Selective attention to food-related stimuli in hunger: are attentional biases specific to emotional and psychopathological states, or are they also found in normal drive states?

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Abstract

Previous work has indicated that anxiety disorders and eating disorders are associated with selective processing of stimuli relevant to patients' concerns (e.g. Mathews and MacLeod, 1994; Annual Review of Psychology, 45, 25–50; Channon et al., 1988; British Journal of Clinical Psychology, 27, 259–260). A dot probe task was used to investigate whether attentional biases are also a feature of a normal drive state. Specifically, we examined whether hunger is associated with biases in selective attention and in pre-attentive processes for food-relevant stimuli. Subjects with high levels of hunger showed a greater attentional bias for food-related words presented in a suprathreshold exposure condition (words shown for 500 msec), in comparison with those with low hunger. There was no evidence in the present study of a hunger-related bias in pre-attentive processes (i.e. when words were shown for 14 msec and masked). Results suggest that a non-emotional motivational state, such as hunger, is associated with a bias in certain aspects of information processing, such as selective attention, for stimuli that are relevant to the motivational state. Findings are discussed in relation to recent research into emotion-related cognitive biases. © 1998 Elsevier Science Ltd. All rights reserved

Key words: Attentional bias, Hunger, Drive, Selective attention, Food

1. Introduction

There is considerable evidence that anxiety is associated with an attentional bias for threat-related information (e.g. review by Mathews and MacLeod, 1994). For example, anxious individ-
uals are more likely to shift their attention towards the spatial location of threat stimuli than normal control subjects (e.g. MacLeod et al., 1986; Mogg et al., 1995). Several theorists have proposed that this attentional bias may play a role in the onset or maintenance of clinical anxiety states (e.g. Beck et al., 1985; Williams et al., 1988).

It is clearly helpful in the development of cognitive models of clinical emotional disorders to know whether these observed attentional biases are a specific characteristic of some emotional motivational states, such as anxiety, or whether they are a feature of motivational states in general. Indeed, there is evidence suggesting that similar biases may be associated with hunger and with interest-relevant information. For example, Channon and Hayward (1990) found, using the modified Stroop task, that subjects who had fasted for 24 hours were slower in naming the colours of food-related words than control stimuli, in comparison with non-fasting subjects; which was consistent with a hunger-related processing bias. Lavy and van den Hout (1993), also compared fasting and non-fasting subjects on their colour-naming times for food-related words versus control words. The results were equivocal, and depended on the choice of control words. Fasting subjects showed greater interference than non-fasting subjects in colour-naming food words compared with positive words (holiday-related, e.g. fun, beach), but not with neutral words (tool-related, e.g. hammer, chisel).

Several other studies using the modified Stroop task have found evidence suggesting selective processing of interest-relevant stimuli, such as hobby-related (Dalgleish, 1995) and personally relevant information (e.g. Rieman and McNally, 1995), although there have been failures to find such effects (e.g. Mogg and Marden, 1990). The interpretation of these findings is complicated because it is unclear whether such colour-naming interference effects are due to the motivational salience of the stimuli, or to some other variable, such as differential familiarity or subjective word frequency effects (e.g. names of birds will be more familiar to ornithologists than to non-bird-watching control subjects).

