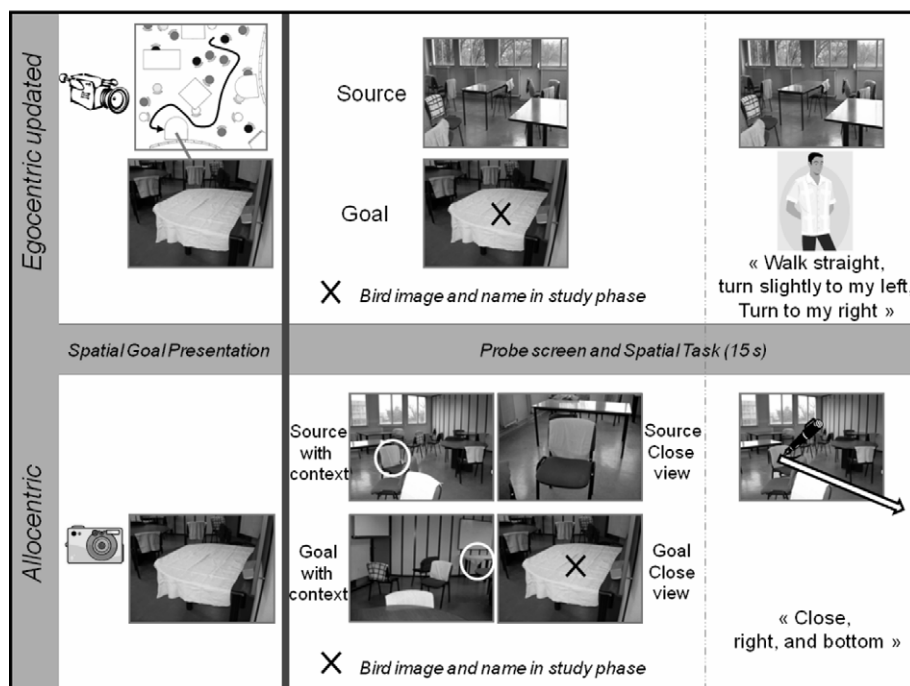


Fig. 2. General overview of the procedure.

location information necessary to solve the frame tasks. Only the probe screen of each condition, composed of static pictures of the room with identical presentation characteristics, contained the birds' names and pictures (see Fig. 2).

In each condition, participants were presented with the probe screens for a period of 15 s. In the probe screens the item-to-be-remembered was presented embedded in the goal object and participants are required to use the bird names rather than goal objects in their responses (verbal response example: egocentric-updated, "Walk straight, turn slightly to my left, and turn to my right to face the buzzard"; Allocentric, "Close, to the right and to the bottom of the buzzard", also see Fig. 2). Otherwise the tasks were the same as in the training phase. To prevent any bias introduced by presentation order, the order of items was randomized and the frame task trial types were randomly interleaved. Assignment of experimental items to a learning frame task was counter-balanced across subjects.

Because there is only one environment, and because conditions are presented in an interleaved way, in a within-subjects design (i.e. the same participant saw movies of the environment and multiple pictures of it in a random order) participants were able to build a unique and detailed representation of the environment. General knowledge, on the elements constituting the environment and on their spatial arrangement, was progressively built during the training and study phases, and thus remained equal between conditions. This experimental design prevents a potential interpretation in terms of a more life-like presentation in one of the conditions, or in terms of differences between movies and pictures, as items are encoded during the probe screens only, which are equal on the level of similarity with real life.

### 2.8. Test phase

Episodic memory was assessed via two tests: 1) a recall test with a RKG paradigm, and 2) a two-part recognition test using both an RKG question and a source-monitoring test on each item. To test free recall, participants were asked to recall the names of birds they saw and named in the study phase. Participants then assigned

a level of consciousness to each recalled word. Including an RKG paradigm within the recall task was important to assess the subjective feeling of autoegetic consciousness which simple recall does not address. Thus, as in the recognition test, participants could answer: (1) I "Remember" when I learned the word, and recollect some aspects, details of the episode (2) I "Know" that the word has been presented, but I cannot recollect or travel back in time; (3) I "Guess" but I am not sure about this word. Instructions explicitly referred to the elicited consciousness. Each answer had to be validated by an explanation to systematically check the cues used, as proposed by Gardiner (2001).

