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Original Articles

Unconscious memory suppression

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ABSTRACT

Recent evidence suggests that high-level executive control can occur unconsciously. In this study, we tested whether unconscious executive control extends to memory retrieval and forgetting. In a first experiment, participants learned word-word associations and were trained to either actively recall or forget theses associations in response to conscious visual cues (Think/No-Think paradigm). Then, the very same cues were subliminally presented while participants were performing a grammatical gender categorization task on distinct word pairs. Memory retrieval tested a few minutes later was significantly influenced by conscious and masked cues, suggesting that memory recall could be manipulated unbeknownst to the participants. In a second experiment, we replicated these findings and added a baseline condition in which some words were not preceded by masked cues. Memory recall was significantly reduced both when words were preceded by an unconscious instruction to forget compared to the baseline condition (i.e. no cue), and to the unconscious instructions to recall. Overall, our results suggest that executive control can occur unconsciously and suppress a specific memory outside of one's awareness.

1. Introduction

Memory suppression corresponds to the voluntary alteration of memory retrieval by conscious cognitive control. This mechanism was first demonstrated by Anderson & Green (2001), with a "Think/No-Think" paradigm modelled on the Go/No-Go task. In the original study, participants first learned a set of word pairs. Then, they were presented with the first word of a pair (hint word) and asked, in response to a visual cue, to either retrieve the associated word (Think trials) or prevent it from coming to mind (No-Think trials). The results showed that executive control could modulate recall: recall could be improved through rehearsal, or deteriorated voluntarily, a phenomenon termed "suppression-induced forgetting" (Anderson & Green, 2001). These results have been replicated (for a review, see Anderson & Hanslmayr, 2014) and extended to non-verbal memories, using for instance emotional pictures (Depue, Banich, & Curran, 2006; Depue, Curran, & Banich, 2007; Küpper, Benoit, Dalgleish, & Anderson, 2014). Moreover, the neural substrates of this phenomenon have been clarified: fMRI studies indicated that memory suppression may involve top-down modulation of hippocampal activity by the dorsolateral prefrontal cortex (Anderson, Bunce, & Barbas, 2016).

Whether suppression-induced forgetting can be triggered unconsciously remains unknown. Indeed, long-term declarative memory has long been thought to be tightly linked to consciousness (Tulving, 1987). To date, suppression-induced forgetting has always been tested through voluntary and conscious effort to rehearse memories or purge

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them. However, recent behavioural and neuroimaging results suggested that a semantic association could be formed through unconscious processes (Reber, Luechinger, Boesiger, & Henke, 2012; vanGaal et al., 2014).

Interestingly, other studies showed that unconscious instructions could modulate high-level executive control processes, such as attention orientation (Jiang, Costello, Fang, Huang, & He, 2006), task-set preparation (Lau & Passingham, 2007; Weibel, Giersch, Dehaene, & Huron, 2013), task switching (Reuss, Kiesel, Kunde, & Hommel, 2011), error detection (Charles, Opstal, Marti, & Dehaene, 2013; Nieuwenhuis, Ridderinkhof, Blom, Band, & Kok, 2001), conflict adaptation (vanGaal, Lamme, & Ridderinkhof, 2010) and response inhibition (vanGaal, Ridderinkhof, Fahrenfort, Scholte, & Lamme, 2008; vanGaal, Ridderinkhof, Scholte, & Lamme, 2010).

Capitalizing on these results, our study aims to test whether high-level executive control processes can unconsciously suppress a previously learned association between two words, i.e. whether suppression-induced forgetting can occur outside of one's awareness.

We designed two experiments that were modelled on the Think/No-Think paradigm (Anderson & Green, 2001), using conscious and masked cues to manipulate memory retrieval. In the first experiment, we investigated whether memory suppression could be induced by masked (unconscious) cues, which had been previously associated with conscious Think/No-Think instructions. In the second experiment, we aimed to replicate our findings with an addition baseline condition, to confirm that masked cues could induce memory suppression over and above the detrimental effect of time.

2. Experiment 1

Experiment 1 was designed as an unconscious version of the procedure developed by Anderson & Green (2001). Participants first learned word pairs (hint word – response word). Then, they performed a conscious Think/No-Think task, in which they were presented with a subset of hint words and had to actively remember (Think) or try to forget (No-Think) the associated response words, according to conscious visual shape cues. Afterwards, these conscious trials were intermixed with unconscious trials in which participants performed a distracting task on distinct hint words (a grammatical gender determination task), while the same visual shape cues were subliminally presented. The alternation between conscious and unconscious trials aimed to reinforce the association between shape cues and Think/No-Think instructions, fostering the unconscious Think/No-Think effect. A final test then probed whether participants were able to retrieve response words when presented with the hint words.