Another difficulty in interpreting the results from the above studies is that the modified Stroop task does not provide a direct measure of attentional bias. It is widely accepted that a number of different cognitive mechanisms might contribute to colour-naming interference effects (e.g. C. M. MacLeod, 1991). Thus, the main aim of the present study was to use a more direct measure of deployment of visual attention in order to investigate whether a transient motivational state, such as hunger, is associated with an attentional bias for drive-relevant stimuli, such as food-related words. We used a modified version of a dot probe task, similar to that used by Mogg et al. (1995), in which a series of word pairs was presented on a computer screen, one word above the other. Immediately after the display of each word pair, a small dot probe appeared in one of two locations on the screen which had just been occupied by one of the words. Subjects indicated the position of the probe (i.e. upper or lower) by pressing one of two response keys as quickly as possible. Individuals with generalised anxiety disorder were faster to detect probes which replaced threat than neutral words, compared with controls, which indicates attentional vigilance for threat. Moreover, anxious individuals showed an attentional bias towards the location of threat words, even when the words were presented briefly and masked, so that subjects' awareness of the nature of the word stimuli was restricted (Mogg et al., 1995). The latter finding is consistent with the anxiety-related bias for threat operating in pre-attentive processes, i.e., prior to awareness.
Consequently, in the present study, we used this task to examine whether hunger is similarly associated with attentional and pre-attentive biases for food-relevant information. Word pairs were presented on a computer screen, one word above the other. Each critical word pair consisted of a food-related word and a transport-related control word; i.e. each word type was drawn from a relatively coherent semantic category to control for word categorization effects. To examine the effect of awareness of the word stimuli, half the word pairs were presented in a suprathreshold condition (i.e. for 500 msec), and the other half in a subthreshold condition (i.e. for 14 msec, followed by a mask). On each trial, a dot probe replaced the display of one of these stimuli, and subjects pressed one of two response buttons to indicate whether the probe occurred in the upper or lower position. To obtain two groups differing in hunger, half the subjects were randomly allocated to a fasting condition (i.e. they were asked to refrain from eating on the day of testing), and the other half to a non-fasting condition.

Our main hypothesis was that hungry subjects will preferentially shift their attention towards the spatial location of food-related words. That is, they will be relatively faster to detect probes which occur in the same location as food words than control words. Moreover, if the predicted hunger-related bias operates in pre-attentive processes (i.e. outside awareness), the same pattern of results should be obtained when the food words are presented in the subthreshold exposure condition.

2. Method

2.1. Subjects

Thirty two subjects (16 male, 16 female, aged 19–27 yr) were recruited through advertisements asking for volunteers with normal eating habits, and met the following criteria: (i) first language was English, and (ii) no objections to potential fasting requirements of study. Half the male and half the female subjects were randomly allocated to the fasting condition; the other half to the non-fasting condition. Data from one subject in the non-fasting group were excluded from the analyses due to outlying latencies (see Results for details).

2.2. Materials

For the dot probe task, each of 64 food-related words was matched for length and frequency (using the norms of Carroll et al., 1971) with a transport-related word (e.g. chocolate–passenger; honey–coach; sandwich–aircraft). An additional 64 word pairs served as fillers (these were a mixture of household-related and uncategorised neutral words, unrelated to food or transport). The word pairs were divided into two equivalent lists (A and B), each list consisting of 32 food–transport word pairs and 32 filler pairs. The allocation of word sets to the suprathreshold and subthreshold conditions was counter-balanced across subjects, such that half of subjects received Set A words in the suprathreshold condition and Set B in the subthreshold condition, and vice versa for the half. The equipment included an IBM PS/2 Model 30 286 computer, IBM 8512 14 in. monitor, and MEL version 1.0 software (Micro Experimental Laboratory; Schneider, 1988).
2.3. Procedure

All subjects were given written instructions to eat and drink normally (preferably 3 meals) the day before the test session. Testing occurred in the afternoon for all subjects. Those allocated to the fasting group were asked not to eat in the interval between their last evening meal and the test session in the afternoon of the following day (they were advised to drink as normal). Those in the non-fasting group were asked to eat breakfast and lunch before the session, and to drink as normal.

All subjects then completed the attentional task. There were 12 practice and 128 experimental trials (64 trials with food–transport words pairs, 64 filler trials), with half the word pairs presented in the suprathreshold condition, and half subthreshold. In each condition, the food word and probe was presented in either the upper or lower position on the screen with equal probability. The trials were presented in a new random order for each subject, within the constraint that there was an equal number of trials in each condition in the first and second halves of the task. This allowed us to examine attentional responses to food words in each half of the task separately, as there is evidence that cognitive biases may vary over the course of a test session (e.g. Broadbent and Broadbent, 1988; Green et al., 1994).

