Investigating subtypes of reward processing deficits as trait markers for depression

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Investigating subtypes of reward processing deficits as trait markers for depression

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Background: Anhedonia, the loss of pleasure in usually enjoyable activities, is a central feature of major depressive disorder (MDD). The aim of the present study was to examine whether young people at a familial risk of depression display signs of anticipatory, motivational or consummatory anhedonia, which would indicate that these deficits may be trait markers for MDD.

Methods: The study was completed by 22 participants with a family history of depression (FH+) and 21 controls (HC). Anticipatory anhedonia was assessed by asking participants to rate their anticipated liking of pleasant and unpleasant foods which they imagined tasting when cued with images of the foods. Motivational anhedonia was measured by requiring participants to perform key presses to obtain pleasant chocolate taste rewards or to avoid unpleasant apple tastes. Additionally, physical consummatory anhedonia was examined by instructing participants to rate the pleasantness of the acquired tastes. Moreover, social consummatory anhedonia was investigated by asking participants to make preference-based choices between neutral facial expressions, genuine smiles, and polite smiles.

Results: It was found that the FH+ group's anticipated liking of unpleasant foods was significantly lower than that of the control group. By contrast, no group differences in the pleasantness ratings of the actually experienced tastes or in the amount of performed key presses were observed. However, controls preferred genuine smiles over neutral expressions more often than they preferred polite smiles over neutral expressions, while this pattern was not seen in the FH+ group.

Conclusion: These findings suggest that FH+ individuals demonstrate an altered anticipatory response to negative stimuli and show signs of social consummatory anhedonia, which may be trait markers for depression.

Keywords: *reward*; *aversion*; *behaviour*; *consummatory anhedonia*; *motivational anhedonia*; *social anhedonia*; *anticipatory anhedonia*; *trait marker*; *food*; *depression*

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Major depressive disorder (MDD) affects about 7% of the population in a given year (1) and is projected to be the second biggest cause of disability by 2020 (2). A particularly pressing problem is that even after changing medications several times, over 30% of patients continue to be depressed (3). It is, therefore, necessary to gain a better understanding of the aetiology of MDD to be able to develop more effective treatments.

One approach to elucidating the causal factors implicated in depression is to identify trait markers. Trait markers are behavioural or biological abnormalities, which may play a causal role in the development of a disorder and are present before illness onset in people who are at risk for the disorder (4). As approximately 40% of individuals with a parent with MDD will develop the disorder themselves (5), having a family history of depression is a risk factor for MDD. Therefore, identifying trait markers for depression in people with a parent with MDD, as the experiments conducted as part of the present study aimed to do, is the first step towards gaining a better insight into the mechanisms underlying the disorder's development.

An aspect of subjective experience that has been suggested as a possible trait marker for depression is anhedonia (6). Anhedonia is the loss of interest in activities that were previously experienced as enjoyable and is one of the two core DSM-V diagnostic criteria of MDD (7). An obstacle to examining anhedonia is that current self-report measures are not very well suited to detect non-pathological individual differences in anhedonia tendencies. It has been argued that this may partly be the case because current measures fail to differentiate between anhedonia subtypes. For example, a distinction can be drawn between consummatory,

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motivational, and anticipatory anhedonia. Consummatory anhedonia is marked by a decreased enjoyment of currently experienced pleasant events, while motivational anhedonia is characterised by a diminished willingness to exert effort to obtain rewarding stimuli (8). Moreover, anticipatory anhedonia is a decreased expected or experienced enjoyment when imagining or looking forward to something pleasant. This differentiation highlights that anticipation, consummatory hedonic experience and motivation are distinct but related constructs: A stimulus elicits anticipation if it has been repeatedly associated with a rewarding experience and was attributed with incentive salience. The stimulus' incentive salience, in turn, enhances attention and goal-directed behaviour towards the stimulus (9). It is, therefore, interesting to investigate anticipatory, consummatory, and motivational anhedonia separately but within the same population.

Evidence from previous studies for an association between these anhedonia subtypes and depression is inconsistent. While animal studies suggest that motivational but not consummatory anhedonia may be a feature of MDD (10–12), human studies have found evidence for both motivational (13) and consummatory (14–18) deficits in depressed and 'at risk' participants. However, other experiments have failed to find consummatory reward processing abnormalities in MDD patients (19–21).

Animal studies have shown that alterations of dopamine (DA) function can result in a selective impairment or enhancement of motivation, as demonstrated by the animals' willingness to exert effort to gain food rewards, without affecting consummatory responses, as indicated by the animals' orofacial expressions during food intake (10–12). Decreased DA function found in individuals with and at risk for depression (22–24) may, therefore, be associated with impairments in motivation without diminishing consummatory responses. However, abnormal functioning of other systems, such as the opioid system, could additionally lead to decreased consummatory pleasure.

Previous behavioural studies in humans have indeed observed motivational deficits in MDD patients. For example, Treadway and colleagues (13) gave MDD patient and healthy controls a choice between performing a greater number of key presses for a higher monetary reward and performing a smaller number of key presses for a lower monetary reward on trials with different probabilities of winning. They found that MDD patients were significantly less likely than controls to choose the more difficult task with the higher reward (13). This result can be interpreted as demonstrating that depressed individuals are less motivated to exert effort to obtain rewards (or less able to integrate reward information during decision making).

