Acta Psychologica 159 (2015) 14–21

Contents lists available at ScienceDirect

Acta Psychologica

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

Novelty's effect on memory encoding

Mauricio Rangel-Gomez *, Sigita Janenaite, Martijn Meeter

Department of Cognitive Psychology, VU University Amsterdam, The Netherlands Van der Boechorststraat 1, 1081BT Amsterdam, The Netherlands

ARTICLE INFO

Article history:
Received 20 January 2015
Received in revised form 14 April 2015
Accepted 13 May 2015
Available online 21 May 2015

Keywords:
Novelty
Memory
Encoding
ERP

ABSTRACT

It is often thought that novelty benefits memory formation. However, support for this idea mostly comes from paradigms that are open to alternative explanations. In the present study we manipulated novelty in a word-learning task through task-irrelevant background images. These background images were either standard (presented repeatedly), or novel (presented only once). Two types of background images were used: Landscape pictures and fractals. EEG was also recorded during encoding. Contrary to the idea that novelty aids memory formation, memory performance was not affected by the novelty of the background. In the evoked response potentials, we found evidence of distracting effects of novelty: both the N1 and P3b components were smaller to words studied with novel backgrounds, and the amplitude of the N2b component correlated negatively with subsequent retrieval. We conclude that although evidence from other studies does suggest benefits on a longer time scale, novelty has no instantaneous benefits for learning.

1. Introduction

Novelty detection has been suggested to be important for long-term memory formation (Tulving, Markowitsch, Craik, Habib, & Houle, 1996): recognizing something as new would set off a cascade of events that would result in the formation of a new memory (Hasselmo & Stern, 2006; Lisman & Grace, 2005; Meeter, Murre, & Talamini, 2004) — either through activation of the dopaminergic (Lisman & Grace, 2005; Rangel-Gomez, Hickey, van Amelsvoort, Bet, & Meeter, 2013) or cholinergic circuitry (Hasselmo & Stern, 2006; Meeter et al., 2004). These ideas imply that novel stimuli are remembered better than familiar ones, which is often taken to be a fact.

Evidence for this has usually been suggested to come in the form of the Von Restorff effect (Axmacher et al., 2010; Fabiani & Donchin, 1995; Fabiani, Karis, & Donchin, 1985, 1990; Kishiyama, Yonelinas, & Knight, 2009; Von Restorff, 1933; Wiswede, Russeler, Hasselbach, & Munte, 2006). This effect is found when people are presented with a list of elements that are mostly in one standard form, but with some elements standing out through a feature such as color or size. They will usually have better recall for elements that are salient than for those that are less distinctive (Von Restorff, 1933). However, the Von Restorff effect has been argued to reside at retrieval (also see, Waddill & McDaniel, 1998) Dunlosky, Hunt, and Clark (2000), and be an effect of distinctiveness in memory, not of novelty (for an extensive review on the experimental and theoretical implications of Von Restorff's work, see Hunt, 1995). Moreover, recent evidence from our group has failed to find any correlation between Evoked Response Potential (ERP) correlates of novelty, and successful encoding (Rangel-Gomez & Meeter, 2013). The Von Restorff effect may thus not show as tightly as has been suggested (Axmacher et al., 2010; Kishiyama, Yonelinas, & Lazzara, 2004; Parker, Wilding, & Akerman, 1998) that novelty benefits learning.

We therefore developed a different approach to look at the role of novelty on memory. We manipulated the novelty of irrelevant background images in a word learning task. This made novelty orthogonal to both the task and to stimulus characteristics that would normally play a role at retrieval. It has already been found once that novel task-irrelevant pictures can improve memory performance to later presented task-relevant words: Fenker et al. (2008) performed an experiment where participants were shown a series of novel or familiar pictures (that they had to judge as being indoor or outdoor), a few minutes before words had to be learned. The pictures (of easily identifiable scenes) had either been previously familiarized (familiar), or not (novel). The authors found that when the pictures were novel, words were learned better, as shown by better subsequent recall. Whereas Fenker et al. (2008) presented the images in a blocked fashion, here we presented them item by item, to look at immediate effects of novel images on acquisition. Other studies using similar paradigms have found that irrelevant novel images can speed responses given to auditory targets (Schomaker & Meeter, 2014a), and can improve perception for stimuli presented after the novel image (Schomaker & Meeter, 2012).

