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Context-dependent repetition effects on recognition memory

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ABSTRACT

One widely acknowledged way to improve our memory performance is to repeatedly study the to be learned material. One aspect that has received little attention in past research regards the context sensitivity of this repetition effect, that is whether the item is repeated within the same or within different contexts. The predictions of a neuro-computational model (O'Reilly & Norman, 2002) were tested in an experiment requiring participants to study visual objects either once or three times. Crucially, for half of the repeated objects the study context (encoding task, background color and screen position) remained the same (within context repetition) while for the other half the contextual features changed across repetitions (across context repetition). In addition to behavioral measures, event-related potentials (ERP) were recorded that provide complementary information on the underlying neural mechanisms during recognition. Consistent with dual-process models behavioral estimates (remember/know-procedure) demonstrate differential effects of context on memory performance, namely that recognition judgements were more dependent on familiarity when repetition occurs across contexts. In accordance with these behavioral results ERPs showed a larger early frontal old/new effect for across context repetitions as compared to within context repetitions and single presentations, i.e. an increase in familiarity following repetition across study contexts. In contrast, the late parietal old/new effect, indexing recollection did not differ between both repetition conditions. These results suggest that repetition differentially affects familiarity depending on whether it occurs within the same context or across different contexts.

1. Introduction

One key function of declarative memory, the conscious memory for facts and events (Cohen & Eichenbaum, 1993; Tulving, 1972), is to support recognition of stimuli that were previously encountered and to discriminate such stimuli from those that are novel. According to dual-process models of recognition memory, the ability to discriminate between items encountered at study and items only presented at test is supported by two independent processes, recollection and familiarity (Mecklinger, 2000; Wilding & Rugg, 1996; Yonelinas, 2002). Recollection refers to conscious retrieval of contextual details of the original study episode in which an item occurred. Thus recollection provides information both about the prior occurrence of an item and the context of that occurrence. By contrast familiarity based recognition is not accompanied by information from specific study episodes and therefore provides no means for making discriminations on the basis of contextual information. A critical assumption of most dual-process models is that recollection and familiarity are independent retrieval processes, i.e. recognition can be based solely on recollection without evoking recognition based on familiarity and vice versa (Rugg & Yonelinas, 2003; Yonelinas, 2001).

Dual-process accounts of recognition memory receive support from a number of different sources. In addition to findings from a body of behavioral and patient studies (for a comprehensive review, see Yonelinas, 2002) there is also an extensive amount of research demonstrating that event-related potentials (ERP) are sensitive to dissociate the contribution of familiarity and recollection to recognition memory (e.g., Curran, 2000; Friedman & Johnson, 2000; Rugg et al., 1998a). The ERP old/new effect is estimated from the difference between the ERPs associated with correct responses to old and new test items and comprise relatively more positive-going ERPs for old than for new test items. Based on their spatio-temporal characteristics and sensitivity to experimental manipulations this difference can be subdivided into at least two subcomponents. For the present purposes, the most important effects are an early frontal old/new effect (300–500 ms) and a later effect (400–800 ms) maximal over (left) parietal regions. Importantly, evidence suggests that the two ERP effects are dissociable on both topographic (e.g. see Mecklinger, 2000) and functional grounds (Jäger, Mecklinger, & Kipp, 2006; Rhodes & Donaldson, 2007). Within dual-process accounts of recognition memory these ERP effects are taken to dissociate the contribution of familiarity and recollection (e.g., Curran, 2000; Friedman & Johnson, 2000; Opitz & Cornell, 2006), with the

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early frontal old/new effect reflecting familiarity and the late parietal old/new effect linked to recollection.

A common finding of many studies of recognition is a memory improvement when information is repeatedly presented for studying (Baddeley, Vargha-Khadem, & Mishkin, 2001; Curran, Tepe, & Piatt, 2006; van Strien, Hagenbeek, Stam, Rombouts, & Barkhof, 2005). As an example, using a continuous recognition paradigm van Strien et al. (2005) have shown that subjects discriminated old from new stimuli faster and more accurate the more often old stimuli were repeated. It has been assumed that augmented recognition memory is achieved by strengthening the item-context bindings through repeated item presentations during the study episode. Norman and O'Reilly (2003, see also O'Reilly and Norman, 2002) have developed a biologically plausible neuro-computational model[1] suggesting that sparse neural coding within the hippocampus leads to distinct (pattern-separated) representations of arbitrary item-context bindings irrespective of their contextual similarity. In contrast, the medial temporal lobe cortex (MTLC) assigns similar representations to similar input using overlapping representations to code for the shared structure of events. By this means item representations become sharper over repeated exposures across different contexts. That is, the first presentation of an item weakly activates a large number of MTLC units, whereas repeated and thus familiar stimuli strongly activate a smaller number of units. At test, the presentation of a studied test probe initiates a set of processes that may be described as a comparison between the short-lived representation of the actual stimulus and the sharpened representation in the MTLC. Consequently, a scalar signal is provided that tracks the global similarity between the test probe and the studied items (Hintzman, 2001).