However, regarding the presence of consummatory reward processing deficits in depression human behavioural studies have yielded inconsistent results. Some studies have found that MDD patients demonstrate decreased pleasantness ratings for positive pictures (17, 18) and comedy film clips (15). Yet, other studies observed no differences between depressed and control participants' hedonic responses to sweet tastes (19), imagined happy situations (20), or amusing film clips (21).

Furthermore, there is some evidence for an association between MDD tendencies and anticipatory anhedonia, as it has been found that higher depression scores predict lower levels of anticipation of chocolate rewards (25).

The current study aimed to further elucidate which anhedonia subtypes are associated with depression risk by measuring consummatory, anticipatory, and motivational anhedonia within the same sample. Young people at a familial risk for depression (FH+) were recruited to assess whether the different anhedonia subtypes may be trait rather than state markers for MDD.

Consummatory anhedonia was assessed by asking participants to rate the pleasantness of pleasant and unpleasant tastes. Moreover, anticipatory anhedonia was measured by instructing participants to rate their anticipated liking of pleasant, unpleasant and neutral foods, which they imagined tasting when cued by pictures depicting the foods.

It was predicted that at risk participants' anticipatory and consummatory ratings of the pleasant stimuli would be less positive than those of controls. Moreover, FH+ individuals' ratings of unpleasant stimuli were expected to be more negative than those of HC participants, because enhanced negative experience of unpleasant stimuli may be the phenomenological correlate of increased neural processing of negative stimuli which has previously been observed in individuals at risk for depression (14, 15). Additionally, the finding of more negative ratings of unpleasant stimuli by FH+ individuals compared to controls would be in line with the observation of negative attention (26, 27) and memory (28, 29) biases in depressed patients.

The current study also assessed motivational anhedonia. For this purpose an effort task was designed in which participants were asked to perform key presses to either obtain a rewarding chocolate taste or to avoid an aversive apple taste. Unlike the task created by Treadway and colleagues (13), our task did not require participants to make a choice but merely measured their willingness to perform key presses for the taste reward. We hypothesised that FH+ participants would perform fewer key presses than controls and thus display motivational anhedonia.

Additionally, another subtype of consummatory anhedonia was examined by the present study, namely social anhedonia, which is the diminished enjoyment of interacting with other people. Most previous research on social anhedonia has been conducted with individuals suffering from schizophrenia; however, there is some evidence that social anhedonia may be associated with depression symptoms. For example, Blanchard et al. (30) found that 29.1% of individuals with high Revised Social Anhedonia Scale scores (SocAnh) (31) had a lifetime history of

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depression, while only 9% of individuals with low SocAnh scores reported lifetime MDD episodes. Moreover, Kwapil (32) showed that individuals who scored at least 1.96 SDs above the sample mean on the SocAnh scale exhibited more severe depressive symptoms than participants with lower SocAnh scores.

In addition, it has been found that brain regions associated with reward processing, such as the caudate nucleus and putamen, are less active in response to smiling faces in depressed individuals than in controls (33). Therefore, MDD patients seem to have deficits in the processing of the rewarding aspect of social cues such as smiles, which may be associated with social anhedonia on the experiential level.

The present study investigated whether social anhedonia is a trait marker for depression by presenting FH+ and HC participants with pairs of faces displaying a neutral expression, a genuine smile, or a polite smile, and asking them to choose the expression they preferred. It has previously been shown that healthy individuals perceive genuine smiles, which express spontaneously experienced enjoyment, as more rewarding than polite smiles, which are posed (34). By contrast, based on the above-mentioned findings, it may be predicted that FH+ participants are not as sensitive to the rewarding aspects of genuine smiles and may thus have a less pronounced preference of the latter than controls. Therefore, we hypothesised that in the pairing of genuine and polite smiles, HC participants would prefer the genuine smile over the polite smile more often than FH+ participants would. The confirmation of this prediction would suggest that FH+ participants may demonstrate a diminished ability to detect positive social feedback such as genuine smiles, thus displaying signs of social anhedonia, which may, therefore, be a trait marker for depression.

Methods

Participants

The current study was completed by 43 female participants ($N_{HC} = 21$, $N_{FH+} = 22$; age range: 18–25 years; $M_{age} = 19.90$ years). Participants were recruited using flyers, as well as via the online research management system SONA. In exchange for their participation, which took about 2 h, subjects received 2.5 course credits or £20.

The study was conducted in accordance with the Declaration of Helsinki (2008). Ethical approval was obtained from the University of Reading Research Ethics Committee, and all subjects provided written informed consent before their participation.

Potential participants were screened using a structured clinical interview for DSM-IV (SCID), and subjects were excluded if they had a personal current or past history of any Axis 1 disorder, or a family history of bipolar disorder or schizophrenia. For the FH+ group, the parental history of depression was confirmed using the family history method with the participant as an informant (35).

