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Effects of transient, mild mood states on semantic memory organization and use: an event-related potential investigation in humans

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Abstract

The effects of transient mood states on semantic memory organization and use were investigated using event-related potentials. Participants read sentence pairs ending with (1) the most expected word, (2) an unexpected word from the expected semantic category, or (3) an unexpected word from a different (related) category; half the pairs were read under neutral mood and half under positive mood. Under neutral mood, N400 amplitudes were smallest for expected items and smaller for unexpected items when these came from the expected category. In contrast, under positive mood, N400 amplitudes to the two types of unexpected items did not differ. Positive mood seemed to specifically facilitate the processing of distantly-related, unexpected items. The results suggest that transient mood states are associated with dynamic changes in how semantic memory is used on-line.

Keywords: Mood; Semantic memory; Sentence processing; Event-related potentials; N400

Empirical research concurs with the everyday intuition that our moods influence our thinking, judgment, and perceptions. Transient, mild positive mood has been shown to increase integrative decision-making and subjective risk assessment and to facilitate flexibility of thinking and problem solving [8]. For example, Isen et al. [9] found that participants who viewed a humorous as opposed to an affectively neutral videotape were more successful at solving items from Mednick's [14] remote associates test (RAT). In this test, participants see a series of three words (e.g. 'widow, board, cat') and must find a single word related to all of them (e.g. 'black'). Isen et al. [9] proposed that positive mood increases access to remote category associates, thereby extending the breadth of information available for processing.

Kirson [10] extended Isen's et al. finding with the RAT using two established semantic memory tasks, sentence verification and lexical decision. Subjects in both experiments saw an amusing videotape (the positive mood induction) or a neutral videotape (rated as 'boring' by college students). In the sentence completion task, subjects were shown true and false sentences that described category-exemplar relationships (e.g. 'A robin/coin is a bird.'). True sentences contained both exemplars that were a near associate of the category word and those with a more distant association (e.g. 'A robin/parrot is a bird.'). As expected, sentences depicting a close relationship were verified as true in less time than those describing a distant relationship. This difference was smaller, however, with positive mood induction, as positive mood specifically shortened participants' time to verify the distant sentences (Fig. 1). These findings were replicated using lexical decision. Taken together the two experiments support the notion that the 'semantic distance' between distant exemplars and their categories was functionally shortened in the positive mood condition.

The present study builds on the notion that transient mood states can cause dynamic organizational changes in memory and cognitive processing. We use event-related brain potentials (ERPs) to examine when and how mood influences memory retrieval in the context of language processing. Event-related potentials track processing from early sensory analysis and attentional filtering through decision-making and response preparation. One component in particular, a

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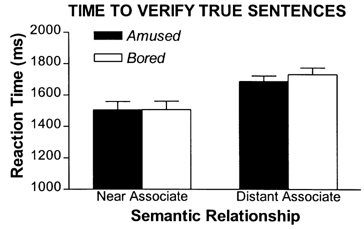

Fig. 1. Reaction times to verify true sentences as a function of the semantic distance between exemplar and category label and the participant's mood state during the task. Error bars indicate standard errors.

negativity peaking around 400 ms (N400), is highly sensitive to semantic relationships, both within a local context and in long-term semantic memory more generally (see Ref. [6]). Changes in the organization of semantic memory as a function of mood would thus be expected to show up electrophysiologically as changes in the amplitude of the N400. If mood's effects on cognitive processing are mediated, instead, by more general changes in arousal or motivation, qualitatively different electrophysiological effects would be predicted.

Stimuli were those used by Federmeier and Kutas [6] to examine semantic memory use during sentence processing. 132 sentence pair contexts (e.g. 'They wanted to make the hotel look more like a tropical resort. So, along the driveway they planted rows of... ') ended with (1) the most expected ending, as determined by cloze probability ratings ('expected exemplars'; e.g. 'palms'), (2) an unexpected item (cloze probability < 0.05) from the expected semantic category ('within category violations'; e.g. 'pines'), or (3) an equally unexpected item from a different, though related, semantic category ('between category violations'; e.g. 'tulips'). Twenty-four right-handed, monolingual English-speaking volunteers (half female; mean age 20) read these sentences, plus 44 congruent fillers, for comprehension. Context sentences appeared in full on a CRT. Target-containing sentences were then presented word by word (two words per second) in the center of the screen, target words for a duration of 500 ms. Participants saw each target item and context only once, but, across participants, target words appeared in all conditions.