Repeated item presentations within the context of the same study episode will add contextual detail to the representation of this study episode, thereby strengthening the item-context bindings. This in turn will lead to a highly distinct hippocampal representation, whereas in MTLC units, a blurred representation will emerge as a large number of units is weakly activated by the item and its study context. During test, when the item is presented as a test probe the hippocampus is able to reconstruct the entire studied pattern, i.e. the item bound to its context (pattern completion, O'Reilly & Rudy, 2001), thereby enabling the retrieval of contextual information. From the dual process perspective, this binding of an item to its study context entails enhanced recollection (cf. Yonelinas & Parks, 2007). In contrast, given the blurred representation in the MTLC, i.e. the inability to sufficiently differentiate the representations of different events owing to the relatively low learning rate, only a weak familiarity signal should be elicited by items repeated within the same context. This proposed increase in recollection is corroborated by a recent study asking the participants to memorize words that were presented either once (weak words) or three times (strong words) during a study phase (Finnigan, Humphreys, Dennis, & Geffen, 2002). At test, correct old decisions after the presentation of strong words elicited a stronger left parietal old/new effect, indexing recollection, as compared to correct old decisions after the presentation of weak words.

Despite converging evidence that recognition of items repeatedly presented within the same study context is mainly based on recollection it is still unknown how repetition affects recognition memory if an item is repeated across different study contexts. This is often the case in real life where a particular event (e.g. the final goal of the soccer championship) is repeatedly encountered in different contexts, e.g. seen on the television and beeing told by a friend. Moreover, it has been speculated that this form of repetition leads to decontextualized factual knowledge about the world (Craik, 2006; Eichenbaum, 2006). According to the model proposed by Norman and O'Reilly (2003) the repetition of items across different contexts gives rise to a small overlap of contextual features resulting in separate but weak hippocampal representations. However, the sharpening mechanism in the MTLC operates faster and much more efficiently as compared to a situation when items are repeated within the same context in that only the item without contextual features is represented by MTLC units. At test, the test probe is compared against this sharpened representation of the item alone in the MTLC and a larger familiarity signal is provided, whereas the recollection of studied contexts is less likely because of the use of a shared structure to represent similar events preventing the binding of an item to an arbitrary context. While the MTLC model cannot support recollection of details from specific events owing to its relatively low learning rate it well supports familiarity judgments based on the sharpness of representations in MTLC. Consistent with this neuro-computational model I argue that item representations become sharper over repeated exposures across different contexts, thereby supporting recognition based on familiarity. In contrast, repetition within the same context should foster item-context bindings which lead to recollection.

The present experiment explored these hypotheses employing visual objects that were studied either once or three times. Crucially, for half of the repeated objects the study context remained the same (within context repetition) while for the other half the contextual features changed across repetitions (across context repetition). Beside the independent remember/know-procedure the putative ERP correlates of familiarity and recollection were used. Thus, an early frontal old/new effect and a late parietal old/new effect should be observed during the retrieval of items repeated across and within context, respectively.

2. Methods

2.1. Subjects

A total of 30 students from Saarland University participated in this study and were paid for their participation. The data from two participants were discarded due to malfunction of the recording equipment. The data from further two participants were excluded from all analyses because they exhibited excessive EOG artifacts. Of the remaining 26 participants (aged 21–29 years, 14 male) all were right handed as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971).

2.2. Materials

Stimuli consisted of 252 colored pictures from the revised Snodgrass and Vanderwart's object pictorial set (Snodgrass & Vanderwart, 1980; Rossion & Pourtois, 2004) that were divided into 6 lists of 42 objects each. Three lists were used as study lists, the three remaining constituted the new distractor items during the recognition test. The study test assignment of the six lists was counterbalanced across participants so that each list (and therefore each object) appeared equally often in study and test lists. All pictures subtended a horizontal visual angle of 2.5° and a vertical angle of 1.75°.

2.3. Experimental procedure

Each participant performed an intentional recognition memory task. The study phase was divided into three different blocks con-

[1] It should be noted that this so-called 'complementary learning systems' (CLS) framework was initially developed to account for the differential contributions of the hippocampus and the surrounding neocortex to learning and memory in general. However, the underlying computational principles can be well applied to recognition memory. In this sense the CLS model belongs to the long tradition of dual-process models (O'Reilly & Norman, 2002).