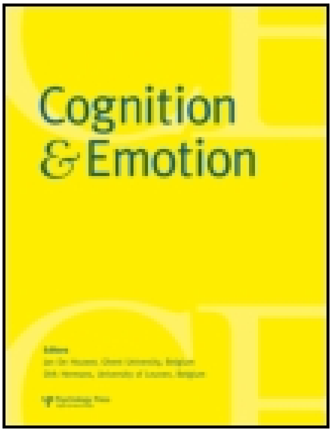

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Emotion-induced modulation of recognition memory decisions in a Go/NoGo task: Response bias or memory bias?

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Emotion-induced modulation of recognition memory decisions in a Go/NoGo task: Response bias or memory bias?

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In recognition memory tests for words, items with negative emotional meaning are more often classified as "old" compared to neutral items, whether or not they are in fact old. Two accounts for this bias have been offered: One proposes that emotions disrupt retrieval and response monitoring processes (*executive control account*), the other proposes that emotions cause illusory feelings of remembering (*memory bias account*). We addressed this issue by varying the target signal in a Go/NoGo variant of a recognition memory task for negative, neutral, and positive words and faces: One group of participants was asked to respond to old items whereas the other group was asked to respond to new items. Results showed that the "Go-for-old" group showed the typical emotion-induced response bias shift for both positive and negative words, while the "Go-for-new" group showed the opposite pattern. Results were nonsignificant for faces, but went into the same direction. The findings are clearly inconsistent with the executive control account and speak for a genuine memory illusion induced by emotional arousal.

Emotionally laden events are often recalled in great detail and with high subjective confidence when they are actually inconsistent and inaccurate. This discrepancy has been demonstrated in reports surrounding the terrorist attacks of 9/11 2001 (Talarico & Rubin, 2003), the O. J. Simpson trial (Schmolck, Buffalo, & Squire, 2000), and the Estonia ferry disaster (Christianson & Engelberg, 1999). Laboratory studies using simple old/new recognition memory tasks are helpful in elucidating this issue as they

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allow for the use of signal detection theory to clearly distinguish between accurate and biased memory performance.

A number of laboratory studies on the effects of emotion on memory performance have indeed found an enhanced bias to judge emotional items as familiar ("old"), whether these items are in fact old or new (Johansson, Mecklinger, & Treese, 2004; Maratos, Allan, & Rugg, 2000; McNeely, Dywan, & Segalowitz, 2004; Windmann & Krüger, 1998; Windmann & Kutas, 2001). These studies have usually presented negative (threatening) words intermixed with neutral words in a randomised fashion, both at study and at test. Their findings imply that subjects continuously and flexibly switch their bias to respond "old" on a trial-to-trial basis in accord with the emotional meaning of the test probe; that is, the response bias becomes more liberal for a negative word, and then shifts back to normal for the next word that is emotionally neutral. The phenomenon will thus be termed the *emotion-induced bias shift* throughout the present article. Crucially, this bias does not increase the ability to correctly discriminate between studied words and unstudied words (i.e., accurate memory), but it does enhance hit rates for negative items at the time of retrieval when the memory strength cannot be improved anymore. It may therefore reflect another mechanism by which the brain ensures that emotional events are not easily forgotten or "missed" (Windmann & Kutas, 2001).

The cognitive and neural origin of the emotion-induced bias shift is elusive, although two accounts have been proposed. The first is the *executive control account* (discussed, e.g., in Johansson et al., 2004; Windmann & Kutas, 2001). This account closely follows signal detection theory by proposing that the emotion-induced bias shift reflects emotion-induced disruptions of the currently maintained decision criterion or response bias during memory testing. Emotions have long been thought to be able to interrupt ongoing task performance as they compete for attentional resources with ongoing task demands (Ellis & Ashbrock, 1988; Gunther, Ferraro, & Kirchner, 1996; Meinhardt & Pekrun, 2003; Newman et al., 1993; Redgrave, Prescott, & Gurney, 1999; Seibert & Ellis, 1991; Windmann & Krüger, 1998). Recognition memory requires such cognitive control (albeit to a limited extent compared to more resourceful memory tasks) for monitoring, criterion setting, and response inhibition functions (Henson, Rugg, Shallice, & Dolan, 2000; Miller, Handy, Cutler, Inati, & Wolford, 2001; Schacter, Norman, & Koutstaal, 1998; Schacter & Slotnik, 2004). The assumption of the *executive control account* is that these control processes are disturbed and abandoned when potential threat is detected in favour of quick-and-dirty processing facilitating fast responding. Consistent with this notion, the emotion-induced bias shift has been observed to be associated with shorter reaction times and early frontal signatures of automatic (as opposed to late-controlled) memory processes in event-related potentials

(Johansson et al., 2004; Maratos et al., 2000; Windmann & Kutas, 2001; Windmann, Sakhavat, & Kutas, 2002b).