Mood was manipulated using photographs from the International Affective Picture system [3,11]. Thirty 'happy' photos (e.g. cute animals, smiling people) had a highly positive mean valence rating (7.89 on a 9 point scale; range 7.61–8.34), with a neutral arousal rating (mean 5.15 on a 9 point scale). Thirty 'boring' photos (e.g. household objects, people with neutral expressions) had a neutral mean valence rating (4.85; range 4.69–4.98), and a somewhat calm arousal rating (mean 2.88). Each participant viewed five blocks of sentence pairs under each mood-induced state; order of mood state and association with experimental stimuli were counterbalanced. Mood induction at experiment start and at the half-way point involved exposing participants to 18 mood-appropriate photos; mood was maintained by showing three additional photos between each experimental block. Participants were not informed about the mood induction but instead were asked to view the photos to later judge their 'appropriateness for experimental use'. The effectiveness of the mood state induction was assessed with a written questionnaire asking participants to report how much they liked the pictures from each set, to compare their feelings about the two sets, and to indicate whether they felt that viewing the pictures had influenced their reading of the experimental sentences. Almost all subjects (11 female/9 male) indicated a preference for the 'happy' over the 'neutral' pictures. Eighteen of these (11 female/7 male) reported a difference in their emotional response to the two picture sets, and twelve (8 female/4 male) indicated that these feelings might have influenced how they read the sentences.

The electroencephalogram (EEG) was recorded from twenty-six tin electrodes embedded in an Electro-cap, referenced to the left mastoid (see icon in Fig. 2). Blinks and eye movements were monitored via electrodes placed on the outer canthus and infraorbital ridge of each eye. EEG was amplified with a bandpass of 0.01–100 Hz and continuously digitized at 250 Hz. Data was re-referenced off-line to the algebraic average of the left and right mastoids. Trials contaminated by eye movements, excessive muscle activity, or amplifier blocking were rejected off-line; blink-contaminated trials were rejected where these were rare or, in six participants, were corrected via a spatial filter algorithm [4]. ERPs were computed from 100 ms before stimulus onset to 920 ms after and averages of artifact-free trials were calculated for each target type in each mood condition after subtraction of the pre-stimulus baseline.

Fig. 2 shows grand-average ERPs obtained under each of the mood conditions. The pattern for neutral mood (Fig. 2, left) replicates that previously reported by Federmeier and Kutas [6] with no mood manipulation. Mean amplitude

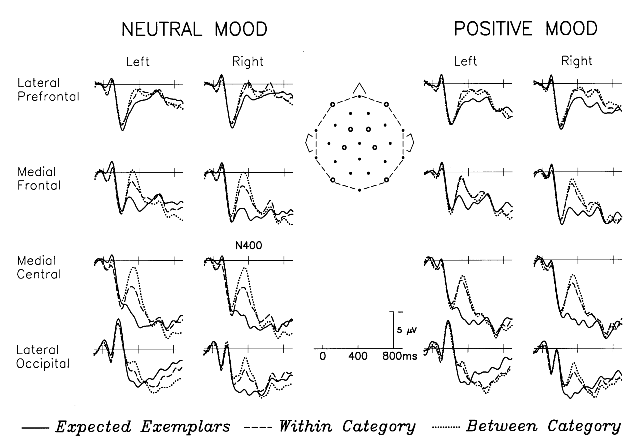

Fig. 2. ERPs to the three types of sentence endings when read under neutral mood (left) or positive mood (right). The scalp positions of the electrode sites shown are enlarged on the small head icon. Negative is plotted up.

N400 responses between 250 and 500 ms were subjected to an ANOVA with three levels of Ending Type and 26 levels of Electrode (*P*-values are reported after Huynh-Feldt correction for repeated measures with greater than one degree of freedom). There is a main effect of Ending Type ($F(2,46) = 17.76$; $P < 0.001$): planned comparisons reveal that expected exemplars are more positive than within category violations (5.60 vs. 3.60 μV; $F(1,23) = 14.04$; $P = 0.001$) and within category violations more positive than between category violations (3.60 vs. 2.58 μV; $F(1,23) = 6.90$; $P = 0.015$). Ending Type interacted with Electrode for both comparisons ($F(25,575) = 3.28$; $P = 0.015$ and $F(25,575) = 3.42$; $P = 0.01$), so data were normalized [13] and subjected to an ANOVA on two levels of ending type (expected vs. within and within vs. between), two levels of hemisphere (left vs. right), two levels of laterality (lateral vs. medial), and four levels of anteriority (prefrontal vs. frontal vs. central vs. occipital). There were no distribution effects in the normalized data; thus, once amplitude differences have been controlled for, the data provide no reason to believe that the spatial configuration of underlying neural sources varies across ending types.