In the suprathreshold exposure condition, each trial started with a fixation cross in the centre of the screen for 500 msec. The cross was replaced by a word pair in uppercase for 500 msec, one word above and one below the preceding fixation point (distance between the centres of the words was 3.8 cm). Immediately after the display of the word pair had terminated, a dot probe appeared in the position of one of the words and remained displayed until response. Subjects were asked to press one of two response keys as quickly as possible to indicate whether the probe was above or below the centre of the screen. The inter-trial interval randomly varied between 500 and 1500 msec.

In the subthreshold exposure condition, the central fixation cross (500 msec) was followed by a word pair, which was in turn replaced by a pair of random letter masks (e.g. FGTRP), matched for length with the preceding word pair. The interval between the onset of the word pair and the onset of the mask pair was 14 msec (i.e. stimulus onset asynchrony, or SOA, between word and mask was 14 msec). The SOA between the mask pair and the probe was 186 msec. Thus, the SOA between the word pair and the probe was 200 msec.

After the attentional task, subjects were given two forced-choice discrimination tasks, in counterbalanced order across subjects, to assess awareness of the masked word stimuli. In the presence/absence task, on half the trials, the stimulus exposure conditions were the same as those in the subthreshold exposure condition of the attentional task (i.e. 500 msec fixation cross →14 msec word pair →186 msec mask pair). On the other half of trials, a blank screen was displayed before the mask instead of a word pair (i.e. 500 msec fixation cross →14 msec blank screen →186 msec mask pair). Subjects pressed one of two keys to indicate whether or not words were presented before the masks. There were 10 practice trials, and 48 main trials in a random order. The 24 stimulus word pairs were a subset of those used in the subthreshold condition of the attentional task, with an equal number of each word type.

In the lexical decision task, on half the trials, a word pair was presented before the mask (i.e. 500 msec fixation cross →14 msec word pair →186 msec mask pair). On the other half of trials, a pair of graphemically legitimate non-words (e.g. BRONGE) was presented instead of a
word pair (i.e. 500 msec fixation cross → 14 msec non-word pair → 186 msec mask pair). Subjects pressed one of two keys to indicate whether words or non-words were presented before the masks. There were 10 practice and 48 main trials. The 24 stimulus word pairs were another subset of those used in the subthreshold condition of the attentional task.

Finally, subjects completed the Eating Attitudes Test (EAT-26 items; Garner et al., 1982) and Hunger Scales (Grand, 1968). The latter consisted of 4 hunger indices:

1. time since last eating (number of hours, estimated to nearest 15 min);
2. subjective hunger (rated on 7 point scale: 1 = not hungry at all, 7 = extremely hungry);
3. subject’s estimate of the amount of their favourite food that they would be able to eat at the time of testing (rated on 6 point scale: 1 = none at all, 6 = as much as I could get);
4. estimate of time until next expected meal (estimated to nearest 15 min).

Subjects were then paid £4 for their participation.

3. Results

For the attentional task, data from trials with errors were excluded. Latencies of less than 200 msec or more than 1500 msec, and then those more than 2 SD above each subject’s mean, were discarded as outliers. One subject had unusually slow and variable response times (mean RT of 640 msec was more than 3 SD above sample mean) and so was excluded. Of the final sample, 2.6% of data was lost due to errors and 3.6% due to outliers. Mean RTs were then calculated for each condition; Kolmogorov–Smirnov tests showed that their distributions did not differ from normality.