Central to the *executive control account* is the belief that detecting old items in an old/new recognition memory task is easier than detecting new items. As old items have been presented before in the study phase, they elicit stronger familiarity signals than new items and are experienced as more fluent and salient. This could make them prone to be more easily confused with emotionally salient cues than new information, which is harder to positively distinguish from other irrelevant noise (Windmann & Krüger, 1998). Furthermore, the higher preactivation of old items might facilitate generation of the associated response ("old") whereas generating a "new" response, without the aid of input-driven preactivation, requires more executive control. Consequently, it is assumed that when the system is under pressure (emotionally or temporally), it tends to produce the more accessible "old" response rather than a "new" response (cf., Perea, Rosa, & Gómez, 2002; Windmann & Krüger, 1998).

Although rarely investigated directly, the literature provides some empirical support for the assumption of a cognitive asymmetry between "old" and "new" responses. First, a standard observation is that "old" responses are faster than "new" responses, presumably because they benefit from higher memory strength. (The same is true for "word" compared to "nonword" responses in lexical decision tasks; see Perea et al., 2002; Windmann, Daum, & Güntürkün, 2002a). Presumably as a side effect of this preactivation, "old" responses are also associated with more variable confidence ratings (Ratcliff, Sheu, & Gronlund, 1992), and higher subjective preferences (Garcia-Marques, Mackie, Claypool, & Garcia-Marques, 2004; Zajonc, 1980). Second, recent research supports the notion that correct rejection of new items involves more controlled recollection than does positive recognition of familiar items, such as elaborated evaluation of the item's memorability and/or recall of co-encoded information (Ghetti, 2003; Hunt, 2003). This holds particularly for new items that are similar to old items with respect to semantic meaning, perceptual appearance, or context during acquisition (Rotello, Macmillan, & Van Tassel, 2000). Finally, and most compellingly, patients with deficits in executive control functions, usually due to frontal lobe damage, show elevated rates of false "old" responding and a reduced ability to suppress currently inappropriate memories (i.e., new items) from a set of activated memories (Schacter & Slotnik, 2004; Schnider & Ptak, 1999; Schnider, Treyer, & Buck, 2000; Swick & Knight, 1999). This is because new items in memory tasks are not genuinely new, but well-known from contexts other than the study phase. It is this source discrimination that patients with executive dysfunctions have difficulties performing and that drives up their false alarm rates. Emotions have a similar effect according to the *executive control account* of the emotion-induced bias shift.

The second explanation of the emotion-induced bias shift, the *memory bias account*, proposes that subjects respond more often "old" to emotional items because emotional items elicit an illusory *feeling* of familiarity. According to this view, subjects truly believe that the emotional items are more often "old" (relative to neutral items), and respond accordingly. Why emotions should elicit this feeling of familiarity is a matter of debate, which is also why two positions within the *memory bias account* can be differentiated. One variant states that emotion circuits in the brain (of which the amygdala may be central) boost the activity of currently activated sensory and mnemonic representations in such a way that emotional stimuli appear clearer and more vivid than nonemotional stimuli (Lang et al., 1998; Schupp, Junghöfer, Weike, & Hamm, 2003; Sharot, Delgardo, & Phelps, 2004). This increased perceptual salience can then be *misattributed* to familiarity (and maybe other task-relevant features, which the system is set to detect; Windmann & Krüger, 1998). The other variant stresses the fact that the stimulus lists producing the emotion-induced bias shift, typically negative and neutral words, are usually not balanced with regards to their semantic structure (e.g., Maratos et al., 2000; Talmi & Moscovitch, 2004; but see McNeely et al., 2004). Specifically, negative concepts like "horror, terror, panic, fear, anxiety" tend to be semantically more strongly related to one another than arbitrarily chosen neutral control concepts like "cloud, school, plastic, speed, food". If so, then the higher interrelatedness of the emotional words should lead to enhanced conceptual priming within old items and between old and new items, with the result that both old and new items appear more familiar at test. This would drive up hit rates and false alarm rates (i.e., the response bias; Miller & Wolford, 1999) and result in the same types of early frontal effects in event-related potentials that have been found in connection with the emotion-induced bias shift (Azimian-Faridani & Wilding, 2004; Azimian-Faridani & Wilding, 2006; Curran, 2004; Nessler, Mecklinger, & Penney, 2001, 2005; Windmann & Kutas, 2001).