For positive mood (Fig. 2, right), there is also an overall effect of Ending Type ($F(2,46) = 14.85$; $P < 0.001$). However, in this case, while expected exemplars are again more positive than within category violations (5.51 vs. 3.57 μV; $F(1,23) = 35.2$; $P < 0.001$), within category violations and between category violations do not differ (3.57 vs. 3.22 μV; $F(1,23) = 0.63$; $P = 0.43$). The difference between expected exemplars and within category violations interacted with Electrode ($F(25,575) = 4.79$; $P = 0.001$), while there was no interaction for the violation type comparison ($F(25,575) = 1.15$; $P = 0.34$). Again, normalized distribution analyses revealed no significant differences.

The mood-related difference in ending type pattern is especially pronounced for the twelve female participants. This may be because positive pictures with low arousal generally elicit higher valence ratings in female subjects (for this set, 8.14 for females versus 7.60 for males; [11]), and, in fact, females in this study also were more likely to report being aware of and affected by the mood manipulation. For this group, planned comparisons reveal that positive mood specifically reduced the N400 (300–400 ms) to between category violations (2.69 μV vs. 0.60 μV; $F(1,11) = 6.11$; $P = 0.03$) without altering the response to within category violations ($F(1,11) = 0.04$; $P = 0.85$) or expected exemplars ($F(1,11) = 0.56$; $P = 0.47$). These effects did not interact with electrode. Male participants' responses to the three ending types did not differ between the two mood conditions (expected exemplars: ($F(1,11) = 0.00$; $P = 0.95$); within category violations: ($F(1,11) = 0.83$; $P = 0.38$); between category violations ($F(1,11) = 0.02$; $P = 0.89$)). There were also no significant effects of mood in earlier time windows (i.e. 50–150 ms (N1), 150–250 ms (P2)) for either group. Fig. 3 shows the pattern of N400 responses as a function of mood state for male and female participants. Note that the neutral mood pattern in both groups replicates Federmeier and Kutas [6]: smaller N400s to expected exemplars than within category violations (female: ($F(1,11) = 13.65$; $P < 0.01$); male ($F(1,11) = 5.16$; $P < 0.05$)) and to within than to between category violations (female: ($F(1,11) = 23.43$; $P < 0.001$); male: ($F(1,11) = 2.93$; $P = 0.11$) – the difference for males alone was also only marginally significant in the Federmeier and Kutas [6] data).

Thus, we find that the pattern of ERP responses to precisely the same materials in exactly the same normal young adults varies as a function of the mood state induced prior to reading the sentences. In the neutral mood condition, we observe both a congruency effect, such that expected items elicit less negativity than unexpected items, and a category effect, such that unexpected items which share many features in common with the expected item elicit less negativity than equally unexpected items from a different semantic category. This replicates the pattern found with no mood manipulation [6] and with initial presentation to the left hemisphere in a visual half-field paradigm [5]. Following a positive mood induction, however, there is a similar congruency effect, but the category effect has been significantly reduced if not eliminated. Since all other factors were held constant, this difference must be due to the nature of the pictures that the participant had viewed just prior to reading the sentences – and, presumably, the mood state that these pictures induced.

We also observe that the effect of mood is specific, not general. At least in female participants, we find that positive mood selectively reduces the N400 to between category violations without altering the amplitude of the response to the other two ending types. This is not the pattern one might predict if mood-related effects were driven by non-specific arousal or motivational factors, which, in general, have not been found to influence N400 responses (see Ref. [17]). Furthermore, in this study mood did not significantly affect earlier ERP components (N1, P2), which are known to vary with both arousal and attentional allocation (see Refs. [2,7,17]). Instead, positive mood, relative to a neutral or 'bored' state, seemed to particularly influence meaning processing, as indexed by the N400. With positive mood,

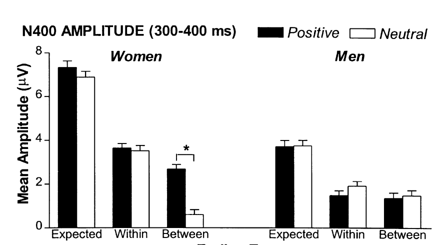

Fig. 3. Mean N400 amplitudes (300–400 ms, all channels, all participants) for the three ending types as a function of mood state, for both female (left) and male (right) participants. Error bars indicate standard errors.

there was facilitated access to more distantly related semantic concepts – here, those that are not from the same semantic category but that nonetheless shared some general features in common with the expected item. Our data thus support hypotheses developed from behavioral studies [9,10] suggesting that transient mood states are associated with dynamic changes in how semantic memory is used on-line.