We included two kinds of novelty (see Schomaker, Roos, & Meeter, 2014). Contextual novelty refers to stimuli that are easily identifiable because they resemble stimuli already represented in memory, but that differ substantially from those seen in the recent context (Polich & Comerchero, 2003). The second novelty type, stimulus novelty, refers

* Corresponding author at: Department of Cognitive Psychology, VU University Amsterdam, The Netherlands.
E-mail addresses: m.rangelgomez@vu.nl (M. Rangel-Gomez), janenaitesigita@gmail.com (S. Janenaite), m.meeter@vu.nl (M. Meeter).

http://dx.doi.org/10.1016/j.actpsy.2015.05.004
0001-6918/

to stimuli that have never been seen or experienced before (Courchesne, Hillyard, & Galambos, 1975). In most experiments, stimuli that are novel in either way are also *deviant*; they also stand out from other stimuli in the context in some aspect or other. To look at the effects of pure deviance, we also included a third category of stimuli, namely semantic oddballs that did not match the category of other items in the list. Such discrepancies are known to be picked up by the brain; words that do not match a sequence of other words elicit an evoked response potential (ERP) component called the N400 (Kutas & Federmeier, 2011; Kutas & Hillyard, 1983, 1984a), which is also elicited by words that do not match their sentence context (Kutas & Hillyard, 1980, 1984b).

To match possible effects of deviance, stimulus- and contextual novelty on memory to neural processes during acquisition, we measured electrophysiological responses elicited by stimuli. Three evoked response potential (ERP) components of interest were the N400 discussed above, and the N2 and P3a components that are elicited by novel stimuli. The N2 appears at around 180 ms to 325 ms after visual stimulus (Courchesne et al., 1975). This component can be divided into three subcomponents. The N2a, also known as mismatch negativity, is found in the range of 150 to 250 ms for deviant auditory (Naatanen & Alho, 1995; Naatanen, Gaillard, & Mantysalo, 1978) and visual stimuli (Czigler & Csibra, 1992; Heslenfeld, 2002). The N2a seems to be generated in sensory brain areas — A1 for auditory stimuli (May & Tiitinen, 2010), and occipital cortex for visual stimuli (Csibra & Czigler, 1991). The N2b, most pronounced at frontal electrodes, is elicited by non-target stimuli that are novel or deviant with respect to a context. The last subcomponent, the N2c, is largest at posterior electrodes, and has been related to executive control (Folstein & Van Petten, 2008).

The P3a component, or novelty P3 (Courchesne et al., 1975), is elicited by oddballs in 2- or 3-stimulus oddball tasks (Squires, Squires, & Hillyard, 1975; Yamaguchi & Knight, 1991). It has been argued to be a response more to deviance from context than to novelty per se (Schomaker et al., 2014). Of note, it is only generated by stimuli that could in principle be task-relevant (Schomaker & Meeter, 2014b). However, it does not reflect target processing; targets usually elicit a later, larger and more posterior component called the P3b (Ferrari, Bradley, Codispoti, & Lang, 2010; Squires et al., 1975).

Another component that has been studied in relation to novelty tasks (oddball paradigm) is the N1 (Tome, Barbosa, Nowak, & Marques-Teixeira, 2015). Although this component cannot be considered a novelty component, it is altered by auditory mismatch (Naatanen & Picton, 1987) and by variations in task demands (Garcia-Garcia, Barcelo, Clemente, & Escera, 2010). This suggests that its amplitude is modulated more generally by violations of regularity, not limited to the auditory modality.