Differences between the two variants of the *memory bias account* notwithstanding (see Johansson et al., 2004; Maratos et al., 2000; McNeely et al., 2004, for empirical tests and discussions), both refer to a genuine memory illusion in explaining the emotion-induced bias shift: Participants respond "old" to emotional items more often than to neutral items because they truly experience the emotional stimuli as more familiar. By contrast, the executive control account refers to the effects of interrupted cognitive control: Subjects respond "old" to the emotional items more often than to the neutral ones because the emotions reduce their ability to maintain executively controlled retrieval and output monitoring processes, thereby favouring the faster and less demanding response alternative.

The present study was carried out to specify the conditions under which the emotion-induced bias shift would be observed to help decide between the *executive control account* and the two variants of the *memory bias account*. Our first goal was to test the assumption of the *executive control account* that the emotion-induced bias results from impaired executive control of preactivated response tendencies. To this end we employed a Go/Nogo paradigm (cf., Perea et al., 2002) where we manipulated definition of the "Go-signal" and thereby the type of preactivated response ("old" or "new"). Specifically, old items were defined as the to-be-detected signal in the "Go-for-old" group (and new information was to be ignored), whereas new items were defined as the to-be-detected signal in the "Go-for-new" group (and old information was to be ignored). If the emotion-induced bias shift reflected a genuine disruption of criterion-setting functions, caused by the relaxation or withdrawal of executive control over preactivated response tendencies, then the emotion-induced bias shift should be observed in both groups of subjects. That is, both groups should reduce their response control under emotional influences, and respond more liberally to emotional items relative to neutral items, regardless of the type of information (old or new) they were prepared to respond to. Alternatively, if the emotion-induced bias shift reflected a sincere memory bias rendering subjects to truly *believe* that emotional items are more familiar than neutral items, then the bias should be present only in the "Go-for-old" group, and should be *reversed* in the "Go-for-new" group where subjects had to withhold a response to indicate "oldness". It is not possible to predict on the basis of the available evidence which of these two outcomes is more likely as previous studies have always asked subjects to give both types of responses, "old" and "new" (e.g., Maratos et al., 2000; McNeely et al., 2004; Windmann & Krüger, 1998; Windmann & Kutas, 2001).

A second goal of the present study was to establish the role of semantic cohesion in eliciting the emotion-induced bias shift (see Maratos et al., 2000, versus McNeely et al., 2004, and Johansson et al., 2004). To this end, we compared the effectiveness of emotional words in eliciting the bias with that of emotional faces in the same subjects (in a within-subjects design). One previous study did in fact find the emotion-induced bias shift for black-and-white photographs of positive and negative facial expressions, although only for those rated high in expressiveness (Johansson et al., 2004). We used high-quality colour photographs of faces of actors that ensured standardised conditions and easy recognition of emotional expressions. We hypothesised that if the emotion-induced bias is a function of semantic cohesion, then it should be present only in the words (or at least be significantly larger than in the faces). The reason why the effect should not be present in the faces (or should at least be significantly smaller than in the words) is that the number of different individuals whose faces were shown was the same in all conditions so that the homogeneity of the emotional and neutral stimulus lists was comparable. In other words, what differed between the emotional and neutral conditions was not the categorical structure or variance of the facial stimuli, but only the type of emotion that the faces expressed. As an attempt to control the effects of semantic cohesion in the word lists as well, we eyesight-matched the word lists for their categorical structure and designed a fairly homogeneous list of neutral words, all surrounding the topic of "arts and academia". This measure should make it harder to find any differences, first, between emotional and neutral words, and, second, between words and faces, if the semantic cohesion account is true.

