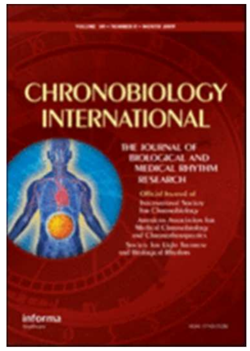

Effect of chronotype on emotional processing and risk taking.

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Effect of chronotype on emotional processing and risk taking.

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Abstract

There is increasing evidence to suggest that late chronotypes are at increased risk for depression. The putative psychological mechanisms underpinning this risk, however, have not been fully explored. The aim of the present study was to examine whether, similar to acutely depressed patients and other 'at risk' groups, late chronotype individuals display biases in tasks assaying emotional face recognition, emotional categorisation, recognition and recall and attention. Late chronotype was associated with increased recognition of sad facial expressions, greater recall and reduced latency to correctly recognise previously presented negative personality trait words and reduced allocation of attentional resources to happy faces. The current results indicate that certain negative biases in emotional processing are present in late chronotypes and may, in part, mediate the vulnerability of these individuals to depression. Prospective studies are needed to establish if the cognitive vulnerabilities reported here predict subsequent depression.

Keywords: Chronotype; Depression; Negative bias; Cognition

Introduction

Morningness-eveningness refers to inter-individual differences in diurnal rhythmicity (Horne & Östberg, 1976). Along this continuum individuals can be classified into three broad circadian typologies (chronotypes): morning types (or larks) who prefer early rise and bed times, late (owls) who prefer to sleep late and go to bed late, and intermediate chronotypes that fall between the two. Although there is significant individual variation in chronotype, social constraints (e.g. school/university/ work schedules) show a much narrower distribution. For example, with few exceptions, the working day begins between 7am and 9am. For many individuals, therefore, a substantial clash exists between their circadian rhythm and external demands. Moreover, there is increasing evidence to suggest that this descynchronisation of circadian rhythms negatively impacts on aspects cognitive function. Typically, participants show improved performance when tested at their chronotype-specific preferred time of day (morning time for an early chronotype) as compared to their suboptimal daytime period [for a review see (Schmidt et al., 2007)]. For example, Lara, Madrid and Carrera (2014) reported impaired executive control (as indexed by performance accuracy in a no-go task and precision strategy in a sustained attention to response task) when participants were tested at a suboptimal time of day according to their circadian profiles (Lara et al., 2014). Similarly, Goldstein and colleagues (2007) reported reduced performance on measures of fluid intelligence in adolescents tested at times that clashed with their diurnal preferences. From a purely research perspective, investigators should take into account individual sleep preferences when administering cognitive tasks given that their study population is likely to include early, late and intermediate chronotypes (Reske et al., 2015). From a socio-economic perspective, students tested at suboptimal times of the day may be at risk of impaired academic performance (Goldstein et al., 2007). Similarly shift workers, or those on fixed work schedules, may be forced to perform demanding tasks and make important decisions at times when their physiology is likely to negatively impact on performance.

In addition to effects on cognition, there is also increasing evidence to suggest that chronotype is involved in the aetiology and pathophysiology of depression. For example, Hidalgo and colleagues (2009) observed a 5-fold increase in the likelihood of reporting moderate to severe depressive symptoms (as assessed by the Montgomery–Äsberg Depression Rating Scale [MADRS] (Hidalgo et al., 2009) in healthy individuals with an evening typology as compared to morning or intermediate types. Similarly, Levandovski *et al.* (2011) reported higher Beck Depression Inventory [BDI] scores in late chronotypes as compared to early and intermediate types in a large population sample free of sleep disorder and psychoactive drug use and homogeneous with respect to cultural, socioeconomic status and light exposure (Levandovski et al., 2011). More recently, Merikanto *et al.* (2013) reported that evening-types were 3.8 times more likely to report depressed mood and anhedonia, four times more likely to report a diagnosis of depression and ~3 times more likely to report use of prescribed antidepressant medication (Merikanto et al., 2013).

While these converging findings (Hidalgo et al., 2009; Levandovski et al., 2011; Merikanto et al., 2013) provide evidence for an association between late chronotype and depression they are essentially observational and do not address the underlying mechanisms that lead to depression in at risk individuals. The primary aim of the present study, therefore, was to explore the cognitive mechanisms of late chronotype that may, if combined with adverse life events or other stressors, precipitate depression.

