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Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Dissociating electrophysiological correlates of subjective, objective, and correct memory in investigating the emotion-induced recognition bias

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ARTICLE INFO

Article history:

Received 11 March 2014

Available online 3 October 2014

Keywords:

Subjective experience
 Unconscious recollection
 Event-related potentials
 Memory illusion
 Recognition bias
 Response bias
 Decision-making
 Uncertainty
 Ambiguity
 Dissociation

ABSTRACT

Performance on tasks requiring discrimination of at least two stimuli can be viewed either from an objective perspective (referring to actual stimulus differences), or from a subjective perspective (corresponding to participant's responses). Using event-related potentials recorded during an old/new recognition memory test involving emotionally laden and neutral words studied either blockwise or randomly intermixed, we show here how the objective perspective (old versus new items) yields late effects of blockwise emotional item presentation at parietal sites that the subjective perspective fails to find, whereas the subjective perspective ("old" versus "new" responses) is more sensitive to early effects of emotion at anterior sites than the objective perspective. Our results demonstrate the potential advantage of dissociating the subjective and the objective perspective onto task performance (in addition to analyzing trials with correct responses), especially for investigations of illusions and information processing biases, in behavioral and cognitive neuroscience studies.

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1. Introduction

Behavioral and Cognitive Neuroscience experiments typically involve two or more stimulus conditions in which responses are being observed, to be linked later on with brain measures or reaction times. Before data analysis, researchers typically sort the trials in which the dependent measures were taken into "bins" that are then to be compared. The sorting is usually performed in accordance with the pre-defined task design, and demarcates objective stimulus differences between conditions. Trials with incorrect responses are often eliminated so that only correct responses are compared between conditions. Most rarely, researchers adopt the subjective perspective onto task conditions by sorting trials into bins depending on the experience of the participants as indicated by their responses, whether or not these are objectively correct.

When task performance is perfect, the objective perspective onto differences between experimental conditions corresponds one on one with both, the subjective perspective and the analysis of correct response trials. However, inasmuch as the task is difficult or otherwise induces uncertainty or ambiguity, the subjective, objective, and correct perspectives

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should yield quite different pictures. Particularly interesting are cases where participants *believe* that their responses are correct when this belief is independent of, or even contrasts with, objective reality. Such systematic deviations of the subjective from the objective perspective usually occur due to biases or illusions.

The interesting question for scientists interested in cognition and consciousness is how and at what level of processing objective stimulus features are being transformed by the brain into subjectively experienced attributes that determine responses. What might be expected is that input-driven, bottom-up processes covary more with variations in objective stimulus attributes whereas the decision output is more reflective of the selective, distorted, or otherwise biased processes controlled by subjects. Such dissociations between the objective and the subjective realm are conceivable for all kinds of cognitive tasks including perceptual, memory, reasoning, and decision-making tasks. The present article attempts to apply this rationale in investigating accurate versus biased recognition memory processes as indexed by event-related potentials (ERPs).

Two prior experiments that have taken ERPs while participants performed a recognition memory task illustrate some of the potential benefits associated with adopting different perspectives onto the data. First, [Rugg et al. \(1998\)](#) found a fascinating dissociation between ERP correlates of implicit/unconscious and explicit/conscious recognition memory. They made use of the fact that ERPs recorded during memory tests are typically more positive going for studied (old) items relative to unstudied (new) items, a difference called the ERP old/new effect ([Allan, Wilding, & Rugg, 1998](#); [Mecklinger, 2000](#); [Rugg & Curran, 2007](#)). [Rugg et al. \(1998\)](#) found that at parietal sites between 300 and 500 ms poststimulus, ERPs associated with correctly identified studied items (hits) and ERPs associated with incorrectly identified studied items (misses) were both more positive going than were ERPs associated with correctly identified unstudied items (correct rejections). Apparently, ERPs generated from implicit/unconscious memory systems detected the *objective* difference between studied and unstudied items while participants *subjectively* did not (in the case of the missed items). By contrast, later during the recording epoch, between 500 and 800 ms poststimulus, ERPs associated with missed studied items did indeed go alongside ERPs associated with correctly identified unstudied items (correct rejections), whereas ERPs to correctly identified old items (hits) were more positive going. Thus, ERPs in that later time-window (the late positive complex, LPC) reflected the *subjective* perspective onto the study status of the items. Finally, at around 400 ms poststimulus, ERPs indexed a subjective feeling of “familiarity” that is thought to arise automatically but lacks conscious recollection and thus appears to mark the transition between unconscious and conscious memory processes. It is presumably at this processing stage when automatically processed, input-driven memory processes are accessed by subjective experience. Later investigations with magnetoencephalography confirmed the time-point and the frontal distribution of this transition process ([Staresina, Bauer, Deecke, & Walla, 2005](#)).