Finally, as did Johansson et al. (2004), we included negative, neutral, and positive stimuli to find out whether the emotion-induced bias is a function of emotional arousal or valence. Previous studies with words have used negative stimuli only (Maratos et al., 2000; McNeely et al., 2004; Windmann & Krüger, 1998; Windmann & Kutas, 2001; Windmann et al., 2002a,b), which is reflected in the threat-specific formulation of the *executive control account*.

METHODS

Subjects

Forty healthy subjects (20 female, 20 male) participated in the study, mean age 24.5 ($SD = 4.45$; range 19–34). Of the subjects, 28 were given course credit for participation, 12 received monetary compensation (€ 7.50), and 90% were students of psychology.

Materials and procedures

Pictures of faces ($n = 108$; 36 neutral, 36 positive, 36 negative) were selected from two picture databases. Of these pictures, 68 (23 neutral, 23 positive, 22 negative) were selected from the "Karolinska Directed Emotional Faces" database (Lundqvist, Flykt, & Öhman, 1998), and the other 40 (13 neutral, 13 positive, 14 negative) from the "NimStim Face Stimulus Set" (http://www.macbrain.org/). Only anger emotions were used as negative pictures. In addition, 120 German nouns were selected (40 neutral, 40 positive, 40 negative; for a translation see the appendix), and matched carefully for abstractness, length, and frequency (using the Cosmas II database; www.ids-mannheim.de/cosmas2).

Half of both the words and the faces were presented in the study phase (counterbalanced across participants) while all stimuli were shown in the test phase. The encoding task was gender discrimination for the faces, and letter counting (referring to the letter E) for the words. All stimuli were presented centred on a 17-inch computer screen for 1000 ms with

1000 ms interstimulus interval in quasi-randomised order. Faces were sized 8.5×11 cm, letter height of words was approximately 3 cm.

After encoding, there was a break of approximately 25 minutes during which subjects were allowed to rest and walk around. For the following recognition memory test, subjects were assigned randomly to the "Go-for-old" or the "Go-for-new" group. Subjects in the "Go-for-old" group were instructed to press the space bar as quickly as possible whenever they recognised an old stimulus whereas subjects in the "Go-for-new" group were instructed to indicate new items. The order by which the tasks with faces and words were administered at encoding and at test was counterbalanced across subjects.

Data analysis

For both groups, hits were defined as correct responses and false alarms as incorrect responses. Recognition accuracy (P_r) and response bias (B_r) were determined according to Snodgrass and Corwin (1988), where P_r = (Hit_Rate – False_Alarm_Rate), varying between 0 (null sensitivity) to 1 (perfect sensitivity), and B_r = False_Alarm_Rate/(1 – P_r). varying between 0 (maximally conservative bias) over 0.5 (neutral bias) to 1 (maximally liberal bias). ANOVAs with repeated measures for Valence and the independent factor Group were used for analysis.

RESULTS

Hit rates and false alarm rates to emotional and neutral words and face photographs are reported in Table 1; results on the signal detection theory measures are shown in Figure 1. Across the two groups, the response bias in the task involving the words did not vary significantly with emotional valence ($F = 0.48$). However, the Group × Valence interaction was highly significant, $F(2, 76) = 10.21$, $p < .001$, reflecting the fact that relative to neutral words, the bias was significantly higher for both positive, $t(19) = 2.35$, $p < .05$, and negative words, $t(19) = 2.32$, $p < .05$, in the "Go-for-old" group whereas the opposite was true for the "Go-for-new" group, $t(19) = 3.56$, $p < .005$, and $t(19) = 2.57$, $p < .05$, respectively (see Figure 1, top left). Thus, the emotion-induced shift in response bias was significant for negative as well as for positive words in the "Go-for-old" group, but was reversed for both types of words in the "Go-for-new" group. In addition, the "Go-for-new" group showed a more liberal response bias overall than did the "Go-for-old" group, main effect of Group, $F(1, 38) = 9.81$, $p < .005$, meaning that these subjects responded more often than did subjects in the "Go-for-old" group.