Cognitive theories of depression posit that negative schemata constrain how emotional information is attended to, processed and recollected (Beck et al., 1979). Numerous studies have demonstrated an association between acute depression and preferential processing of negative information and/or impaired processing of positive emotional information (Bradley et al, 1995; Gilboa-Schechtman et al., 2002; Gur et al., 1992; Peckham et al., 2010; Ridout et al., 2003; Surguladze et al., 2004) which persists into periods of remission (Anderson et al., 2011; Bhagwagar et al, 2004; Hayward, et al., 2005). There is debate, however, as to whether these behavioural abnormalities are present prior to the onset of illness, and therefore reflect a trait vulnerability marker, or are the consequences of current or previous depression.

One approach to identify vulnerability markers for depression is to establish if similar behavioural and neural abnormalities are also present in individuals at increased risk for depression but who have never been depressed. Chan and colleagues (Chan, et al., 2007) reported that high neuroticism (a recognised risk factor for depression) was associated with reduced latency to classify negative *vs.* positive personality descriptors, reduced positive memory intrusion at subsequent recall and reduced capacity to recognise happy facial expressions as compared to individuals with low levels of neuroticism. Using a similar emotional categorisation task in young adults at increased familial risk of depression, Mannie *et al.,* (2007) reported increased response times to classify both negative *and* positive personality descriptors. These data (Mannie et al., 2007) do not provide direct evidence of a negative emotional bias in this at risk group, but do indicate difficulties in the initial encoding of emotionally valenced words. Further, Joorman *et al.* (2007) observed an attentional bias to negative facial expressions (i.e. a bias away from positive toward negative facial stimuli which can be assessed using a dot-probe task) following a negative mood induction in daughters of depressed mothers compared to control females (Joormann et al., 2007). Together (Chan et al., 2007; Joormann et al., 2007; Mannie et al., 2007), these findings suggest that biases in emotional processing may reflect vulnerability markers for depression and precede the disorder rather than occurring through prior experience or treatment for depression.

In addition to biases in emotional processing limited evidence indicates the presence of abnormal reward mechanisms in at risk groups. For example, neuroticism is associated with increased online gaming (Mehroof & Griffiths, 2010), problem gambling (Sundqvist & Wennberg, 2014) and reduced performance in older adults on the Iowa Gambling Task (Denburg et al., 2009). In addition, reduced risk taking on the Cambridge Gambling Task has been reported in young adults at increased familial risk of depression (Mannie et al., 2015). A finding that may reflect impaired reward-seeking which is also seen in acutely depressed patients (Forbes et al., 2007). Similarly, eveningness has been associated with increased risk-taking. Wang and Chartrand (2014) reported a negative relationship between financial risk-taking (as measured by the Domain-Specific Risk Attitude Scale [DOSPERT],(Weber, Blais, & Betz, 2002)) and morningness. Stolarksi, Ledzinska and Matthews (2012) observed greater future-directed thinking in early chronotypes and greater drive for immediate rewards in evening-type individuals. Of note, acutely depressed patients also show increased impulsivity [i.e. a preference for smaller more immediate rewards] (Cáceda et al., 2014; Pulcu et al., 2014). Together (Cáceda et al., 2014; Pulcu et al., 2014; Stolarski, Ledzinska, & Matthews, 2012; Wang & Chartrand, 2015), these data suggest that acute depression and eveningness are associated with altered risk-taking behaviour and impulsivity. The secondary aim of the present study was to further explore risky decision making and impulsivity in late chronotype individuals as compared to a control group (early/intermediate chronotype).

Methods

Participants

The study was approved by the local ethics committee and written informed consent was obtained prior to any study procedures taking place. Exclusion criteria were current or previous depression, presence of major depression in a biological parent and diagnosed sleep disorder. A total of 96 participants were initially recruited by poster advertisement and personal communication. Of these, 5 were excluded from the study due to current or previous depression or anxiety disorders (as determined by The Structured Clinical Interview for DSM-IV) and a further 5 were excluded due to technical difficulties, leaving a total of 86 participants that completed the study. Chronotype was determined using the Morningness-Eveningness Questionnaire [MEQ] (Horne & Östberg, 1976). Participants scoring 42 or above were determined to be early/intermediate chronotype [EIC] (n = 43, M 50.00, SD 6.84, range 42-72), those with a score less than 42 were considered late chronotype [LC] (n = 43, M 34.67, SD 6.03, range 16-41). Across the sample studied (n = 86), 6% were morning-type, 44% intermediate and 50% evening-type.

