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Recollection in the light of eye movements:

The relational eye movement effect and its role in recollection

Theses

Introduction

It is an unanswered and important question what are the behavioural markers of unconscious access to relational representations. These markers would allow us to test the theoretically important questions about whether recollection is best characterized as a two-stage process. According to the two-stage model (Moscovitch, 2008; Moscovitch et al., 2016) the first stage of recollection is a rapid, unconscious, hippocampus-dependent obligatory interaction between a cue and the previously encoded memory trace, which results in the access to the episodic representation. This access at the first stage is not consciously apprehended but it enables conscious access. During the second, slower stage the representation becomes accessible to conscious processes, which can give rise to the unique phenomenological experience and make the content explicit. There is a striking feature overlap between the relational eye movement effect (Hannula et al., 2007; Hannula & Ranganath, 2009) and the first step of recollection (see Table 1).

Measureable index of relational retrieval: Relational eye movement effect (REME)	Theoretical concept of recollection: First stage of recollection
Rapid and obligatory	Rapid and obligatory
It can occur in the absence of conscious recollection	It can occur in the absence of conscious recollection
hippocampus dependent	hippocampus dependent
Appears before overt responses are made	Appears before conscious access to the representational content

Table 1. Feature overlap between the measureable REME and the theoretical concept of the first stage of recollection (based on the REME results of Hannula et al., 2007; Hannula & Ranganath, 2009).

This feature overlap of the theoretical concept and the measurable eye movement effect suggests that the REME could be used as the behavioural index of the first step of recollection. Making this link between the REME and the first-stage of recollection is not new in the literature, Hannula and Ranganath (2009) also expressed that their results are consistent with the two-stage model (see page 53). Others also highlighted that the REME might signal the first-stage of recollection (Sheldon & Moscovitch; 2010, Moscovitch et al., 2016). Based on the summary of previous results and the feature overlap of the REME and the first-stage of recollection we could make the following assumption:

The REME is a universal and necessary indicator of relational memory retrieval. It accompanies successful relational retrieval obligatorily and unconsciously. It can be regarded as the behavioural marker of the first-stage of recollection. This assumption provided us with a powerful tool to explain previous experimental results in the literature. Based on its explanatory power we accepted the assumption and we formed basic predictions to test in experiments.

Predictions tested in our experiments:

There are four main predictions based on our assumption that the REME necessarily accompanies successful relational retrieval:

1. Based on the assumption the REME signals a necessary process for relational retrieval, which predicts that when there is evidence of relational memory retrieval in the task, the REME has to appear.
- The other three predictions are derived from our first general prediction:
2. The REME is independent of conscious retrieval processes. The effect can dissociate from conscious retrieval.
 3. The REME is task independent.
 4. The REME is stimulus-type independent.

Methods

Our experiments were based on previous methods that demonstrated the REME (Hannula et al., 2007; Hannula & Ranganath, 2009). We used our own stimulus set with 99 faces (and 99 objects) and 99 background scenes. The experiments consisted of two phases. During the learning phase participants saw randomly paired face (or object) & scene pairs, while their task was to try to remember the pairs for a future memory test. During the test phase a display consisted of three faces (or objects) superimposed on the scene image. Two of the targets were previously paired with different scenes and one of the targets was the original pair of the presented scene (matching target). The task of the participants varied across experiments. They either had to explicitly choose the target stimulus that they thought was the original pair of the scene or they had to learn relationship between the elements of the test displays (the three target stimuli and the scene) for a forthcoming memory test. The eye movements were recorded during the test phases and we used different methods to calculate the viewing time proportion of the target stimuli (raw-data-based and fixation-based methods).

We conducted four experiments, which were intended to test our predictions about the relational eye movement effect. In this overview we will list the experiments and their main questions related to the characteristics of the REME:

In Experiment 1 we used the same face-scene choice task as Hannula & Ranganath (2009) with our own stimuli. We wanted to replicate previous results showing the REME in the task. Moreover, we asked participants to report their subjective confidence levels after each choice they made. We used these confidence ratings to test the emergence of the REME on different criteria levels. Our first prediction states that the REME has to emerge on confidence levels where there is evidence of relational retrieval in the task. By comparing different confidence levels we tested this prediction and we also checked whether the magnitude of the REME is connected to subjective experience of conscious retrieval, what would point to the direction that the REME is tightly linked to conscious retrieval processes. Moreover, we also tested whether we can find any evidence that the REME can dissociate from

conscious retrieval (our second prediction). We separately analysed whether we can find a matching face preference in incorrect responses, when there is supposedly no conscious retrieval of the matching face.