TABLE 1

Mean hit and false alarm rates and associated reaction times (RT, in ms) of subjects instructed to detect old items (''Go-for-old'' group) or new items (''Go-for-new'' group) in the Go/NoGo recognition memory tasks involving words and faces

	Words			*Faces*		
	Negative	*Neutral*	*Positive*	*Negative*	*Neutral*	*Positive*
''Go-for-old''						
Hit rate	0.49 (0.19)	0.43 (0.19)	0.49 (0.20)	0.59 (0.17)	0.58 (0.14)	0.53 (0.14)
False alarm rate	0.26 (0.14)	0.21 (0.15)	0.28 (0.14)	0.32 (0.14)	0.26 (0.11)	0.32 (0.13)
Hit RT	872 (25)	867 (20)	837 (13)	785 (11)	788 (15)	798 (16)
False alarm RT	891 (22)	872 (21)	882 (23)	798 (15)	852 (20)	788 (15)
''Go-for-new''						
Hit rate	0.63 (0.19)	0.68 (0.21)	0.58 (0.23)	0.49 (0.16)	0.61 (0.19)	0.52 (0.13)
False alarm rate	0.32 (0.15)	0.47 (0.21)	0.31 (0.15)	0.33 (0.20)	0.29 (0.17)	0.34 (0.19)
Hit RT	1037 (41)	995 (44)	1040 (39)	980 (33)	952 (25)	976 (32)
False alarm RT	1090 (45)	1060 (53)	936 (30)	908 (22)	952 (29)	922 (27)

Note: Standard deviations are given in parentheses.

This pattern was different for faces. Like the words, the faces did not show any significant main effect of Valence ($F = 0.096$), but contrary to the words, they also showed no significant effect of Group ($F = 0.057$), and, most importantly, no significant interaction of Group × Valence, $F(2, 76) = 1.62$, $p > .20$. Although there was a slight tendency into the same direction (see Figure 1, top right), a direct comparison showed that the emotion-induced modulation of the response bias tended to be significantly smaller for the faces than for the words, $F(1, 38) = 3.52$, $p < .07$.

With regard to the sensitivity measure, the words yielded no significant effects. The faces yielded only a significant effect of Valence, $F(2, 76) = 9.24$, $p < .001$, indicating higher recognition accuracy of neutral faces compared to both negative and positive faces. Negative and positive faces did not differ significantly from each other ($F = 0.45$; see Figure 1, bottom), which means that the effect is related to the arousal of the two types of emotional stimuli.

In both faces and words, accurate recognition performance (collapsed across the three valences) did not correlate significantly with the emotion-induced modulation of the bias. Likewise, the emotion-related modulation of P_r for the faces (with neutral items being more accurately recognised) did not correlate significantly with the emotion-induced modulation of bias, either in words or in faces. All correlations were below .20. This shows that the effects in accuracy and bias were independent, as signal detection theory would predict.

Reaction times of correct responses (hits) showed a marginally significant main effect of Group for the words, $F(1, 37) = 2.93$, $p < .10$, and a significant

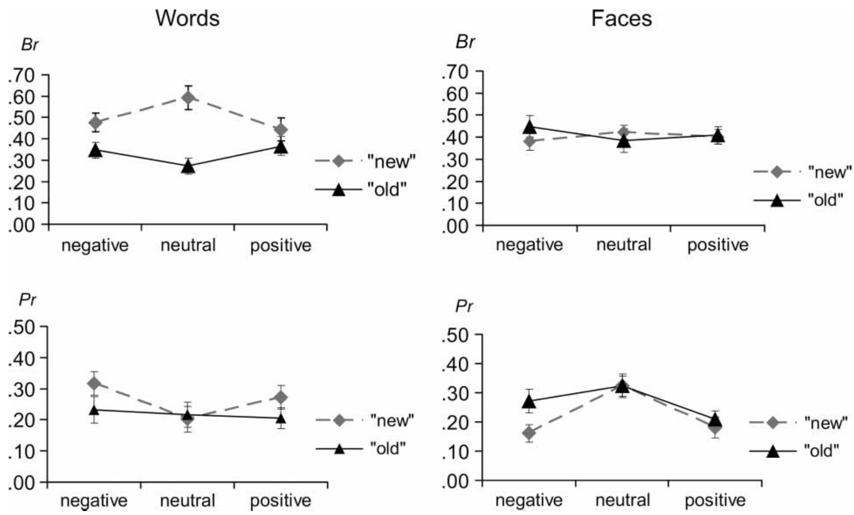

Figure 1. Response bias (top row) and recognition memory accuracy (bottom row) of the "Go-for-old" group instructed to detect old items ("old") and the "Go-for-new" group instructed to detect new items ("new") in the Go/NoGo Recognition Memory Task involving emotional and neutral words (left column) and faces (right column).