Experimental procedure

Participants were emailed a link to several online questionnaires, which assessed their depression tendencies (BDI, Beck Depression Inventory) (36); anhedonia tendencies [RSAS, Revised Social Anhedonia Scale (31); FCPS, Fawcett–Clark Pleasure Scale (37); SHAPS, Snaith–Hamilton Pleasure Scale (38); TEPS, Temporal Experience of Pleasure Scale (39)] and eating attitudes (EAT, Eating Attitude Test) (40). Before the testing session, participants filled in the Befindlichkeits Scale (BFS) (41) as a measure of their current mood and the participants' body mass index (BMI) was calculated. Subsequently, subjects performed the three computer-based tasks described below which had been designed using E-Prime 2 Pro 2.0.10.353. The tasks were presented in a fixed order, starting with the anticipatory task, followed by the social stimulus preference task, and concluding with the effort task, because there was a concern that the food consumption in the effort task may otherwise have influenced participants' anticipated liking of the foods in the anticipatory task.

Anticipatory task procedure

At the beginning of the task, participants were informed that they were going to see pleasant, unpleasant and neutral food pictures. They were instructed to imagine the feel and taste of each of the foods in their mouth and to rate how much they liked the food. Since these ratings were based on the anticipated rather than the actually experienced hedonic response to the depicted foods, they were assumed to provide a measure of anticipatory liking.

No standardised scale was provided for the rating, and participants were encouraged to use *any* numbers whatsoever which they felt best represented their anticipated liking of the depicted foods and to type this number in the provided box. A self-chosen scale was used instead of a standardised one in order to address the issue that on standardised scales the highest and lowest points are fixed. This makes it difficult to detect group differences, because it is likely that participants equate the maximum value of the scale with the highest level of pleasure *they* can experience.

After having provided ratings for three practice pictures, participants were presented with pictures of 15 pleasant, 15 neutral, and 15 unpleasant foods, the valence of which had been confirmed in a pilot study. Each picture was shown twice in a random order and remained on the screen until the participants had entered their response. The participants' ratings were recorded.

Effort task procedure

The effort task began with two practice trials followed by 40 experimental trials, which consisted of 10 randomised

repetitions of four conditions: easy and difficult chocolate reward trials and easy and difficult aversive apple trials.

At the beginning of each trial, participants were presented with an image (5 s) to indicate if they were on a pleasant or aversive trial. On the pleasant trials, participants were shown a chocolate picture which meant that if they pressed a computer key enough times within a certain time period they would receive 0.5 ml of chocolate taste reward (chocolate milk). The easy chocolate trials gave participants more time (8 s) and required them to perform fewer key presses (55) to receive the reward than the difficult chocolate trials (5 s; 73 key presses), everything else remained the same. The chocolate taste used in the current study was rated as pleasant and wanted in previous studies from our lab (14, 15).

On aversive trials, participants were presented with a picture of mouldy apples, which indicated that if they did *not* press the computer key enough times within a certain time frame they would receive 0.5 ml of an unpleasant apple taste (1:5 ratio of distilled vinegar to apple concentrate). The easy apple trials gave participants more time (8 s) and required them to perform fewer key presses (55) to avoid the aversive taste than the difficult apple trials (5 s; 73 key presses), everything else remained the same. The apple taste used in the present study was confirmed to be unpleasant in a pilot study.

Difficult trials were introduced to ensure that on some trials participants did not receive the chocolate taste or could not avoid the unpleasant apple taste, which was assumed to sustain participants' motivation. If participates did not acquire the chocolate taste on the pleasant trials or if they managed to avoid the apple taste on the aversive trials, they received 0.5 ml of water. The tastes were delivered by the experimenter, who squirted the liquids into the participants' mouths through a one-way syringe which was connected to bottles of the solutions via Teflon tubes. Which taste was to be administered after a given trial was indicated by the E-Prime programme.

Immediately after having received the tastes, participants were instructed to rate the pleasantness of the tastes from 0 to 10 on a Likert scale (5 s). Once participants had provided their ratings, they received 0.5 ml of water to cleanse their mouths and the next trial began. The number of key presses performed in each trial and the pleasantness ratings were recorded.

Social stimulus preference task procedure

The task consisted of three practice trials and 150 experimental trials. In each trial, participants were presented with two pictures, side by side, depicting the same individual displaying two different facial expressions. Each individual had been photographed while assuming the following three expressions: genuine smile (G), polite smile (P), and neutral expression (N). Thus, there were three possible pairings, namely G–P (condition 1), P–N (condition 2), and G–N (condition 3). Half of the 150 pairings were presented in the above order and half in the reverse order, i.e. P–G, N–P, and N–G. Each picture pair remained on the screen for 500 ms. Subsequently, instructions occurred on the screen asking participants to press the '1' key if they preferred the picture on the left or to press the '2' key if they preferred the picture on the right. Once the participants had entered their response, the next trial began. Participants' preference responses and reaction times (RTs) were recorded.

