Neuropsychologia 57 (2014) 179–190

Contents lists available at ScienceDirect

Neuropsychologia

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

More ways than one: ERPs reveal multiple familiarity signals in the word frequency mirror effect

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ARTICLE INFO

Article history:
Received 5 December 2013
Received in revised form
9 February 2014
Accepted 12 March 2014
Available online 24 March 2014

Keywords:
Absolute familiarity
Event-related potentials
FN400
Mirror effect
N400
Recollection
Relative familiarity
Word frequency

ABSTRACT

Recent dual-process models of the word frequency mirror effect place absolute familiarity, an item's baseline familiarity at a given time point, as responsible for false alarm differences and recollection for hit rate differences between high and low frequency items. One of the earliest dual-process propositions, however, posits an additional relative familiarity mechanism which is sensitive to recent presentation but relative to the absolute familiarity of a particular item (Mandler, 1980). In this study, it was possible to map these three mechanisms onto known event-related potential (ERP) effects in an old/new recognition task with high and low frequency words. Contrasts between ERPs elicited by high and low frequency new items were assumed to index absolute familiarity, and the distribution of this effect from 300 to 600 ms was topographically distinct from a temporally-overlapping midfrontally-distributed old/new effect which was larger for low than high frequency words, as would be expected from a relative familiarity mechanism. A later left parietal old/new effect, strongly linked to recollection, was only present for low frequency items. These frequency-sensitive amplitude differences for both old/new effects disappeared in a second recognition task in which old/new decisions were made under a time constraint, although the posterior absolute familiarity effect remained unaffected by the speeding of responses. The data support the assertion that three distinct recognition processes are affected by word frequency in recognition memory tasks, and the qualitatively distinct distributions associated with the two familiarity contrasts support the presence of two cognitively distinct familiarity mechanisms.

1. Introduction

Familiarity refers to one of two independent processes which can be used to support recognition memory judgments, as is postulated by dual process-models of recognition memory (see Yonelinas, 2002). Familiarity is usually described as a sense or feeling of oldness; an experience which is qualitatively distinct from recollection, which supports the reinstatement of explicit contextual details associated with the encoding episode (although reports in which familiarity appears to contribute to contextual-like retrieval are accumulating; see Kriukova, Bridger, & Mecklinger, 2013; Mollison & Curran, 2012 for recent examples; and Yonelinas, Aly, Wang, & Koen, 2010 for a review). One criticism recently leveled at dual-process accounts is that, whereas the phenomenon of recollection-based remembering is relatively well-described, familiarity is not as clearly characterized, making it easier under some conditions to define familiarity on the basis of what it is not (i.e. recollection) rather than what it is (Leynes & Zish, 2012; Voss, Lucas, & Paller, 2012). In this study, the issue of characterizing familiarity will be addressed by re-focusing on two memory phenomena which have contributed some of the most important evidence for dual-process models to date: event-related potential (ERP) correlates of recognition and the word frequency mirror effect (Glanzer & Adams, 1990).

The word frequency mirror effect describes the phenomenon by which, compared to high frequency words, low frequency items elicit more correct responses in recognition memory tasks both when they are old (an increase in hit rates) and new (a decrease in false alarm rates). This pattern is problematic for single-process signal-detection models, which presume the placement of an old/new decision criterion along a continuum of memory strength, because a simple strength mechanism cannot predict both the hit and false alarm rate without incorporating additional parameters which make these models unjustifiably complex (DeCarlo, 2007; Hintzman, 1994; Murdock, 1998). Dual-process models have dealt with this issue by positing that the hit and false alarm rates reflect the respective contributions of recollection and familiarity (Joordens & Hockley, 2000; Reder et al., 2000). A greater level of pre-experimental familiarity for high frequency items is assumed

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http://dx.doi.org/10.1016/j.neuropsychologia.2014.03.007
0028-3932/

to make it more likely that high frequency new items will fall above the old/new criterion and thus be incorrectly classified as old. At the same time, low frequency items are inherently more distinctive, in part as a consequence of the low number of contexts in which they have previously been experienced. This increases the likelihood in which the experimental context associated with a low frequency item is recollected during an experimental test phase which drives the increased hit rate for these items. This pattern tallies with a number of data points including those which show that low frequency hits are disproportionately supported by judgments associated with a feeling of remembering, thought to correspond with recollection (Reder et al., 2000). Of particular interest for the current report are data from experimental designs which have capitalized on the assumption that familiarity occurs faster than recollection-based remembering. When participants are required to respond at an early time point by which it should not be possible to make recollection-based responses, the hit advantage for low frequency items has been shown to be removed whilst the false alarm difference remains unchanged (Balota, Burgess, Cortese, & Adams, 2002; Joordens & Hockley, 2000).