effect of Group for the faces, $F(1, 38) = 5.96$, $p < .05$, as subjects in the "Go-for-old" group responded faster than did subjects in the "Go-for-new" group (see Table 1). A tendency towards the same group difference was found for incorrect responses (see Table 1), even when (false alarm) responses to new items of the "Go-for-old" group were compared with (hit) responses to new items of the "Go-for-new" group, for words, $F(1, 37) = 2.07$, $p < .16$; for faces, $F(1, 37) = 4.51$, $p < .05$.

Finally, to determine the quality of our stimulus materials, and find out why our results on the bias shift for the photographs were inconsistent with those reported by Johansson et al. (2004), we carried out a post hoc study in which we had 20 students evaluate the emotional valence and arousal of the words and faces (10 rated the high expression black-and-white faces for which Johansson et al., found a significant emotion-induced bias shift, and another 10 rated both the words and the coloured photographs used in the present study) with the help of the Self-Assessment Manikin (SAM; Bradley, Greenwald, & Hamm, 1993) on 5-point scales. The findings are depicted in Figure 2 (top). They confirmed that all materials showed clearly significant effects of both arousal and valence, as intended. However, the coloured face photographs received lower valence ratings than did the high-expression face photographs of Johansson et al. (2004), main effect of Materials, $F(2, 18) = 6.62$, $p < .05$, particularly for the neutral and positive pictures, marginal Valence × Materials interaction, $F(2, 36) = 2.60$, $p < .10$.

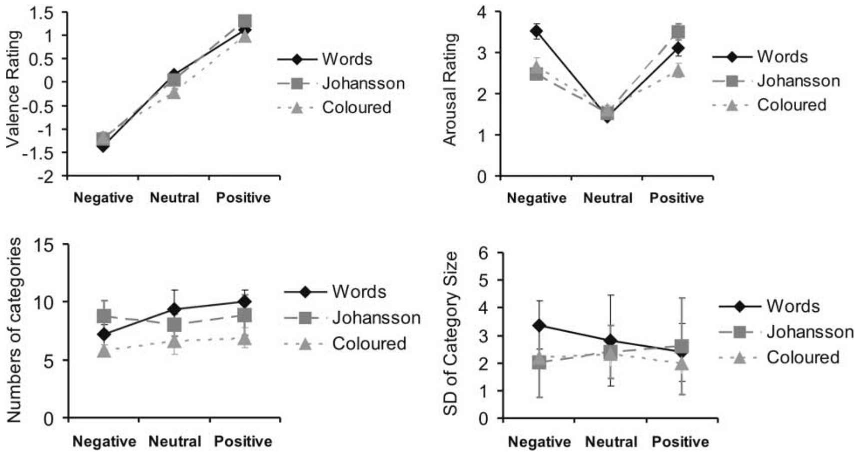

Figure 2. Results of the rating (top) and the sorting experiments (bottom) evaluating the materials of the present study (words and coloured face photographs) in comparison with the high expression face photographs used by Johansson et al. (2004).

In addition, the coloured face photographs were of reduced arousal in the positive and negative conditions compared to the words, main effect of Valence, $F(2, 18) = 7.87$, $p < .001$, Valence × Materials interaction, $F(2, 36) = 5.75$, $p < .001$. The Johansson pictures were more arousing when they were positive relative to both the coloured photographs, Materials × Valence interaction, $F(2, 36) = 10.26$, $p < .001$, and the words, Materials × Valence interaction, $F(2, 36) = 9.66$, $p < .001$.