In our study, participants had to remember words (either category members or semantic outliers) that were presented on a gray square, with an image serving as a background. This background could be novel (presented just once) or standard (presented on in total 144 trials in the experiment); additionally it could be a landscape or a fractal. We reasoned that a novel landscape would be mostly contextually novel, since most participants will be familiar with almost any category of landscape, while fractals would be stimulus novels. Our first aim was to investigate whether words combined with novel images would be remembered better than words combined with standard images, which would be expected when novelty elicits a neuromodulatory response that aids encoding (Fabiani et al., 1985; Wiswede et al., 2006). A secondary aim was to investigate whether novelty- and deviance-related ERP components, the N2, P3a and N400, would predict subsequent memory, which would strengthen the link between novelty processing and memory encoding. A third, more exploratory aim was to test for interactions between background novelty and semantic deviance. If novelty aids encoding, it may benefit words more that are not organized into a semantic category, than words that can be retrieved using the category as a cue. This would be evident as an interaction, with larger background novelty benefits for semantic outliers than words fitting the list category.

2. Methods

2.1. Participants

Forty volunteers (20 female) participated in the experiment. However, due to technical problems, the data of three participants were not recorded properly. Additionally, data from one participant was dropped because of excessive noise in more than 10% of the trials. The data of 36 participants were thus analyzed (18 male and 18 female, mean age 24, range 17–30, three left-handed). All reported normal or corrected to normal vision, Participants reported being healthy and were requested to not consume alcohol or psychoactive drugs 48 h before the testing date. The study was approved by the ethics committee of VU University Amsterdam and performed in agreement with the Declaration of Helsinki.

2.2. Stimuli and design

On each trial a word was presented at the bottom of the screen, in a light gray box that was 2.5° high and 19.17° wide. A landscape or a fractal was presented centrally as background. All images were presented against a dark gray frame and were the same resolution and size, subtending 17.98° vertically and 28.39° horizontally. 129 fractals were generated using the open-source program ChaosPro (http://chaospro.de/), of which a random one was chosen as standard image for every participant anew. The others were used as novels. Landscapes were picked from several internet websites, and were selected for being instantly recognizable as a landscape but not recognizable as individual places (i.e., mountain scenes and tropical beaches, but not the Eiffel Tower). Again, a random landscape was picked as standard for every participant anew. Fig. 1 presents a typical trial.

Sixteen word lists of 40 words were created. On each list, 28 standard words belonged to a category (a different one for each list) such as fruits (e.g., peach, lemon, apple) and body parts (e.g., arm, leg, foot). The remaining 12 were outliers, chosen from the list of Van Overschelde, Rawson, and Dunlosky (2004), which were concrete nouns that were identified by a population belonging to three American universities (approximately 600 participants per noun category) as the most common answer to each one of 70 categories, and did not belong to any of the categories selected for the learning lists. Words had their first letter capitalized followed by lower case letters. The length of word stimuli varied from three letters to thirteen letters in a word and resulted in approximately 0.8° vertical visual angle and 2.4° horizontal visual angle for short words and vertical (0.8°) and horizontal (9.8°) visual angles for longer words.

2.3. Procedure and design

Subjects were seated in a sound-attenuated, dimly lit room approximately 75 cm from the computer screen. There were 16 blocks, in each of which one list of words was learned. Which list was assigned to which block was randomized for each participant. Moreover, in a random half of blocks words were presented with landscapes on the background, and the other half with fractals in the background. Within each block, the first six words always had a standard image and were related to the list category to set expectations (these were not analyzed — also to neutralize primacy effects). After that, the block contained, randomly intermixed, sixteen novel background trials and eighteen standard background trials. Independently randomized, in 22 trials a standard word was presented, and in 12 an outlier word. The randomization resulted in the following trial numbers per condition (averaged across the 36 participants in the experiment): For fractals, Novel background/Outlier word — 45.4 (s.d. 3.5), Novel background/Standard