During the recognition test, 56-bird names were presented sequentially. Twenty-eight of the bird names were presented in the previous phase (14 in the egocentric-updated condition, 14 in the allocentric condition), 28 were new. New items remained constant across subjects. Each word appeared for 2000 ms. For each word, participants had to decide between previously cited possible answers (1), (2) or (3), and an additional answer (4) "New", when the item was believed not to have been previously presented. For the source-monitoring part of this task, recognized words had to be classified as seen during the Egocentric-updated or Allocentric frame task condition. Participants were also allowed to specify that they could not give this information.

### 2.9. Experimental setup

Experiments were performed using the E-Prime 2.0 software (Psychological Software Tools, Pittsburgh, PA). During the learning phase participants stood in front of a PHILIPS 21-inch colour screen, placed 140 cm from the floor and located at a distance of 75 cm from the participants. During test phase participants sat in front of a laptop.

## 3. Results

As we expected an overall retrieval performance effect, and crucially in R responses, an ANOVA was conducted on the number of recalled, recognized and correctly source-monitored words, using

350 the encoding frame task (Egocentric-updated condition *vs.* Allo-  
351 centric condition) and the RKG response (R, K or G) as *within-sub-*  
352 *ject* factors.

### 353 3.1. Recall data

354 There was a significant main effect of the frame task during  
355 learning:  $F_{\text{subject}}(1, 21) = 15.05$ ,  $p = 0.0008$ ;  $F_{\text{item}}(1, 27) = 14.71$ ,  
356  $p = 0.0007$ , in favour of *egocentric-updated* processing during  
357 encoding. Unsurprisingly, recall responses were mainly R ones:  
358  $F_{\text{subject}}(2, 42) = 13.85$ ,  $p = 0.0000$ ;  $F_{\text{item}}(2, 54) = 11.90$ ,  $p = 0.0000$ .  
359 We observed, furthermore, a significant interaction (see Fig. 3a) be-  
360 tween frame task conditions and RKG procedure response type:  
361  $F_{\text{subject}}(2, 42) = 5.38$ ,  $p = 0.008$ ;  $F_{\text{item}}(2, 54) = 7.24$ ,  $p = 0.001$ . We  
362 *cannot* assert that this interaction gives a reliable supplementary  
363 result since the near floor performance on K and G responses in-  
364 duced heterogeneity of variances which might have artificially  
365 strengthened the interaction. However, planned contrasts ensured  
366 that this frame task effect was present for R responses, associated  
367 with auto-noetic consciousness  $F_{\text{subject}}(1, 21) = 11.61$ ,  $p = 0.002$ ;  
368  $F_{\text{item}}(1, 27) = 13.81$ ,  $p = 0.0009$ .

### 369 3.2. Recognition data

370 After a *four-hour* delay, subjects remembered well enough for  
371 us to get significant results; the associated  $d'$  was 1.09, with an  
372 average performance of 19.08 words correctly recognized out of  
373 24. Although, the recognition measure was directly the number of  
374 correct responses. In fact,  $d'$  could not be used to run our analy-  
375 ses or plot the results. False positives could not be assigned to one  
376 or the other condition since a new item did not referred neither to  
377 an egocentric-updated learning condition nor to an allocentric  
378 learning condition. Significantly more words were correctly recog-  
379 nized in the Egocentric-updated than in the Allocentric condition  
380 [ $F_{\text{subject}}(1, 21) = 6.72$ ,  $p = 0.017$ ;  $F_{\text{item}}(1, 27) = 8.40$ ,  $p = 0.007$ ]. Most  
381 recognitions were assigned to an R response:  $F_{\text{subject}}(2, 42) = 17.00$ ,  
382  $p = 0.0000$ ;  $F_{\text{item}}(2, 54) = 34.75$ ,  $p = 0.0000$ . Again, a significant  
383 interaction between frame task conditions and RKG procedure  
384 response type was observed, but only in the by-item analysis  
385 (see Fig. 3b):  $F_{\text{subject}}(2, 42) = 2.33$ ,  $p = 0.10$ ;  $F_{\text{item}}(2, 54) = 5.80$ ,  
386  $p = 0.005$ . Planned contrasts on R responses ensured that this effect  
387 was indeed present for responses associated with auto-noetic con-  
388 sciousness:  $F_{\text{subject}}(1, 21) = 6.23$ ,  $p = 0.02$ ;  $F_{\text{item}}(1, 27) = 12.75$ ,  
389  $p = 0.001$ . Contrary to R responses, there is no indication that there  
390 is an effect of learning frame task neither for K nor for G responses  
391 ( $F_s < 1$ ).