Subjective hunger ratings were significantly higher in the fasting group compared to the non-fasting group, (i.e. the manipulation had been successful: mean hunger ratings were 4.9 and 2.3, respectively, Mann–Whitney U = 36, \(P < 0.05\)), but we noted some overlap in hunger ratings between the groups, despite no overlap in time since their last meal. For example, in the non-fasting group, the time since last meal ranged from 0.5 to 3.5 hr, and a few subjects reported moderate hunger levels (range 1–5; mean 2.3). On the other hand, in the fasting group, the time since last meal was considerably longer, ranging from 16 to 22 hr, while subjective hunger ranged from 1–7 (mean 4.9). Therefore, to provide a more sensitive and direct test of our hypotheses, we allocated subjects to two groups on the basis of their subjective hunger ratings: the ‘low hunger’ group with hunger ratings below the sample median of 4, and the ‘high hunger’ group with hunger ratings of 4 or more (see Table 1 for details; Mann–Whitney U tests were used to compare the groups because several questionnaire measures did not show normal distributions). The groups did not differ significantly in age or EAT scores. The high hunger group not only gave higher hunger ratings, but also reported longer times since their last meal, shorter times to their next meal, and estimated that they could eat a larger amount of their favourite food, in comparison with the low hunger group.

A \(2 \times 2 \times 2 \times 2 \times 2\) mixed design analysis of variance (ANOVA) was carried out of the RT data with one between subjects variable of Hunger (high, low), and four within subjects variables: Exposure condition (suprathreshold, subthreshold), Half of task (first, second), Position of Food Word (upper, lower), and Probe position (upper, lower). There were several significant
Table 1
Characteristics of low and high hunger groups

<table>
<thead>
<tr>
<th></th>
<th>Low hunger</th>
<th>High hunger</th>
<th>U</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>15</td>
<td>16</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex ratio (M/F)</td>
<td>8/7</td>
<td>7/9</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>20.9</td>
<td>20.6</td>
<td>120</td>
<td>ns</td>
</tr>
<tr>
<td>Eating Attitudes Test</td>
<td>3.5</td>
<td>4.1</td>
<td>108</td>
<td>ns</td>
</tr>
<tr>
<td>Hunger rating</td>
<td>1.7</td>
<td>5.4</td>
<td>0</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Time since last meal (hr)</td>
<td>4.8</td>
<td>15.4</td>
<td>28</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Time to next meal (hr)</td>
<td>3.5</td>
<td>0.9</td>
<td>21</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td>Amount of favourite food that could be eaten</td>
<td>2.9</td>
<td>4.8</td>
<td>29</td>
<td>&lt;0.05</td>
</tr>
</tbody>
</table>

results which were not relevant to our hypotheses because they did not involve the Food Word Position × Probe Position interaction (i.e. Hunger × Probe position; Half; Exposure × Half; P < 0.05). The Food Word Position × Probe Position interaction was significant (F(1,29) = 8.40, P < 0.05), and this was subsumed under a significant four-way interaction of Hunger × Exposure × Food Word Position × Probe position (F(1,29) = 6.71, P < 0.05), which was not influenced by the half of the task (F < 1).

To clarify this four-way interaction, separate ANOVAs were conducted for each exposure condition (see Table 2 for means). For the subthreshold condition, there were no significant results. However, in the suprathreshold condition, there was a significant interaction of Hunger × Food Word Position × Probe Position (F(1,29) = 4.52, P < 0.05), which did not interact with the half of task (F < 1); see Fig. 1. To clarify the latter result, ANOVAs were calculated separately for the data from each hunger group (i.e. RT data from suprathreshold trials, collapsed across both halves of the task). For the low hunger group, the Probe Position × Food Word Position interaction was not significant (F(1,14) = 0.04, ns). By contrast, the high hunger group showed a significant Probe Position × Food Word Position interaction (F(1,15) = 10.36, P < 0.01), as they were on average 15 msec faster to detect probes that occurred in the same position as food words, than probes which occurred in a different position to food words (see Fig. 1).