Sleep quality, trait anxiety, mood and neuroticism were estimated, respectively, with the Pittsburgh Sleep Quality Index [PSQI] (Buysse et al., 1989), Spielberger State/Trait anxiety inventory [STAI] (Spielberger et al., 1970), Beck Depression Inventory [BDI] (Beck et al., 1961) and the Eysenck Personality Questionnaire Revised [EPQ-R] (Eysenck et al., 1984).

Procedures

Emotional categorisation

The emotional categorisation, recall and recognition tasks were adapted from a similar set of paradigms developed by Harmer *et al.,* (Harmer et al., 2003). Sixty personality characteristics (Anderson, 1968) selected to be extremely disagreeable (e.g. unreliable) or agreeable (truthful) were presented on a computer screen for 500 ms, 3000 ms interstimulus interval (ISI). Participants were asked to categorise, via keyboard response, the word presented as likeable or dislikeable. Specifically, participants were instructed to imagine whether they would be pleased or displeased if they overheard someone describe them using this word. Classifications and reaction times for correct identifications were computed. For all experiments E-Prime v2 (build 2.0.10.242, Psychology software tools) was used to present stimuli and record participant responses.

Emotional memory

Incidental memory for positive and negative personality trait words was assessed approximately 15 minutes after completion of the emotional categorisation task. Participants were asked to recall as many words as possible and the number of correctly and incorrectly words recalled was recorded. Recognition memory for positive and negative personality trait words was then assessed by asking participants to indicate if the word presented on the computer screen was ‘old’ (previously presented at categorisation) or ‘new’. The sixty target words plus 60 (30 positive) matched distractors were presented in random order and with the same timings as the categorisation task. Response accuracy and latency were recorded.

Facial expression recognition

The facial expression recognition task featured two basic emotions (happiness and sadness) taken from four individual characters included in the NimStim series of facial expressions (Tottenham et al., 2009). All images were presented in greyscale and had been morphed between each prototypical and neutral expression in 10% steps (0% = neutral, 100% = full emotion). Four examples of each emotion at each intensity were given (two emotions x ten intensities x four examples = 80 stimuli). Each face was also presented in a neutral (0% = neutral expression, four stimuli), giving a total of 84 stimuli presentations. The facial stimuli were presented on a computer screen (in random order) for 500 msec and replaced by a blank screen. Participants made their responses using a mouse (clicking on a text box displayed on the screen (SAD NEUTRAL HAPPY). Participants were asked to respond as quickly and as accurately as possible.

Balloon analogue risk task

The Balloon Analogue Risk Task [BART] is a computerised measure or risk-taking behaviour. At each trial, participants inflate (pump) a simulated balloon and accrue points for each successive pump. The participant can ‘cash-out’ at any point during a trial and secure the cumulative points for that trial, which are added to their total bank (points earned on previous trials). Alternatively, the balloon may ‘explode’, in which case the participant loses the points earned on that particular trial (banked points are not affected). Here, each successful pump earned the participant 5 points and the explode threshold for each trial was determined by drawing a random number from a uniform distribution with a maximum value of 64. The resulting probability that a balloon will burst on any given a number of pumps is:

$$P(explode) = 1/(64\text{-number of pumps})$$

Thus, the explosion probability of each additional pump within a trial increased exponentially during the trial. Participants were not given any information about the explosion parameters and completed a total of 40 trials. Based on the probabilities of explosion earnings would be maximised by pumping 32 times per balloon. Consistent with previous work (Lejuez et al., 2002) mean adjusted pumps were computed for each individual (i.e. the average number of pumps on each balloon that did not explode). Adjusted pump scores, rather than absolute pump scores, are utilised as the number of pumps on explode trials is necessarily constrained and therefore restricts the range of risk behaviour. In addition to adjusted pump scores, which provide an overall measure of risk taking and can be extracted directly from the data, we also applied mathematical modelling techniques to the BART data in order to explore the cognitive processes underlying learning and sequential choice in a risk-taking task (Wallsten et al., 2005). Here, we adopted the best-fitting model (Model 3) from Wallsten, Pleskac and Lejuez (2005). The estimated parameters from this model include γ^+ - an individual's value of potential gains on a given trial; β - which describes an individual's response consistency; and $Var(q_1)$ - an individual's degree of uncertainty that the first balloon will not explode. Best fitting parameter values were estimated from the data individually for each participant using maximum likelihood methods implemented within Matlab (R2013a) and following the algorithm developed by Wallsten, Pleskac and Lejuez (2005).