The primary aim of this experiment was to test whether masked cues could induce a Think/No-Think effect as previously evidenced in conscious settings (Anderson & Green, 2001). For methodological reasons, our experimental paradigm differs from the original in several aspects. First, in Anderson's experiments, two different methods were used to signal what task participants should perform. One method was to allocate each hint word to the Think or the No-Think conditions and to train participants until they could distinguish these words ("hint training", Anderson & Green, 2001). Alternatively, specific colours could be associated with the Think/No-Think task such the font colour indicated the type of task participants should perform ("colour cueing", Anderson et al., 2004). In our design, we associated shape cues (diamond and square) to Think and No-Think tasks ("shape cueing"). These cues were displayed at the beginning of each trial to indicate to participants whether they should perform a Think or a No-Think task on the subsequent word, which allowed us to then mask these visual cues in the unconscious condition. Secondly, in the original paradigm, a baseline condition was included whereby some words were not presented at all between learning and final recall, allowing active retrieval and active forgetting to be compared to a neutral condition. In Experiment 1, we did not include such a baseline, maximising the Think/No-Think effect by associating every unconscious trial with a masked cue. However, a comparable baseline condition was added to Experiment 2.

In these experiments we hypothesised that we would observe a Think/No-Think effect with both conscious and masked cues, i.e. that final recall in the No-Think condition would be significantly lower than initial recall, and significantly lower than the Think condition in final recall but not in initial recall performance.

2.1. Materials and methods

2.1.1. Participants

Forty-four healthy subjects were recruited through advertising (25 females and 19 males, mean age 24.5 years, range 21–33). All participants had normal or corrected-to-normal vision and were naive to the purpose of the experiment. No participant took part in both experiments. Participants gave written informed consent before taking part. All methods were carried out in accordance with relevant guidelines and regulations, in particular with the Declaration of Helsinki. No participants were excluded from Experiment 1.

2.1.2. Procedure

The procedure consisted of three phases: a learning phase, a Think/No-Think phase (comprising a few conscious Think/No-Think trials then intermixed with unconscious Think/No-Think trials), and a final recall test (Fig. 1a).

2.1.2.1. Learning phase. First, participants were asked to learn 30 word pairs (composed of a hint word and a response word, e.g. "candle – champagne"). Word pairs were presented in random order and each pair was presented twice. Each word was displayed on screen for 4 s. Hint words were preceded by a 200 ms fixation cross and response words were followed by a 500 ms inter-pair interval. A recall test was then performed: each hint word was displayed for 4 s (e.g. "candle") and participants had to say aloud the corresponding response word (e.g. "champagne"). They could give an answer as soon as the hint word appeared on screen and had 4 additional seconds after it had disappeared to answer, i.e. 8 s in total to answer. No feedback was provided. A new learning phase (maximum 3) started if the minimum of 50% correct answers was not reached. All subjects reached the 50% correct answers criterion after one run of the learning phase, with an average of 80% correct answers.

2.1.2.2. Think/No-Think phase. During the Think/No-Think phase, participants were presented with the hint words preceded by Think or No-Think cues (n = 760 trials, 20 trials per target word, 240 conscious trials for 12 word pairs, 240 unconscious trials for 12 word pairs and 280 trials for 6 filler word pairs).

Conscious Think/No-Think trials. On conscious Think trials, participants were asked to retrieve the response word associated with the hint word, without saying it aloud. Comparatively, on No-Think trials, subjects were asked to prevent the response word from coming to mind for 3 s, while the hint word was presented on screen. No-Think instructions were unguided: no strategy was proposed to help the participants (Benoit & Anderson, 2012). A visual shape cue, in the form of either a diamond or a square, was presented at the beginning of each trial to indicate which task (Think or No-Think) the participant should perform ("shape cueing"). The association between shapes (diamond/square) and instructions (Think/No-Think) was defined at the beginning of the experiment and counterbalanced across participants. The visual sequence was as follows: fixation cross (500 ms), blank screen (300 ms), shape cue (200 ms), blank screen (166 ms), and hint word (3000 ms) (Fig. 1b).

Unconscious Think/No-Think trials. On unconscious trials, participants had to perform a grammatical gender categorization task on the hint words (i.e. determine whether it was feminine or masculine).