Also, to investigate the semantic structure of the stimulus lists, we had 30 subjects (no students of psychology) sort the words and pictures into categories according to their perceived similarity (cf., Miller, 1969; Rosch & Lloyd, 1978), and compared the average number of categories as well as the standard deviation of the size of the formed categories for neutral, negative, and positive items (each sorted by 10 subjects). Subjects were free in the number of categories they created and in the number of items they sorted into each category. Results are depicted in Figure 2 (bottom row). Although the differences between the three valences were not significant, as expected given the small sample size and the efforts taken to balance the materials, two findings seem noteworthy: First, the pictures of Johansson et al. were truly comparable to our words in overall homogeneity (main effect of Materials on Numbers of categories, $F = 0.08$), while the coloured photographs were perceived as more homogenous than were the pictures of Johansson et al., main effect of Materials on the Numbers of categories, $F(1, 54) = 5.22$, $p < .05$, as was intended. Second, our negative words were perceived as more homogenous than were the neutral words (mean difference in number of categories was 2.2, with ~20% higher standard deviation of the category size). Importantly, however, this was not true for the positive words where the mean difference in numbers of categories was 0.6 in the opposite direction. Matching for semantic cohesion thus seemed to have been more successful for the positive words than for the negative words.

DISCUSSION

This study investigated whether emotion-induced variations in the response bias in a recognition memory task is literally a modulation of the bias to make a response that emerges at the stage of decision making, or, alternatively, a *memory* bias reflecting the (illusory) feeling that emotion-laden items are more familiar than neutral items. To disentangle these two possibilities, a Go/NoGo recognition memory task was employed in which subjects' response sets were varied. Furthermore, words were compared with faces to find out whether the bias modulation is a function of semantic coherence or of emotionality per se. Positive stimuli were included in addition to negative stimuli to explore whether the bias relates to emotional arousal or valence.

For words, we found, first, that the emotion-induced shift of the response bias was clearly present in the "Go-for-old" group, but inverted in the "Go-for-new" group. That is, whereas subjects in the "Go-for-old" group responded more often to emotional stimuli than they did to neutral stimuli, subjects in the "Go-for-new" group did the opposite: They responded less often. This means that both groups classified emotional words more often as "old", whether they needed to render a response or to withhold a response to indicate "oldness". Importantly, this bias was not specific to negative words but was comparably strong for positive words.

The result clearly speaks against the *executive control account* that refers to facilitated "signal" detections and reduced response monitoring as a by-product of automatic threat processing (Windmann & Krüger, 1998) for two reasons, first, because it was not selective for negative words (and can therefore not be threat related), and second, because the "Go-for-new" group showed intact and even enhanced control of responses to emotional items. Instead, results suggest that subjects of both groups truly believed that the emotional items were more often old than the neutral items. The finding therefore supports the notion of an emotion-induced *memory* bias in the sense of a memory illusion, in accord with the *memory bias account* of the emotion-induced bias shift.

The bias shift for emotional words tended to be larger than it was for emotional faces, for which it was in fact not significant. Accounts that attribute the bias shift to the effects of emotions would have expected the shift to be present in all types of emotional stimuli, verbal or not (Johansson et al., 2004). On the one hand, this might indicate that semantic cohesion contributes to the effect (Maratos et al., 2000). In fact, the sorting experiments confirmed our suspicion that the negative words were semantically more homogeneous than the neutral words, despite our efforts to match the two word lists. On the other hand, the bias shift also occurred for positive words, where semantic cohesion was not enhanced according to our post hoc experiments. This fact is difficult to explain for a purely cohesion-based account.

The post hoc sorting studies suggested that the emotional expressions of the coloured face photographs were not perceived as intense as were the words and the black-and-white faces for which Johansson et al. (2004) found the emotion-induced bias shift to be significant, although the overall differences between the materials were quite small. In addition, the neutral faces in our study were remembered better than were the positive and negative faces (the opposite was found in the Johansson et al. study). Thus, although the coloured pictures were certainly appealing and showed highly significant variations in both arousal and valence, their emotional expressions seem to have been of reduced intensity relative to the high-expression faces in the Johansson study, which may have rendered these pictures less effective in shifting the bias than the other materials. It is perhaps no coincidence that the Johansson faces were evaluated somewhat more like our words in terms of arousal, valence, and homogeneity. If true, then the lack of a significant emotion-induced bias shift found for our coloured pictures cannot be taken as evidence against the emotional nature of the bias shift, especially since the mean values of the bias went into the expected direction for both groups of subjects.