The second recognition memory study demonstrating dissociations between subjective and objective perspectives onto ERP old/new differences investigated the response bias in recognition memory judgments ([Windmann, Urbach, & Kutas, 2002](#)). The response bias can be defined as the tendency to guess “old” when there is uncertainty as to which response, “old” or “new”, is correct. [Windmann et al. \(2002\)](#) compared ERPs of one group of individuals who showed a spontaneous tendency to guess liberally in favor of old items (i.e., who showed a preference to respond “old” when they were unsure), with those participants who spontaneously adopted a conservative bias (i.e., a preference to respond “new” when unsure). While the two groups of individuals were comparable in terms of accurate recognition memory performance (i.e., correct old/new discrimination), their frontal ERPs recorded at 300–500 ms poststimulus showed differential amplitudes depending on their preferred response biases. Most importantly, the groups differed significantly in their ERP old/new effects only when ERPs associated with “old” responses were compared with ERPs associated with “new” responses. By contrast, there were no significant group differences in ERP old/new effects for the objective perspective (contrasting old items versus new items), and only marginally significant group differences for correct responses (contrasting hits versus correct rejections). Thus, subject-controlled, bias-related memory processes were maximally reflected in ERP old/new differences when participant’s responses determined trial sorting into the to-be-compared bins, least successful when the objective perspective was applied, and half-way successful when correct responses were analyzed as typically done in ERP analyses of recognition memory processes.

In the present study, we applied that same logic to an ERP investigation of the mechanisms underlying a phenomenon in which individuals shift their response bias following semantic analysis of test stimuli. The phenomenon has been termed the *emotion-induced recognition bias* and refers to the finding that in a recognition memory task with words, participants use a more liberal response criterion for “old” responses when classifying test items with an emotional meaning compared to emotionally neutral items, whether or not the items are in fact old ([Dougal & Rotello, 2007](#); [Maratos, Allan, & Rugg, 2000](#); [McNeely, Dywan, & Segalowitz, 2004](#); [Windmann & Krüger, 1998](#); [Windmann & Kutas, 2001](#)). Research in natural settings has described similar effects by showing that memories of emotional events such as 9/11, the Estonia ferry disaster, or the O.J. Simpson trial are biased in a similar vein: The memories appear subjectively stronger than is objectively justified (cited, e.g., in [Phelps & Sharot, 2008](#); [Rimmele, Davachi, Petrov, Dougal, & Phelps, 2011](#)). Functional magnetic imaging studies have suggested that this illusory feeling of remembering can result from misattribution of emotional arousal induced by the amygdala at the time of retrieval ([Sergerie, Lepage, & Armony, 2007](#); [Sharot, Delgado, & Phelps, 2004](#)), although the mechanisms of the misattribution remain unclear.

Cognitive studies have linked the emotion-induced recognition bias to the kinds of memory intrusions that are induced by semantically cohesive stimulus lists, as in the Deese–Roediger–McDermott (DRM) paradigm, where studying semantically interrelated words such as “tooth, bite, ocean, and fish” can prompt participants to produce the semantically central

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