To allow correlational analyses, attentional bias scores for food words were calculated separately for each exposure condition by subtracting the mean RT when food words and probes

Table 2
Mean latencies in msec to probes in low and high hunger groups

<table>
<thead>
<tr>
<th>Exposure condition</th>
<th>Position of food word</th>
<th>Position of probe</th>
<th>Low hunger</th>
<th>High hunger</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subthreshold</td>
<td>Upper</td>
<td>Upper</td>
<td>382</td>
<td>358</td>
</tr>
<tr>
<td></td>
<td>Upper</td>
<td>Lower</td>
<td>377</td>
<td>363</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>395</td>
<td>359</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>Lower</td>
<td>370</td>
<td>363</td>
</tr>
<tr>
<td>Suprathreshold</td>
<td>Upper</td>
<td>Upper</td>
<td>382</td>
<td>349</td>
</tr>
<tr>
<td></td>
<td>Upper</td>
<td>Lower</td>
<td>370</td>
<td>373</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>Upper</td>
<td>387</td>
<td>369</td>
</tr>
<tr>
<td></td>
<td>Lower</td>
<td>Lower</td>
<td>372</td>
<td>364</td>
</tr>
</tbody>
</table>
Fig. 1. Mean latencies in msec to probes on trials with suprathreshold food words (i.e. shown for 500 msec) in low and high hunger subjects.

were in the same position from the mean RT when they were in different positions. This score summarises the Probe Position \( \times \) Food Word Position interaction (also used in Mogg et al., 1995). Positive values of the bias score indicate vigilance for food words (i.e. faster responses to probes occurring in the same position as food words rather than control words), whereas negative values indicate avoidance of food words. Mean bias scores for suprathreshold food words were 15 msec and 1 msec respectively, for high and low hunger groups. The bias score of
the high hunger group was significantly greater than zero (0 = no bias), consistent with hunger-related vigilance for food stimuli (t(15) = 3.22, P < 0.01, two-tailed).

Spearman correlations were calculated between the attentional bias scores for food words in each exposure condition and the self-report measures of hunger and EAT. There were two significant results: vigilance for suprathreshold food words correlated with higher hunger ratings (r = 0.36, P < 0.05, two-tailed) and with larger estimates of the amount of favourite food that could be eaten by subjects (r = 0.57, P < 0.05).

3.1. Awareness checks

On the lexical decision task, binomial tests were conducted on each subject’s percentage correct score to assess whether their performance exceeded chance level (i.e. 50% trials correct). None performed significantly above chance level (P < 0.05). Also, the overall performance of the sample was not significantly different from chance level (mean percentage correct = 49%). These results indicate that subjects were unaware of the lexical content of the masked word stimuli.

On the presence/absence task, data from one subject were missing due to a coding error. Fourteen of the remaining 30 subjects performed significantly better than chance (mean percentage correct = 65%). These results suggest that a substantial proportion of subjects were able to detect the presence versus absence of the masked word stimuli, despite being unable to identify their lexical content.

4. Discussion

Our main hypothesis was supported; subjects with high levels of hunger were more likely to shift their attention towards suprathreshold food-related words than control words, whereas those with low hunger showed no attentional bias for food-related stimuli. The attentional bias for food-related words was significantly predicted by subjects’ hunger ratings and estimates of how much of their favourite food they could eat. These results provide evidence that a non-emotional motivational state, such as hunger, is associated with a bias in selective attention to stimuli that are relevant to that motivational state. Evidence of the hunger-related bias was only found when the food stimuli were presented in the suprathreshold condition.

Although the effect of the fasting instructions on subjective hunger ratings was significant, indicating that the experimental manipulation had been successful, there was some overlap in hunger ratings between the two conditions (despite no overlap in time since last eating). Thus, allocation of subjects to two groups on the basis of their self-reported state of hunger allowed a stronger and more direct test of our hypotheses. Previous studies have primarily examined the effect of the experimental manipulation, namely fasting instructions, on processing effects (e.g. Lavy and van den Hout, 1993). Reliance on fasting manipulations as a primary index of subjects’ motivational state may contribute to inconclusive findings regarding hunger-related cognitive biases.