In their recent paper, Coane, Balota, Dolan, and Jacoby (2011) combined this dual-process model with another mechanism proposed to contribute to the word frequency mirror effect: a relative familiarity mechanism, which refers to the change in familiarity strength relative to its pre-experimental familiarity level after an item has been presented during the study phase of an experiment. A mechanism of this kind would necessarily elicit a greater feeling of familiarity for low than high frequency *old* items, because low frequency items would experience a greater change in strength following presentation than high frequency items, due to their relatively low pre-experimental familiarity level. This characterization corresponds with Mandler's (1980) original definition of incremental familiarity as it was termed in one of the earliest dual-process models of recognition. Mandler's perspective provides a simple mechanism by which familiarity would be larger for low than high frequency words which is described in the following equation:

$$\text{Relative familiarity} = d/(d+F)$$

where d is the incremental strength increase (following a single presentation), and F refers to the level of pre-experimental familiarity for a particular class of item (hereafter referred to as absolute familiarity in keeping with the terminology employed by Coane et al., 2011). The important aspect of this relative mechanism is that it necessarily presupposes the role of two distinct familiarity mechanisms, because: (i) it depends mathematically upon an index of absolute familiarity and (ii) it cannot explain the increase in FA rates for high compared to low frequency new items because relative familiarity should always be greater for low frequency items. Thus, if a relative familiarity component does exist, it cannot do so in the absence of differences in absolute familiarity.

To determine whether both absolute and relative familiarity contribute to recognition performance, Coane et al. (2011) adapted Jacoby's (1991) two-list exclusion task in which only a proportion of old words presented at test are to be endorsed as old depending upon their study context. The particular experimental set-up ensured that the successful exclusion of those old items from a non-targeted study context depended upon recollection, such that failures to exclude these items (exclusion errors) would be considerably greater under speeded response conditions in which response decisions need to be made before recollection is thought to be available. At these earlier response times, only early familiarity-type mechanisms should be available on which to base recognition judgments. If these early recognition processes include a relative familiarity mechanism, then the number of exclusion errors (old items which should have been excluded on the basis of their study context, but were not) should be significantly greater for low than high frequency old items. At the same time, if an additional absolute familiarity signal is present, the greater false alarm rate to high compared to low frequency new items should also be evident, in line with the standard mirror effect. Across two experiments with different response deadline implementations, Coane and colleagues observed significantly more exclusion errors for low than high frequency old words and a less reliable, but nonetheless broad trend for increased false alarms to new items for high than low frequency, as would be expected if two distinct familiarity mechanisms were contributing to response judgments in this paradigm. The finding that, under response conditions which ostensibly removed recollection, more exclusion errors were made to low than high frequency old items, provides the clearest behavioural demonstration that a relative familiarity-type signal contributes to recognition differences to high and low frequency words.

These outcomes are in line with the intriguing notion that word frequency manipulations can dissociate three distinct processes which contribute to recognition judgments: absolute familiarity for new items and relative familiarity and recollection for old items. It is worth bearing in mind, however, that this pattern was observed in Coane et al.'s study using a demanding exclusion/response-deadline task combination which differs somewhat from standard recognition conditions and which may in part be responsible for the fact that a robust increase in false alarms for high frequency items was not observed. One worthwhile approach towards providing convergent evidence for this pattern with more typical recognition task parameters would be to exploit the capacity of ERPs to index functionally distinct but temporally overlapping or contiguous processes. These characteristics have been successfully and robustly used to dissociate distinct ERP old/new effects (contrasts between ERPs elicited by correctly responded to old and new items) across a variety of recognition paradigms (Mecklinger, Brunnemann, & Kipp, 2011; Rugg & Curran, 2007; Wilding & Herron, 2006). Of most interest for the current topic are dissociations between an early old/new effect which usually elicits a midfrontal distribution from 300 to 500 ms post-stimulus and a later occurring old/new effect which is largest over left parietal sites around 500–700 ms. The earlier of the two effects, often referred to as the midfrontal old/new effect or the FN400, has been shown to operate in a way which is consistent with an index of familiarity. Examples of this are demonstrations that the effect varies with subjective familiarity strength (Woodruff, Hayama, & Rugg, 2006; Yu & Rugg, 2010) but does not distinguish old items and semantic lures (Curran, 2000; Nessler, Mecklinger, & Penney, 2001; Rugg & Curran, 2007). The later left parietal effect has been shown to correlate reliably with recollection-based responding and the amount of information recollected (Vilberg & Rugg, 2009) and is significantly larger for responses associated with a correct compared to an incorrect source attribution (Wilding & Rugg, 1996). These ERP effects cannot provide an exact 1:1 mapping of familiarity and recollection because other processes can elicit comparable functional modulations of these effects (see Voss et al., 2012, for considerations of this kind). With these restrictions in mind, these effects can nonetheless be usefully employed as putative neural correlates of familiarity and recollection (Rugg & Curran, 2007) given those reports in which the two effects have been shown to doubly dissociate in a manner corresponding with dual-process models of recognition memory (Jäger, Mecklinger, & Kipp, 2006; Stenberg, Hellman, Johansson, & Rosén, 2009; Woodruff et al., 2006).

A number of reports have previously investigated the impact of word frequency on ERP old/new effects. In a series of experiments, Rugg and colleagues (Rugg, 1990; Rugg, Cox, Doyle, & Wells, 1995; Rugg & Doyle, 1992) reported a significant late old/new effect