The images used in the task were acquired by taking photographs of volunteers in Reading town centre in front of a neutral background, and pictures of an equal number of female and male volunteers across different ethnicities and age groups were acquired. All volunteers gave their verbal consent for the use of their images in the present study. Volunteers were instructed to smile politely as if they had just been introduced to someone they had never met before, and subsequently to assume a neutral expression. Moreover, an emotion induction procedure (42) was used to elicit genuine smiles: volunteers were asked to recall an experience that had amused them or made them happy, which enabled them to express a spontaneous genuine smile. Pictures of a genuine smile, a polite smile, and a neutral expression were acquired from 50 volunteers, resulting in a total of 150 colour images.

Data analysis

The computer task results were extracted from the E-Prime files using MatLab 2014b and analysed with SPSS 22. Before the data analysis, it was assessed whether the data violated normality, homogeneity of variance, or sphericity assumptions. Unless otherwise specified, these assumptions were met.

As most of the questionnaire and demographics data were not normally distributed, possible group differences were examined using independent-samples Mann–Whitney *U*-tests, and potential correlations between questionnaire scores and task performance measures were assessed with Spearman's rho.

For the anticipatory task, the minimal and maximal value used by each participant during the task was determined, and a comparison of the magnitude of these values between the FH+ and HC groups was conducted using a Mann–Whitney *U*-test. As no group differences were found for the utilised minimum or maximum values, all ratings were converted into percent scores. Mann–Whitney *U*-tests and independent-samples *t*-tests were then conducted with these percent scores to assess group differences in the anticipatory ratings.

Similarly, Mann–Whitney *U*-tests and independent-samples *t*-tests were used to analyse group differences in the consummatory taste ratings and in the amount of key presses performed during the effort task.

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Moreover, two-way mixed analyses of variance (ANOVA) and Bonferroni-corrected *post hoc* tests were performed to assess group differences in the social stimulus preference task.

Results

Demographic and questionnaire data

None of the demographic or questionnaire measures, besides the TEPS (both subscales), were normally distributed, which is why Mann–Whitney *U*-tests were performed to analyse group differences of these measures (while independent-samples *t*-tests were utilised to analyse TEPS scores). It was found that there were no significant differences between individuals with a family history of depression (FH+) and controls (HC) in either the demographic variables of age and BMI, or on any of the questionnaire measures of mood (BDI; BFS), anhedonia (either subscale of the TEPS, FCPS; SHAPS; RSAS) or eating attitude (EAT; see Table 1).

Pleasant and unpleasant food stimulus ratings

Anticipatory ratings

Mann–Whitney *U*-tests were performed because the data were not normally distributed. As expected, it was found that FH+ participants' anticipated liking of unpleasant foods ($M_{\text{rating rank}} = 16.45$) was significantly lower than that of HC participants ($M_{\text{rating rank}} = 25.44$, $U = 109.00$, $z = -2.42$, $p = 0.015$; see Fig. 1). However, there was no group differences (FH+ $M_{\text{rating rank}} = 20.70$; HC $M_{\text{rating rank}} = 20.25$) in the anticipated liking of pleasant foods ($U = 202.50$, $z = 0.12$, $p = 0.904$).

Consummatory ratings

The ratings for each taste were combined across easy and difficult trials, and an independent-samples *t*-test was performed for the normally distributed apple taste ratings, while a Mann–Whitney *U*-test was conducted for the non-normally distributed chocolate taste ratings. The analyses revealed that there were no differences between FH+ ($M_{\text{apple rating}} = 2.87$) and HC ($M_{\text{apple rating}} = 3.55$) participants in their pleasantness ratings of the unpleasant apple taste, $t(19.76) = -1.05$, $p = 0.309$ (equal variance not assumed). Moreover, no group differences in the ratings of the pleasant chocolate taste (FH+ $M_{\text{chocolate rating rank}} = 14.07$; HC $M_{\text{chocolate rating rank}} = 16.85$) were found ($U = 93.00$, $z = -0.73$, $p = 0.483$).

Additionally, a paired-samples *t*-test demonstrated that the chocolate taste ($M = 7.09$) was rated significantly higher than the apple taste ($M = 3.36$) in the combined data of both groups ($t(18) = 6.45$, $p < 0.001$), confirming that the former taste was experienced as more pleasant than the latter.

Effort task performance

The data of the performance on easy chocolate trials and on easy and difficult apple trials were not normally distributed, which is why Mann–Whitney *U*-tests were used to analyse group differences in these conditions. There were no group differences in the performance on either the easy chocolate ($M_{\text{HC}} = 53.80$ kp, $M_{\text{FH+}} = 52.20$ kp; $U = 188.50$, $z = -1.03$, $p = 0.302$), the easy apple ($M_{\text{HC}} = 55.23$ kp, $M_{\text{FH+}} = 54.63$ kp; $U = 203.00$, $z = -0.68$, $p = 0.496$), or the difficult apple condition ($M_{\text{HC}} = 77.40$ kp, $M_{\text{FH+}} = 74.83$ kp; $U = 195.50$, $z = -0.86$, $p = 0.388$). Moreover, an independent-samples *t*-test, used due to normally distributed data, did not reveal any group differences in the performance on difficult chocolate trials either ($M_{\text{HC}} = 76.15$ key presses (kp), $M_{\text{FH+}} = 74.82$ kp; $t(41) = 0.61$, $p = 0.546$).