392 Finally, as defined in the procedure, participants monitored the  
393 source of recognized items. There was a significant main effect  
394 of the contextual task during learning on the number of correctly  
395 source-monitored words:  $F_{\text{subject}}(1, 21) = 8.28$ ,  $p = 0.009$ ;  
396  $F_{\text{item}}(1, 27) = 6.52$ ,  $p = 0.01$ . Egocentric-updated source-monit-  
397 oring with 3.5 words ( $SD = 0.38$ ) was superior to Allocentric source-  
398 monitoring with 2.31 words ( $SD = 0.23$ ). To insure that no bias in  
399 the source-monitoring task was responsible for these results, we  
400 looked at false alarms related to each condition. We observed an  
401 equivalent mean number of false alarms from the Egocentric-up-  
402 dated and Allocentric frame tasks (1.50 and 1.54, respectively).

## 403 4. Discussion

404 This study assessed the effect of the spatial processing type en-  
405 gaged during encoding on the subsequent episodic retrieval. Two  
406 proposals have been compared, (a) the allocentric hypothesis  
407 asserting that object-to-object relations enhance episodic memory,  
408 and (b) the Egocentric-updated hypothesis asserting that episodic  
409 memory relies on self-to-environment relations updated during  
410 navigation. We asked whether successful episodic retrieval  
411 depends more on *Allocentric* or on Egocentric-updated repre-  
412 sentations during encoding.

413 Episodic memory was assessed using three tasks: recall, recog-  
414 nition and source-monitoring, by means of an RKG paradigm. Our  
415 analyses were mainly focused on Remember judgments that reflect  
416 a state of auto-noetic consciousness, characteristics of multidimen-  
417 sional bindings (i.e. “What”, “Where”, “When” binding). A *source-*  
418 *monitoring* task was added to the recognition task in order to  
419 obtain additional evidence on the circumstance of encountering  
420 of the event, a specific subpart of episodic memory. To test the  
421 facilitation effect induced on episodic memory per se and not on  
422 spatial memory, performance was assessed on verbal items,  
423 embedded in a contextual spatial task during encoding, rather than  
424 on source recall of spatial characteristics. As predicted, items  
425 learned in the Egocentric-updated condition were retrieved better  
426 than those studied in the Allocentric condition. Using the RKG  
427 paradigm, we insured that this advantage was observed for the R  
428 responses of recall and recognition. These responses are phenome-  
429 nologically associated with auto-noetic consciousness. The study  
430 phase procedure operates on type and/or depth of processing dif-  
431 ferences. Due to the difference in the contextual information  
432 potentially enclosed in a video versus a static presentation, rich-  
433 ness or depth of processing differences on the global context of  
434 the item-to-be-remembered (although not on the object itself)