Visual-probe task

Stimluli were 32 fearful, happy and neutral facial expressions taken from the NimStim (Tottenham et al., 2009). Uncropped, full colour images were used. Each emotional face was paired with a neutral face (different character same gender) to yield 32 fear-neutral pairs, 32 happy-neutral pairs and 32 neutral-neutral pairs. Each trial started with a fixation cross presented for 2000 ms followed by an image pair presented to the left and right of the fixation cross for 500ms. Emotional faces appeared with equal frequency to the left and right of the fixation cross. Image presentation was immediately followed by a probe (asterisk) in the location of one of the preceding images. Participants were required, by key press, to indicate the location of the probe (left or right). The probe appeared to the left or right with equal frequency and the participant's response terminated the trials. Individual's vigilance scores were computed by subtracting median response time (excluding error trials) when the probe replaces emotional face (congruent, or valid trial) from the response time when the probe appears in the location of the neutral stimulus, referred to as incongruent, or invalid trials. Thus, the higher the vigilance score the greater the bias towards the emotional stimulus.

Delay discounting

Participants were presented with a series of questions on a computer screen asking about their preferences for receiving a larger amount (e.g. £100) after some delay or a smaller randomly selected amount (e.g.£45) to be received immediately (e.g. "Would you prefer £45 now, or £100 in 1 month"). The experiment included three amounts (£100, £1000 and

£10000) each presented with the following delays (1 week, 1 month, 12 months, 5 years and 10 years). If the participant rejected the immediate reward its value was increased until the participant accepted. This process was then repeated and the indifference point computed as the average of the two accepted values. Participants completed all three conditions of the experiment (£100, £1000 and £10000) which were presented in random order. Following previous work discounting effects were modelled according to the following equation: $V=A/(1+kD)$. Where V = present value of a reward (i.e. indifference point), A = amount of reward and D = delay. The numeral 1 appears in the denominator to prevent $V \rightarrow$ infinity as $D \rightarrow 0$. The value k (a free parameter determined by fitting the model to the data) increases with larger effects of delay on degrading value.

Time of testing

The date and time of appointments were determined by mutual agreement between the experimenter and participant. In the current study all experimental procedures were completed in a single session (duration ~ 60 minutes) on a working day between 09:00 and 19:00 hours.

TABLE 1 NEAR HERE PLEASE

Statistical treatment

Independent samples *t*-tests and Pearson's chi-square test for independence were used to explore participant demographics and trait characteristics. All other measures were analysed using split-plot two-way analysis of variance (ANOVA). In each case the between subjects factor was group (EIC/LC), the within subjects factors were emotion (emotional categorisation, recognition and recall; facial expression recognition accuracy; visual-probe task) or amount (delayed discounting). Response times +/- two standard deviations an individual's mean were considered outliers and removed from all psychological tasks. Relationships between MEQ and outcome measures were assessed using simple Pearson product-moment correlation coefficient. To explore potential synchrony effects, time of test was categorised as either morning (09:00 – 12:00, afternoon (12:01 – 16:00) or late afternoon early evening (16:01 – 19:00) and the number of participants from each group (LC & EIC) attending each session compared using Pearson's chi-square test for independence.

Results

Groups were similar in terms of age, gender, sleep quality, mood (BDI), trait anxiety and neuroticism (see Table 2). Neither number of cigarettes smoked per day or units of alcohol consumed per week distinguished between groups (Table 2).