Additionally, the average number of key presses performed during all apple trials, all chocolate trials,

Table 1. Descriptive statistics of demographic variables

	Mean		Standard deviation		
	HC (N = 21)	FH+ (N = 22)	HC	FH+	*p*-value of group difference
Age (years)	19.74	20.05	1.85	1.32	0.141
BMI	22.21	21.94	4.04	2.46	0.986
BDI	6.16	5.15	7.17	5.05	0.771
BFS	6.00	6.05	7.29	7.51	0.677
TEPS – ant.	48.70	50.95	6.48	5.74	0.253
TEPS – cons.	35.40	38.25	5.25	6.03	0.119
FCPS	143.16	148.75	14.38	15.51	0.224
SHAPS	2.40	2.63	4.19	4.54	0.749
RSAS	5.07	5.52	4.23	4.47	0.654
EAT	9.60	5.74	7.54	6.22	0.084

BMI, body mass index; BDI, Beck Depression Inventory; BFS, Befindlichkeits Scale; TEPS, Temporal Experience of Pleasure Scale (ant., anticipatory; cons., consummatory); FCPS, Fawcett–Clark Pleasure Scale; SHAPS, Snaith–Hamilton Pleasure Scale; RSAS, Revised Social Anhedonia Scale; EAT, Eating Attitudes questionnaire; HC, healthy controls; FH+, individuals with a family history of depression.

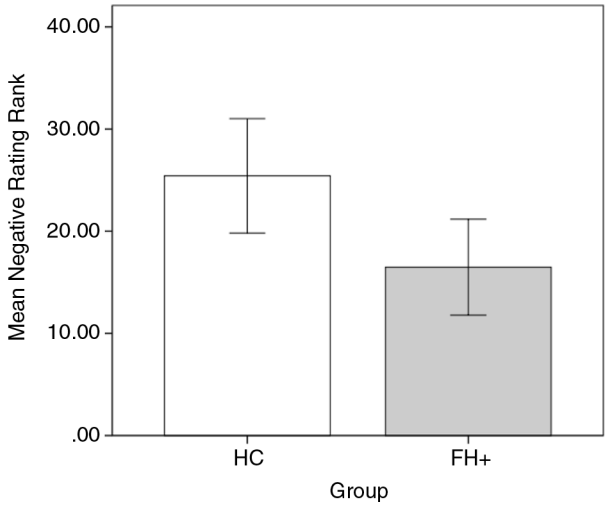

Fig. 1. Mean ranks of anticipatory liking ratings of unpleasant foods for HC and FH+ participants.

and all trials independent of the condition was calculated for each participant and group differences were assessed using Mann–Whitney *U*-tests. It was found that HC ($M_{chocolate} = 64.97$ kp, $M_{apple} = 66.32$ kp) and FH+ ($M_{chocolate} = 63.51$ kp, $M_{apple} = 64.73$ kp) participants did not differ significantly in the amount of key presses they performed overall on chocolate ($U = 199.00$, $z = -0.78$, $p = 0.437$) or apple ($U = 188.00$, $z = -1.05$, $p = 0.296$) trials. Moreover, there were no group differences in the overall effort task performance independent of condition ($M_{HC} = 65.64$ kp, $M_{FH+} = 64.11$ kp; $U = 184.50$, $z = -1.13$, $p = 0.259$).

Social stimulus preferences

A two-way mixed ANOVA (preference in three picture pairing conditions × two groups) revealed a significant condition × group interaction ($F(2,72) = 8.90$, $p < 0.001$). Moreover, while no main effect of group was observed, $F(1,36) = 0.12$, $p = 0.728$, a main effect of the factor condition (polite smile vs. genuine smile, polite smile vs. neutral expression, or genuine smile vs. neutral expression) was found ($F(2,72) = 10.81$, $p < 0.001$).

Bonferroni-corrected *post hoc* tests were conducted separately for the two groups. It was shown that for the HC group the percentage of times that genuine smiles were preferred over polite smiles (the expected choice in condition 1, $M_{expected\ choice\ (ec)} = 70.47\%$) did not differ significantly from the percentage of times that polite smiles were preferred over neutral expressions (the expected choice in condition 2, $M_{ec} = 62.98\%$), $p = 0.092$. However, the percentage of times genuine smiles were preferred over neutral expressions (the expected choice in condition 3, $M_{ec} = 77.97\%$) was higher than both the percentage of the expected choices in condition 1 ($p = 0.001$) and in condition 2 ($p = 0.001$). For the FH+ group, by contrast, the percentage of expected choices differed neither between conditions 1 ($M_{ec} = 70.87\%$) and 2 ($M_{ec} = 72.55\%$; $p = 1.00$), nor between conditions 1 and 3 ($M_{ec} = 73.30\%$; $p = 1.000$) or between conditions 2 and 3 ($p = 1.000$; see Table 2).

An independent-samples *t*-test of the mean difference of expected choices between the conditions (conditions 3–2 and 3–1) revealed that for HC participants, the mean difference between the percentage of expected choices in condition 3 compared to condition 2 ($M_{difference} = 14.99\%$) was significantly higher than for FH+ participants ($M_{difference} = 0.75\%$; $t(24.20) = 3.74$, $p = 0.001$; equal variance not assumed; see Fig. 2).