The question of how to interpret the higher bias for positive words relative to neutral words depends on what variant of the memory bias account one favours. If the bias shift is an effect of semantic cohesion, as the reduced effects in our coloured face photographs suggest, then this finding must not be interpreted in emotional terms but in terms of semantic priming, spreading activation, or other mnemonic mechanisms. If, however, the effect is genuinely thought to be related to the emotion dimension (Garcia-Marques et al., 2004; Monin, 2003; Phaf & Rotteveel, 2005), in line with our finding that the positive words were equally effective in driving the bias up despite being no more semantically coherent than the neutral words, then the finding speaks for a valence-independent effect of arousal on the bias. Whichever interpretation is valid for the present data, it should be noted that results obtained with various other paradigms suggest that emotional arousal is not the only source of activation that can induce illusory feelings of familiarity and thereby enhance the bias to respond "old" (Azimian-Faridani & Wilding, 2004; Goldinger & Hanson, 2005; Jacoby & Whitehouse, 1989).

Two differences between the "Go-for-old" and "Go-for-new" groups that did not interact with the emotionality of the stimuli seem noteworthy. First, subjects in the "Go-for-old" group responded faster than did subjects in the "Go-for-new" group. Importantly, this was true even when subjects responded "old" incorrectly (i.e., to new items; see Table 1). This pattern cannot be explained by repetition priming or memory strength as new items have not been presented before. Instead, it suggests that there is a natural cognitive asymmetry between detecting and signalling old items relative to new items, as was presumed (Windmann & Krüger, 1998). Second, subjects in the "Go-for-new" group responded more often to words, but not to pictures, than did the subjects in the "Go-for-old" group, while showing comparable recognition accuracy. Although this finding again suggests that there is an asymmetry between "old" and "new" responses, it is harder to interpret on the basis of the available evidence. It may be a by-product of the homogeneity differences between the materials, with the words being less homogeneous than the photographs according to our post hoc study. More heterogeneous materials might foster more "new" responses in the "Go-for-new" group because these subjects are specifically searching for mismatching features that differentiate new items from studied items. Relative to the faces, this may have increased their response rates above the level of a neutral bias (which would have been .50), and slowed down their responses, contrary to subjects in the "Go-for-old" group who could always base their responses on familiarity and fluency.

In conclusion, despite having confirmed our core presumptions, the results of the present study are incompatible with the *executive control account* of the emotion-induced bias shift, and instead speak for the *memory bias account*, as does a recent study from our laboratory in patients with deficits in executive functions (Windmann et al., 2007). What still needs to be shown is whether emotional arousal per se, without the effects of semantic cohesion, can alter the response bias in a memory task. By ruling out one account after the other, we hope to eventually begin to understand the true nature of this intriguing phenomenon.

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APPENDIX

Word lists

Negative words			
Obsession	Appal	Misfortune	Scare
War	Calamity	Rape	Evil
Accident	Repulsion	Funeral	Sorrow
Disease	Violence	Cripple	Purulence
Manslaughter	Terror	Fear	Murderer
Injury	Tumour	Massacre	Harm
Despair	Crime	Horror	Grief
Miscarriage	Scar	Inflammation	Cadaver
Catastrophe	Anxiety	Pain	Epidemic
Decay	Infection	Shock	Agony
Positive words			
Gladness	Salary	Happiness	Affection
Understanding	Goodness	Infatuation	Laud
Charm	Pep	Present	Peace
Passion	Humour	Gentleness	Tenderness
Love of Life	Beauty	Benefit	Cheerfulness
Kiss	Grace	Recreation	Pleasure
Flirt	Trust	Laughter	Respect
Well-Being	Amenity	Harmony	Reward
Talent	Warmth	Ingenuity	Relaxation
Hero	Ease	Vim	Tolerance
Neutral words			
Standpoint	Sculpture	Monument	Thesis
Perspective	Design	Symbol	Essay
Position	Opus	Feature	Publication
Interview	Drawing	Aspect	Composition
Poll	Sketch	Rubric	Reproduction
Dialogue	Graphics	Index	Literature
Conference	Draft	Contents	Curvature
Conversation	Figure	File	Reprint
Meeting	Motive	Card Index	Fact
Contact	Material	Accessory	Function