TABLE 2 NEAR HERE PLEASE

Emotional categorisation

Categorisation accuracy for agreeable words was significantly greater than disagreeable words ($F(1,84) = 11.46$, $p < .001$; agreeable words M = 88.64, SD = 9.42, disagreeable words M =84.69, SD =7.68). There was no main effect of group ($F(1,84) = 2.84$, $p < .096$) or group x emotion interaction ($F(1,84) < 1$). Similarly we observed a main effect of emotion on response latency (F(1,84) = 75.10, p < .001; positive words M = 792.99 ms, SD = 138.67, disagreeable words M = 874.76 ms, SD =171.60) with no main effect of group (F(1,84) < 1) or group x emotion interaction (F(1,84) = 1.39, p < .243)

Emotional recognition

We observed a significant main effect of emotion recognition accuracy (F(1,84) = 25.97, p < .001; agreeable words M = 63.71, SD = 9.26, disagreeable words M = 67.89, SD = 8.86). There was no main effect of group (F(1,84) < 1) or group x emotion interaction (F(1,84) < 1). For recognition response latency there was a significant group x emotion interaction (F(1,84) = 5.74, p < .019). Early/intermediate chronotypes showed reduced response times to correctly recognised agreeable words *vs.* disagreeable personality trait words as compared to the LC participants (Figure 1).

FIGURE 1 NEAR HERE PLEASE

Emotional recall

Free recall accuracy was significantly greater for agreeable as compared to disagreeable words (F(1,84) = 13.76, p < .001; agreeable words M = 3.19, SD = 2.37, disagreeable words M = 2.49, SD = 2.19) witht no main effect of group. The group x emotion interaction was significant (F(1,84) = 6.12, p < .015) and reflected greater recall accuracy to agreeable words *vs.* disagreeable words in the EIC group as compared to the LC participants (Figure 2). Across all groups there was a small, although significant, negative relationship between recall accuracy for disagreeable words and MEQ (Pearson's $r = -.214$, $p = .047$) such that greater eveningness was associated with greater recall accuracy to disagreeable words.

FIGURE 2 NEAR HERE PLEASE

Facial expression recognition

Expression recognition was significantly greater for positive faces ($F(1,84) = 23.12$, $p < .001$; happy faces M = 68.49, SD = 7.69, sad facial expressions M = 62.38, SD = 9.85) but did not differ between groups. Furthermore, there was also a significant chronotype by valence interaction for facial expression recognition accuracy ($F(1,84) = 7.08$, $p = .009$). Early/intermediate chronotypes showed reduced accuracy to sad faces as compared to LC individuals ($t(84) = -2.01$, $p = 0.048$, M = 60.30, SD = 9.62, M = 64.48, SD = 9.74) with no between group differences in accuracy to happy faces (Figure 3). Across all participants Pearson's correlation revealed a significant negative relationship between accuracy for sad facial expressions (Pearson's $r = -.298$, $p = .005$) such that participants with greater evening preference correctly identified a greater number of sad facial expressions. Analysis of EIC and LC groups separately revealed a significant negative relationship in EIC participants ($r = -.524$, $p = .<.001$) but no significant association in LC individuals.

FIGURE 3 NEAR HERE PLEASE

Balloon analogue risk task

The average number of pumps on cash-out trials (adjusted pumps) was significantly different from the balloon tolerance in both EIC and late LC participants (one-sample *t*-test: EIC t(42) = -16.96, $p < .001$, LC t(42) = -13.04, $p < .001$) suggesting that participants were, on average, risk-averse (see Table 2). In particular, a risk-neutral participant would maximise expected earnings if they pumped to the level of the average tolerance for each balloon. Independent samples *t*-tests comparing adjusted pumps, γ^{+}, β and $Var(q_1)$ did not reveal any significant between-group differences (all p's ≥ 0.09).

TABLE 3 NEAR HERE PLEASE

Visual probe task

For the visual probe task we observed a significant group x emotion interaction ($F(1,84) = 5.05$, $p < .027$). Early/intermediate chronotypes (Figure 3) displayed an attentional bias towards positive (happy) facial expressions when compared to the LC group. Further analyses comparing response times to neutral pairs subtracted from happy congruent trials and happy incongruent trials revealed a facilitation of attentional resources to positive facial expressions (i.e. faster response times to happy congruent trials compared to neutral-neutral trials) in the EC group ($t(84) = -2.29$, $p = .024$). No between group differences for disengagement (i.e. slower response times to happy incongruent trials compared to neutral-neutral trials) were observed ($t(84) = 0.686$, $p = .495$). Across all participants Pearson's correlation revealed a significant positive relationship between vigilance to happy facial expressions (r = .26, p = <.016) thereby indicating that greater morning preference was associated with increased vigilance to happy faces. In addition, a significant negative relationship between MEQ and facilitation of attentional resources to positive facial expressions (r = - .357, p = <.001) was observed; i.e. a greater preference for mornings was associated with faster response times to happy congruent trials compared to neutral-neutral trials.