The influence of positive mood on semantic memory use may arise, as suggested in a model by Ashby et al. [1], because of changes in dopamine levels to the anterior cingulate and striatum that facilitate the generation and selection of appropriate semantic properties and allow more fluid switching between cognitive sets. In this study, positive mood may have (1) allowed participants to predict a richer set of semantic properties for upcoming items, not only those shared in common with other category members but also those shared with items from different but related categories and/or (2) facilitated participants' ability to flexibly accommodate the unexpected and more distantly related between category violations. Alternatively, it is possible that positive mood alters the relative balance of left and right hemisphere contributions to language processing. The pattern observed with positive mood is similar to that obtained with initial presentation to the right hemisphere ([5], though in that study the difference between the hemispheres was driven by the response to within category violations). This pattern mirrors the plausibility of the items in the sentence contexts and is thus suggestive of a processing strategy wherein the fit of the items to the context itself (rather than their similarity to a predicted completion) is key. It is possible that positive mood enhances right hemisphere involvement in processing (see Refs. [12,15,16]), such that participants adopt this more plausibility-driven – as opposed to predictive – strategy.

Regardless of the precise mechanism involved, however, these data argue convincingly that mild, transient mood states influence even well-practiced, everyday tasks like sentence comprehension. Further, the ERP data reveal that mood specifically influences brain activity associated with the retrieval and integration of word-related information from long-term semantic memory, facilitating the processing of items more distant from those predicted in the context. Further work will hopefully uncover more details of the mechanism by which a picture, a smile, or a joke can change our perceptions of, our reactions to, and our memories of the world around us.

[1] Ashby, F.G., Isen, A.M. and Turken, A.U., A neuropsychological theory of positive affect and its influence on cognition, Psychol. Rev., 106 (1999) 529–550.

[2] Burkhart, M.A. and Thomas, D.G., Event-related potential measures of attention in moderately depressed subjects, Electroencephalogr. Clin. Neurophysiol. Evoked Potentials, 88 (1993) 42–50.

[3] Center for the Study of Emotion and Attention CSEA-NIMH, The International Affective Picture System: Digitized Photographs, The Center for Research in Psychophysiology, University of Florida, Gainesville, FL, 1995.

[4] Dale, A.M., Source Localization and Spatial Discriminant Analysis of Event-related Potentials: Linear Approaches, Department of Cognitive Science, University of California San Diego, La Jolla, CA, 1994, 175 pp.

[5] Federmeier, K.D. and Kutas, M., Right words and left words: Electrophysiological evidence for hemispheric differences in meaning processing, Cogn. Brain Res., 8 (1999) 373–392.

[6] Federmeier, K.D. and Kutas, M., A rose by any other name: Long-term memory structure and sentence processing, J. Mem. Lang., 41 (1999) 469–495.

[7] Hillyard, S.A., Hink, R.F., Schwent, V.L. and Picton, T.W., Electrical Signs of Selective Attention in the Human Brain, Science, 182 (1973) 177–179.

[8] Isen, A.M., Positive affect, In T. Dalgleish and M.J. Power (Eds.), Handbook of Cognition and Emotion, Wiley, Chichester, England, 1999, pp. 521–539.

[9] Isen, A.M., Daubman, K.A. and Nowicki, G.P., Positive affect facilitates creative problem solving, J. Pers. Soc. Psychol., 52 (1987) 1122–1131.

[10] Kirson, D.A., The Effect of Mood on Access to Remote Category Associates, Department of Psychology, University of Denver, Denver, CO, 1990, 130 pp.

[11] Lang, P.J., Bradley, M.M. and Cuthbert, B.N., International Affective Picture System (IAPS): Technical Manual and Affective Ratings, The Center for Research in Psychophysiology, University of Florida, Gainesville, FL, 1995.

[12] Liotti, M. and Tucker, D.M., Emotion in asymmetric corticolimbic networks, In R.J. Davidson and K. Hugdahl (Eds.), Brain asymmetry, MIT Press, Cambridge, MA, 1995, pp. 389–423.

[13] McCarthy, G. and Wood, C.C., Scalp distributions of event-related potentials: an ambiguity associated with analysis of variance models, Electroencephalogr. Clin. Neurophysiol., 62 (1985) 203–208.

[14] Mednick, S., The Associative Basis of the Creative Process, Psychol. Rev., 69 (1962) 220–232.

[15] Tucker, D.M., Lateral brain function, emotion, and conceptualization, Psychol. Bull., 89 (1981) 19–46.

[16] Tucker, D.M. and Williamson, P.A., Asymmetric neural control systems in human self-regulation, Psychol. Rev., 91 (1984) 185–215.

[17] Wesensten, N.J. and Badia, P., Time of day and semantic category effects on late components of the visual ERP, Biol. Psychol., 33 (1992) 173–193.