The present results also have implications for research into cognition, emotion and psychopathology. First, they indicate that attentional biases are not specific to emotional states, such
as anxiety, but are found in at least one other biologically-oriented motivational state (i.e. hunger). However, it remains uncertain whether such attentional biases are a feature of all biologically-oriented drive states (such as hunger, fear and thirst), or whether they are associated with more general motivational states (e.g. related to interests or hobbies). As discussed earlier, studies using the modified Stroop colour-naming task have suggested processing biases for hobby-relevant information (e.g. Dalgleish, 1995), although such findings do not provide direct evidence of attentional biases because colour-naming interference effects may arise from other cognitive mechanisms (e.g. MacLeod, 1991). Thus, the generality of motivational effects on selective attention remains uncertain.

Second, the present results are relevant to investigations of processing biases in eating disorders. For example, several studies have demonstrated selective interference in colour-naming food- and eating-relevant words in individuals with anorexia and bulimia nervosa, in comparison with control subjects (e.g. Channon et al., 1988; Cooper et al., 1992; Green et al., 1994). While this interference has been typically interpreted as being due to the presence of an eating disorder, it would seem helpful for future research to examine to what extent differences in hunger may contribute to differences in processing biases between eating-disordered and control subjects.

Third, we failed to find evidence of a pre-attentive bias for hunger-relevant information. On the other hand, there is evidence, from tasks similar to the one used here, suggesting a bias in pre-attentive processes in non-clinical and clinical anxiety (e.g. Bradley et al., 1997; Mathews et al., 1996; Mogg et al., 1995). For example, in the latter study, anxious subjects were relatively faster to detect probes that occurred in the same spatial location of subthreshold threat words than controls. These results might be taken to suggest that a bias in pre-attentive processes may be a specific feature of anxiety, and not of other non-emotional motivational states, such as hunger. However, such an interpretation would seem premature, as there may be several other explanations for the failure to demonstrate a hunger-related bias in the subthreshold exposure condition. For example, the stimuli may have not been sufficiently salient—perhaps pictures of food would be better in provoking a hunger-related bias in pre-attentive processes, as they would be more naturalistic and relevant to the subject’s motivational state than stimulus words. Also, in the present study, the masking conditions may have been too effective in restricting subject’s awareness of the word stimuli (the mask duration was longer than that used in Mogg et al., 1995), so that the stimuli may have been too far below subjects’ awareness thresholds to elicit pre-attentive effects. However, one argument against this interpretation is that Bradley et al. (1997) found evidence of a pre-attentive bias for masked negative words associated with high trait anxiety in a non-clinical sample, using the same exposure conditions as those used here (i.e. 14 msec word pair + 186 msec mask).

It is also of interest to note that the awareness check results are consistent with other non-clinical studies (e.g. Bradley et al., 1997; Mogg et al., 1994); i.e. lexical judgments were at chance level, while presence/absence discriminations tended to be above chance. This apparent discrepancy may be easily explained as subjects commonly report that the combined display of word pair and mask seemed brighter or flickered slightly, compared with the mask alone. That is, subjects may detect the physical presence of word stimuli (in terms of brightness judgments) without any awareness of their lexical content. This pattern of results confirms the findings of Dagenbach et al. (1989) that objective awareness thresholds vary according to the type of judgment
required. It also cautions against a simple unitary concept of awareness (i.e. under restricted viewing conditions, an individual may be aware of some stimulus features, but not others) and highlights the usefulness of including more than one awareness check. Previous studies examining the effects of hunger on pre-conscious processing of food-related stimuli have yielded rather inconclusive findings (e.g. review by Dixon, 1981), partly because such studies have not typically included systematic objective measures of awareness thresholds (Holender, 1986). Thus, it remains uncertain whether or not hunger is associated with selective processing of food-relevant stimuli outside awareness.

In conclusion, motivational states, such as hunger and anxiety, appear to play an important role in determining the allocation of selective attention to environmental stimuli. An anxiety-related attentional bias for threat would seem helpful in detecting potential threat cues in the environment, in order to take appropriate action, such as behavioural avoidance. Similarly, a hunger-related bias in selective attention for food-relevant stimuli would seem to have obvious adaptive value, in helping a food-deprived individual locate and acquire food. The present study provides further experimental evidence illustrating the link between motivational and cognitive processes.

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References