FIGURE 4 NEAR HERE PLEASE

Delay discounting

A main effect of amount of reward was observed (F(1.71,168) = 5.43, p < .0008. Pairwise comparisons, with Bonferroni correction, revealed a significant difference between £100 and £10,000 (M = 0.008, SD = 0.013, M = 0.018, SD = 0.029, p = .009), but no difference between £100 and £1,000 or £1,000 and £10,000. Both the main effect of group and the group by amount of reward interaction were non-significant.

Time of test

There was a significant association between chrontoype and testing session time $\chi^2(2)$ = 9.05, p = .015. Within the EIC group 42% of participants elected to attend a morning session. By contrast, LC participants preferred afternoon/early evening appointments with only 14% attending a morning session. Across all participants Pearson's correlation revealed a significant negative relationship between testing-session start time and MEQ (r = - .406, p

<.001) thereby supporting the notion that participants with greater evening preference self-selected testing sessions scheduled for afternoon/evening.

Discussion

Acutely depressed patients display a range of negative biases in emotional processing including enhanced memory for, and attentional biases towards , negatively valenced emotional information combined with impaired recognition of facial expressions (Bradley et al., 1995; Gilboa-Schechtman et al., 2002; Gur et al., 1992; Peckham et al., 2010; Ridout et al., 2003; Surguladze et al., 2004) . The current data indicate that similar emotional biases are present in never-depressed LC individuals. Across a range of tasks including emotional categorisation, recognition and recall, facial expression recognition and attentional bias, we observed increased negative or decreased positive processing. By contrast, there was no evidence for effects of late chronotype on sequential risk taking (as measured by the BART) or delay discounting.

The current findings highlight a number of interesting observations when compared with earlier studies in at-risk groups although a direct comparison across studies is challenging due to differing participant characters and task parameters. For example, we found an attentional bias towards positive (happy) facial expressions in EIC individuals as compared to the LC group. By contrast, Chan and colleagues (Chan et al., 2007) found no evidence of an attentional bias in highly neurotic individuals as compared to controls.

However, in that study socially threatening and socially positive words were presented. It is possible, therefore, that differences in task design underlie these conflicting findings. Alternatively, attentional biases may play no role in neuroticism but are relevant to circadian typology. We also observed increased recognition of sad facial expressions in LC and no effect on happy faces. Previous work in remitted depressed patients has reported increased recognition of sad facial expressions as compared to currently depressed and healthy participants (Anderson et al., 2011). By contrast, Mannie and colleagues (Mannie, et al., 2007) found no effect of familial risk for depression on facial expression recognition. Based on these data (Anderson et al., 2011; Mannie et al., 2007), Anderson and colleagues suggested that increased recognition of sad faces may reflect a "scar" effect (i.e. occurs as a consequence of previous depression) rather than a pre-existing vulnerability factor. More recently, however, Chan *et al.,* (Chan et al., 2007) observed a reduced capacity to correctly report happy faces in highly neurotic individuals as compared to participants low in neuroticism. These data (Chan et al., 2007) combined with the current findings suggest that alterations in face emotion recognition may exist prior to the onset of depression in certain at-risk groups rather than solely arising as a result of depressive experience. Finally, group differences were also observed during recall and recognition of personality trait words. Specifically, EIC were quicker to correctly recognise positive *vs.* negative personality trait words and recalled significantly more positive than negative words. These findings are similar to those reported by Chan and colleagues (Chan et al., 2007) who reported that high neuroticism was associated with reduced latency to classify negative *vs.* positive personality descriptors coupled with reduced positive memory intrusion at subsequent recall.