Another two-way mixed ANOVA was performed for the reaction times (RTs) of the choices in each condition (RTs in three picture pairing conditions × two groups). As Mauchly's test of sphericity was significant ($p < 0.001$), the Greenhouse-Geisser corrected results are reported below. The analysis revealed a significant condition × group interaction, $F(1.30,46.61) = 8.87$, $p = 0.002$. Furthermore, while there were no RT differences between the groups, $F(1,36) = 1.21$, $p = 0.280$, RTs did differ significantly between conditions, $F(1.30,46.61) = 5.64$, $p = 0.015$.

Bonferroni-corrected *post hoc* tests were conducted separately for the two groups. It was revealed that HC participants' RTs differed neither between conditions 1 ($M_{RT} = 612.71$ ms) and 2 ($M_{RT} = 641.39$ ms; $p = 1.00$), nor between conditions 1 and 3 ($M_{RT} = 620.43$ ms; $p = 1.00$) or between conditions 2 and 3 ($p = 1.000$). FH+ participants, on the other hand, showed slower RTs in condition 1 ($M_{RT} = 828.88$ ms) than in condition 2 ($M_{RT} = 626.70$ ms; $p = 0.007$) and condition 3 ($M_{RT} = 664.25$ ms; $p = 0.002$). There was no significant difference in RTs between conditions 2 and 3 ($p = 0.388$).

A Mann–Whitney *U*-test, which was used due to non-normally distributed data, found that the mean difference

Table 2. Preference of the different facial expressions in conditions 1–3 for HC and FH+ participants

	Condition 1: preference of genuine smiles over polite smiles (%)	Condition 2: preference of genuine smiles over neutral expressions (%)	Condition 3: preference of polite smiles over neutral expressions (%)
HC	70.47[a]	77.97[a,b]	62.98[b]
FH+	70.87	72.55	73.30

[a,b]Significant difference at the 0.05 level (two-tailed).
HC, healthy controls; FH+, individuals with a family history of depression.

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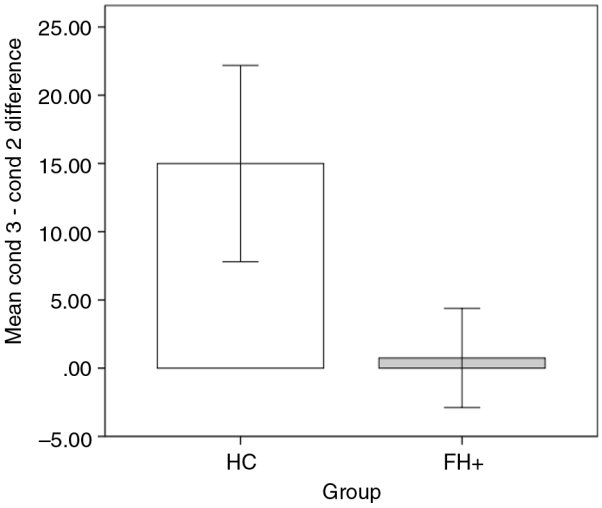

Fig. 2. Mean difference between the percent of expected choices made in condition 3 (genuine smiles over neutral expressions) and in condition 2 (polite smiles over neutral expressions) by HC and FH+ participants.

of RTs between the conditions was significantly lower for HC ($M_{cond1–2} = -28.68$ ms; $M_{cond1–3} = -7.71$ ms) than for FH+ participants ($M_{cond1–2} = 202.18$ ms; $M_{cond1–3} = 164.63$ ms; condition 1–2: $p = 0.003$; condition 1–3: $p = 0.006$; see Fig. 3).

Correlations between task measures and questionnaires

To investigate whether there were any associations between questionnaire scores and task measures, correlations were calculated separately for the FH+ and HC groups. Due to the fact that many of the questionnaire and task measures were not normally distributed, Spearman's rank-order correlation was used for this purpose. Moreover, correlations with the TEPS were analysed separately for the two TEPS subscales, one of which measures consummatory anhedonia, whereas the other assesses anticipatory anhedonia.

Interestingly, when all participants were included in the analysis, the BDI scores were significantly negatively correlated with the scores of the anticipatory subscale of the TEPS ($r_s(39) = -0.49$, $p = 0.002$), whereas there was no significant correlation between the BDI scores and the scores on the consummatory TEPS subscale ($r_s(39) = -0.12$, $p = 0.452$). Conducting separate correlations for the two groups revealed that the significant overall correlation was driven by the FH+ group: for FH+ participants, the BDI scores were significantly negatively correlated with the scores on the anticipatory subscale of the TEPS ($r_s(20) = -0.64$, $p = 0.003$). By contrast, there was no significant correlation between the BDI scores and the consummatory subscale TEPS scores ($r_s(20) = -0.06$, $p = 0.793$). For the HC group, by contrast, neither the anticipatory ($r_s(19) = -0.35$, $p = 0.146$) nor the consummatory ($r_s(19) = -0.14$, $p = 0.563$) TEPS subscale scores were significantly correlated with the BDI scores (see Fig. 4).