In Experiment 2 we changed the task to a no-choice task, where participants did not have to identify the matching face in the three-face test displays, they only had to learn the three faces together with the scene for a later recognition test. We wanted to find evidence for the emergence of the REME in this task, which would confirm our third prediction. Additionally, we separated participants based on their level of awareness for the presence of the matching faces in test displays to a high and a low awareness group. By comparing these two groups we intended to show a possible dissociation between the REME and conscious retrieval of the matching faces (second prediction).

In Experiment 3 we used a choice task and changed the perceptual characteristics of the faces between learning and test and we tested for the emergence of the REME. Based on our predictions we hypothesized that the REME has to appear when participants can reliably show relational memory performance on the task, irrespective of stimulus characteristics (fourth prediction).

In Experiment 4 we changed the stimulus category from faces to objects in a choice task. Based on our fourth prediction we hypothesized that when participants show relational retrieval in the task the REME has to emerge.

Main Results

1. We could conclude that by using our own stimuli we could replicate previous results in the relational eye movement literature (Hannula & Ranganath, 2009; Hannula et al., 2007). We found the REME during the first two seconds of the test trials and we also showed that the effect appears before explicit responses were made.
2. We found a link between the magnitude of the REME and the subjective confidence level of the participants. Specifically, our results showed that the magnitude of the disproportionate viewing difference was greater for High confidence level than Medium confidence level, which was driven by the

increase of viewing proportions in correct responses. These results pointed to the direction that the process behind the REME might be tightly linked to conscious retrieval.

3. Contrarily to our prediction, we failed to find a matching face preference in incorrect responses, when there was no sign of conscious retrieval.
4. We separated participants to an unaware and an aware group based on the level of their awareness about the presence of a matching face among the three faces of the test displays. The aware group showed a strong REME effect, while the unaware group did not demonstrate any REME. Moreover, both participant groups showed evidence of relational memory, which affected their allocation of encoding capacity to one of the non-matching faces compared to the matching face. These results strongly suggested that the REME is not independent of conscious retrieval, rather it could be used as a measure of conscious retrieval.
5. There was no evidence for the REME when we used objects as target stimuli instead of faces. These results suggested that the eye movement effect may depend on the category of the target stimuli. It raised questions about whether the retrieval process behind the REME is universal and necessary for relational retrieval.

Conclusions based on our main findings

Conclusion no. 1: The REME is not a valid behavioural measure of the first stage of recollection.

Our experimental results suggested that the REME does not necessarily accompany relational retrieval (Experiment 2 and Experiment 4) and it is not dissociable from conscious retrieval (Experiment 1 and Experiment 2). These characteristics of the relational eye movement effect are in contrast with the proposal that the REME is a measure of the first-stage of recollection.

Conclusion no. 2: The REME signals a process, which is obligatorily connected to the conscious access to relational memory representations. This proposes the conscious access framework of the REME.

In our experiments we demonstrated that the emergence of the REME is strongly associated with conscious access to the relational representational content. Our results suggested a conscious access framework of the REME, which asserts that the relational eye movement effect is a precursor for conscious retrieval in a sense that whenever it occurs, it obligatorily brings on conscious retrieval.

Conclusion no. 3: The process indexed by the REME does not necessarily accompany conscious relational retrieval. Conscious retrieval can emerge without the REME.

It is important to point out that the proposed obligatory link between the emergence of the REME and conscious retrieval in our conscious access framework does not entail that the process always accompanies conscious retrieval. There could be other pathways leading to conscious access apart from the involvement of the process behind the REME.

The fact that conscious retrieval can be obtained without the REME suggests that rapid and automatic retrieval processes do not necessarily determine conscious access to the elements of a relational representation. Conscious access to the elements of an episode might be attained when there is no priming induced (quasi-)automatic activation of the representational content.

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