Of note, recent work exploring diurnal preference and Emotional Intelligence [EI] (Stolarski & Jankowski, 2015) reported a greater ability to recognise, interpret and understand self and other's emotions in evening as compared to morning-orientated individuals but no difference in the ability to assimilate and manage emotions. Such an EI profile, increased emotion perception untempered by emotion management and assimilation, may predispose late chronotypes to reduced mood and more negative affective states (Stolarski & Jankowski, 2015) and would be consistent with previous work indicating an association between late chronotype and depression (Hidalgo et al., 2009; Levandovski et al., 2011; Merikanto et al., 2013). These findings may, however, appear at odds with the current work. For example, we did not observe a general increase in expression recognition in late chronotypes, rather we found a greater ability to recognise specifically sad facial expressions. A direct comparison between the current findings and those of Stolarksi and Janowski (2015), however, is challenging. Here we asked participants to indicate the facial expression displayed on the computer screen. By contrast, within the framework of EI, emotion recognition is assessed within the context of subjective experience as well as in other's behaviour (Śmieja et al., 2014). Future studies that incorporate measures of circadian typology, EI and measures of emotional memory, expression recognition and attentional biases are warranted.

We found no effect of chronotype on sequential risk (as indexed by the BART) or temporal discounting. The former result replicates previous work (Kilgore, 2007) and supports the notion that late chronotype is not associated with increased sequential risk-taking. Of note, Pulcu and colleagues (Pulcu et al., 2014) reported increased delay discounting in currently depressed patients as compared to remitted patients and healthy controls. These data (Pulcu et al., 2014) indicate that an increased preference for smaller rewards coupled with a shorter delay is state dependent and may, therefore, reflect current symptomatology rather than a vulnerability factor for depression (which would extend into periods of remission). The current findings are, however, contrary to earlier studies that have reported increased financial risk taking (Wang & Chartrand, 2015) and increased preference for immediate rewards in evening types (Stolarski et al., 2012). The apparent inconsistencies may reflect task differences (e.g. we did not directly measure financial risk taking) or participant demographics (Wang and Chartrand, included adults with a broader age range [18 to 69] than the current study). Further work combining questionnaires (e.g. the DOSPERT) and experimental paradigms are required.

The current study has a number of limitations and these should be taken into account when interpreting the results. First, chronotype status was determined using a single metric [the Morningness-Eveningness Questionnaire self-assessment version (Horne & Östberg, 1976)]. This instrument is designed to estimate phase preferences in circadian rhythms based on self-report. Although this questionnaire is one of the most widely used to assess morningness-eveningness preferences (Levandovski et al., 2013) and has been validated against physiological measures (Bailey & Heitkemper, 2001) and the age-range included in this study (Horne & Östberg, 1976) future studies could benefit from objective tools such as acrophase estimates of cortisol and core body temperature, polysomnography and actigraphy to corroborate self-report questionnaire data. Second, we adopted the cut-offs determined by Horne and Östberg (Horne & Östberg, 1976) but combined moderate/definite morning types and intermediate types into a single category (early/intermediate chronotype, EIC). Future studies adequately powered for less frequent events (i.e. able to explore the full range of chronotypes – definite morning, moderate morning, intermediate, moderate evening, definite evening) are required. Third, there is evidence to suggest that time of day impacts on cognitive function (Grier et al., 2003; Manly et al., 2002). However, few studies have assessed the interaction between time of test and chronotype on cognitive performance. Where studies have explored synchrony effects (i.e. time of testing is "synchronised" to an individual's optimal time of day according to their circadian profile) performance is improved compared to suboptimal times (Hahn et al., 2012; Lara et al., 2014). Similar synchrony effects (if applicable to the tasks employed in the current work) are unlikely to account for the results observed here. Late chronotypes preferentially attended testing sessions scheduled for afternoon/evening (i.e. synchronised to their optimal time of day). Similarly, EIC participants preferentially attended morning sessions.

Conclusions

In conclusion, employing a range of tasks including emotional categorisation, recognition and recall, facial expression recognition and attentional bias, this study found a clear association between late chronotype and increased negative or decreased positive processing. These findings may have important theoretical and clinical implications for the prevention and treatment of depression and open avenues for further research.

References

Anderson, I. M., Shippen, C., Juhasz, G., Chase, D., Thomas, E., Downey, D., … Deakin, J. F. W. (2011). State-dependent alteration in face emotion recognition in depression. *The British Journal of Psychiatry*, *198*(4), 302–308. http://doi.org/10.1192/bjp.bp.110.078139

Anderson, N. H. (1968). Likableness ratings of 555 personality-trait words. *Journal of Personality and Social Psychology*, *9*(3), 272–9.