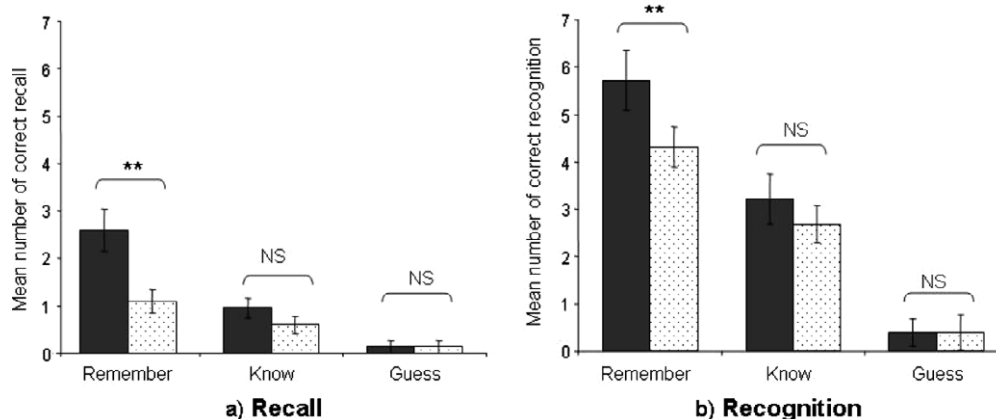


Fig. 3. Average number of items correctly recalled (a) and recognized (b), according to Remember, Know, and Guess responses, after learning items within a Egocentric-updated (black) or Allocentric (white) frame task.  $**p < 0.1$ .

must be addressed as a possible explanation of the results. Nevertheless, the experimental procedure was designed to limit a potential distinctiveness effect of the context, by using a unique environment across conditions (so that participants were able to build a unique and detailed representation of the environment). Moreover, the overall number of contextual objects visible within each complete trial was kept equivalent across conditions (with an average of 20 objects) so that conditions did not differ on the number of contextual objects presented. Therefore, it seems likely that differences in depth of processing would be more likely to be due to the type of processes (i.e. Egocentric-updated or Allocentric) involved rather than the number of contextual details in each condition. These results, hence, suggest that Egocentric-updated processing during episodic encoding facilitates episodic recollection associated with auto-noetic consciousness.

The results presented here are relevant for current multi-trace type memory models that retain only iconic-egocentric and allocentric representations and which suppose that allocentric encoding is the primary source of representation of episodic memory. Thus, they need to be able to explain this facilitation induced by Egocentric-updated over Allocentric processing. In fact, Burgess, Becker, King, and O'Keefe (2001) and Byrne et al. (2007) have recently proposed that retrieval of episodic information from long-term storage requires the imposition of a particular viewpoint. In this model, the medial temporal lobe uses allocentric representations as a key mechanism for long-term storage while parietal iconic-egocentric representations are used to imagine, manipulate and re-experience the products of retrieval. The Papez circuit would act as a referential translation system allowing the brain to translate spatial representations according to the direction of view. The original representation in the parietal lobe would be from the subject's point of view. The translation system transforms this into an allocentric representation for encoding into long-term memory. Upon recall, the translation system rebuilds a subject-centred image from the allocentric memory. Additionally, one could use the translation system to imagine a scene from a different point of view than one experienced during encoding. Viewer-centred representations would then be dynamically generated from long-term memory in the parietal cortex.

In this context, how could we explain the advantage of the egocentric-updated information over the allocentric one?

If we consider allocentric representations to be the primary and sufficient source for episodic memory, then egocentric-updated information simply reflects an online process of the reference translation system, with no memory. Then it would be possible to build from allocentric knowledge any given point of view in an egocentric reference coordinate system. However, in that case, the system cannot differentiate illusory translations from an actual re-experiencing of the point of view corresponding to a learned episode. In other words, the system would keep no information to differentiate between imaginary self-projection to a place (i.e. imagination) and real personal memories of that same place (i.e. episodic memory associated with auto-noetic consciousness).

Now, if we consider that egocentric-updated information is also necessary for episodic memory, then egocentric-updated information would reflect an online process of the referential translation system, with a memory. This memory of egocentric-updated information would be characteristic of episodic memory. In fact, from allocentric knowledge, it would be possible to build any point of view. However, the system would rely on the egocentric-updated information memory to distinguish between re-experiencing (i.e. episodic memory) and imaginary self-projection. Thus, our results would indicate that the enhancement of this memory within the referential translation system would be more effective for episodic retrieval than acute encoding of object-to-object relations within the allocentric coding one.

To conclude, this experiment indicates that egocentric-updated information acquired during encoding yields a better episodic retrieval than encoding which emphasizes object-to-object relations. In the context of Burgess and colleagues' model, we propose that this advantage could be reflected through the addition of a memory property to the referential translation system.

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