Moreover, in an analysis including all participants, the BDI scores were significantly negatively correlated with the percent of expected choices in conditions 1–3 of the social reward task. Separate analyses for the two groups revealed that this result was driven by the FH+ group, for which a significant negative correlation between BDI scores and condition 2 and 3 choices was observed (see Table 3).

Discussion

The aim of the current study was to examine the consummatory, anticipatory, and motivational responses to rewarding and aversive stimuli in young people with a family history of depression (FH+) to identify potential trait markers for MDD.

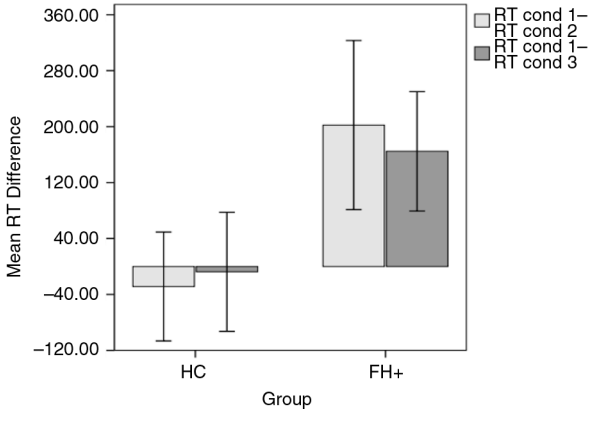

Fig. 3. Mean reaction time (RT) differences of responses in condition 1 (genuine vs. polite smile) compared to condition 2 (polite smile vs. neutral expression) and condition 3 (genuine smile vs. neutral expression) for HC and FH+ participants.

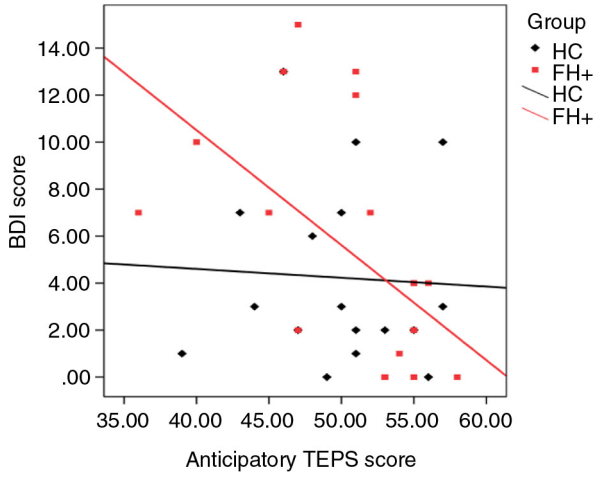

Fig. 4. Correlations between Beck Depression Inventory (BDI) Scores and anticipatory Temporal Experience of Pleasure Scale (TEPS) scores for FH+ and HC participants.

Table 3. Spearman's rho (r_s) for the correlation analysis of BDI scores and social preference task measures

	BDI score	
Social preference task	FH+	HC
Percent of expected choices (genuine over polite smiles) in condition 1	−0.363	−0.348
Percent of expected choices (polite smiles over neutral expressions) in condition 2	−0.520[a]	−0.296
Percent of expected choices (genuine smiles over neutral expressions) in condition 3	−0.544[a]	−0.413

[a]Correlation is significant at the 0.05 level (two-tailed).
BDI, Beck Depression Inventory; HC, healthy controls; FH+, individuals with a family history of depression.

Negative information processing

The present study found that FH+ individuals' anticipated liking of unpleasant foods was significantly lower than that of control participants (HC). This observation is consistent with previous studies reporting negative biases in MDD patients. For example, depressed individuals have been found to recall negative events more quickly than positive occasions (29), to recall negative words better than positive ones (28), to exhibit an attentional bias towards sad faces in dot probe paradigms (26), and to show greater intrusion effects from negative words when compared with controls (27). Our results indicate that even before disorder onset, there might be an increase in negative information processing in those at risk for MDD, suggesting that enhanced responses to negative stimuli may be trait markers for depression.

However, it is interesting to note that we did not find any group differences in the ratings of the actual experience of the unpleasant taste. Thus, it may be the case that compared to controls, FH+ participants *anticipate* aversive stimuli to be worse, while both groups *experience* the unpleasant stimuli in a similar manner. This is interesting in that it suggests that there may be no trait differences in the sensory components of aversion processing but rather only in the hedonic aspects of the anticipation of unpleasant tastes.

Alternatively, the finding that group differences were observed for anticipatory but not for consummatory ratings of unpleasant stimuli may have been due to the fact that the consumed tastes were rated on a standardised scale, which may have been less sensitive than the self-chosen scale on which the anticipatory ratings were made.

Consummatory and anticipatory anhedonia

There were no group differences in either the anticipated liking of the pleasant foods or the pleasantness ratings of the actually experienced pleasant tastes, and thus no indication that FH+ individuals experience consummatory or anticipatory anhedonia. This finding is in line with previous studies which reported no group differences between depressed and control participants in hedonic responses to sweet tastes (19), imagined happy situations (20), or amusing film clips (21).

However, some evidence for a relationship between depression symptoms and an anticipatory deficit was seen in the questionnaire data of FH+ individuals. Specifically, there was a significant negative correlation between BDI scores and anticipatory TEPS scores for the FH+ group. Interestingly, this correlation was not present in the HC group, nor was there a correlation between BDI scores and consummatory TEPS scores for either group. This finding suggests a relationship between depression risk and anticipatory anhedonia.

A possible reason why this relationship was not detected by our anticipatory task is that the TEPS and our task examine different aspects of anticipation: while the TEPS assesses the pleasure taken in looking forward to something, our task measures the pleasure expected to be derived from an imagined stimulus.

Moreover, regarding the consummatory anhedonia measure it should be noted that the standardised scale utilised to measure the pleasantness of the consumed taste stimuli may not have been sensitive enough to detect subtle group differences. The fact that the current study found significant group differences for the anticipatory ratings indicates that a self-chosen rating scale seems be a sensitive measure of subjective experience. Thus, future studies might benefit from combining the self-chosen scale with a task in which participants have an actual reward/taste experience.

Motivational anhedonia

The current study found no group differences in the effort exerted on either easy or difficult chocolate reward or aversive apple taste trials, and thus observed no group differences in motivation.

A possible explanation of why we did not find a significant group difference in the effort task performance is that our task may not have been sensitive enough. We found that the mean number of key presses performed on the easy and difficult trials lay around the number of key presses that were required to avoid the aversive taste or to gain the chocolate reward, and some participants managed to obtain the desired taste on every trial. Thus, there may have been a ceiling effect and participants may not have exerted any effort beyond that necessary to gain the reward or to avoid the aversive taste. Future studies could

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address this limitation by increasing the task difficulty and by making the volume rather than the presence or absence of the pleasant and unpleasant liquids dependent on the performance. It would also be beneficial to alter the task in such a way that it takes individual differences in motor ability and dexterity into account.

Social consummatory anhedonia

In the present study, HC participants had a higher preference of genuine smiles over neutral expressions than of polite smiles over neutral expressions. FH+ individuals' preferences, by contrast, did not differ between the two pairings, as they preferred the two smile types over neutral expressions to a similar degree. Thus, it could be suggested that FH+ individuals responded abnormally to rewarding social stimuli.

Interestingly, during preference choices between polite and genuine smiles FH+ individuals took significantly longer to make their decision than HC participants, suggesting that FH+ individuals found the smiles less interesting or the choice more difficult than controls. These findings are in line with a previous study, which similarly observed that happiness recognition was particularly difficult for those at risk of depression due to high levels of neuroticism compared to a non-vulnerable sample (43).

The current study also found an interesting relationship between the responses to social stimuli and BDI scores. Specifically, there was a significant negative correlation between BDI scores of all subjects and the percentage of expected choices in conditions 1–3. This result is consistent with previous observations of an association between social anhedonia and depression symptoms (32, 30).

Taken together, the results from the social stimulus preference task point to an abnormal processing of rewarding social stimuli in FH+ participants, which might be a trait marker for depression. In future studies, it would be interesting to investigate if consummatory anhedonia subtypes, such as physical anhedonia, i.e. the decreased enjoyment of sensory experiences such as eating, and social anhedonia, are dissociable. It has been suggested that in schizophrenia patients physical anhedonia may cause social anhedonia (44). However, the absence of physical anhedonia and the presence of social reward processing deficits observed in the current study in individuals with a familial risk for depression indicate that a different relation between the two consummatory anhedonia types may be present in MDD compared to schizophrenia.

Future research

The fact that anhedonia tendencies are observed in individuals at risk for depression does, of course, not necessarily mean that anhedonia causally contributes to depression onset. One approach to determining whether a certain factor plays a causal role in the development of a disorder is to use a longitudinal study design and to conduct genetic analyses (45). Future studies could apply this approach to the investigation of anhedonia to elucidate how deficits in reward processing might relate to depression development.

Moreover, considering that 25% of the individuals who develop depression do so before the age of 19 years (46), it is possible that our sample, aged 18 and over, was not young enough to fully capture those at risk. Thus, it may be advisable for future studies to investigate anticipatory, consummatory and motivational anhedonia in a younger sample.

Additionally, it may be interesting to assess aspects of parental MDD, such as the onset, duration, and severity of the parent's depression, and to examine if these measures predict participants' anhedonia tendencies.

Conclusion

The findings of the current study revealed that young people at familial risk of depression display differences in the processing of both negative (unpleasant foods) and positive (smiling faces) stimuli compared to low-risk controls. This supports the notion that abnormalities in aversion and reward processing may be trait markers for depression.

Conflict of interest and funding

Dr. McCabe has acted as a consultant to P1Vital, Givaudan, GWpharma, the British Broadcasting Company (BBC), and Channel 4. Anna-Lena Frey, Lucy Malinowska, Katherine Harley, Louisa Salhi, Somya Iqbal, and Sarika Sharma report no biomedical financial interests or potential conflicts of interest. The research was funded by the University of Reading.

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