Bailey, S. L., & Heitkemper, M. M. (2001). Circadian rhythmicity of cortisol and body temperature: morningness-eveningness effects. *Chronobiology International*, *18*(2), 249–261.

Beck, A. T., Rush, A. J., Shaw, B. F., & Emery, G. (1979). *Cognitive theory of depression*. New York: Guildford.

Beck, A. T., Ward, C. H., Mendelson, M., Mock, J., & Erbaugh, J. (1961). An inventory for measuring depression. *Arch Gen Psychiatry*, *4*, 561–71.

Bhagwagar, Z., Cowen, P. J., Goodwin, G. M., & Harmer, C. J. (2004). Normalization of enhanced fear recognition by acute SSRI treatment in subjects with a previous history of depression. *The American Journal of Psychiatry*, *161*(1), 166–168.

Bradley, B. P., Mogg, K., Millar, N., & White, J. (1995). Selective processing of negative information: effects of clinical anxiety, concurrent depression, and awareness. *Journal of Abnormal Psychology*, *104*(3), 532–536.

Buysse, D. J., Reynolds, C. F., 3rd, Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. *Psychiatry Research*, *28*(2), 193–213.

Cáceda, R., Durand, D., Cortes, E., Prendes-Alvarez, S., Moskovciak, T., Harvey, P. D., & Nemeroff, C. B. (2014). Impulsive choice and psychological pain in acutely suicidal depressed patients. *Psychosomatic Medicine*, *76*(6), 445–451. http://doi.org/10.1097/PSY.0000000000000075

Chan, S. W. Y., Goodwin, G. M., & Harmer, C. J. (2007). Highly neurotic never-depressed students have negative biases in information processing. *Psychological Medicine*, *37*(09), 1281. http://doi.org/10.1017/S0033291707000669

Denburg, N. L., Weller, J. A., Yamada, T. H., Shivapour, D. M., Kaup, A. R., LaLoggia, A., … Bechara, A. (2009). Poor decision making among older adults is related to elevated levels of neuroticism. *Annals of Behavioral Medicine: A Publication of the Society of Behavioral Medicine*, *37*(2), 164–172. http://doi.org/10.1007/s12160-009-9094-7

Eysenck, S. B. ., Eysenck, H. ., & Barrett, P. (1984). A revised version of the psychotism scale. *Personality and Individual Differences*, *6*(1), 21–29.

Forbes, E. E., Shaw, D. S., & Dahl, R. E. (2007). Alterations in Reward-Related Decision Making in Boys with Recent and Future Depression. *Biological Psychiatry*, *61*(5), 633–639. http://doi.org/10.1016/j.biopsych.2006.05.026

Gilboa-Schechtman, E., Erhard-Weiss, D., & Jeczemien, P. (2002). Interpersonal deficits meet cognitive biases: memory for facial expressions in depressed and anxious men and women. *Psychiatry Research*, *113*(3), 279–293.

Goldstein, D., Hahn, C. S., Hasher, L., Wiprzycka, U. J., & Zelazo, P. D. (2007). Time of day, intellectual performance, and behavioral problems in Morning versus Evening type adolescents: Is there a synchrony effect? *Personality and Individual Differences*, *42*(3), 431–440.

Grier, R. A., Warm, J. S., Dember, W. N., Matthews, G., Galinsky, T. L., & Parasuraman, R. (2003). The vigilance decrement reflects limitations in effortful attention, not mindlessness. *Hum Factors.*, *45*(3), 349–59.

Gur, R. C., Erwin, R. J., Gur, R. E., Zwil, A. S., Heimberg, C., & Kraemer, H. C. (1992). Facial emotion discrimination: II. Behavioral findings in depression. *Psychiatry Research*, *42*(3), 241–251.

Hahn, C., Cowell, J. M., Wiprzycka, U. J., Goldstein, D., Ralph, M., Hasher, L., & Zelazo, P. D. (2012). Circadian rhythms in executive function during the transition to adolescence: the effect of synchrony between chronotype and time of day: Synchrony effects on executive function. *Developmental Science*, *15*(3), 408–416. http://doi.org/10.1111/j.1467-7687.2012.01137.x

Harmer, C. J., Hill, S. A., Taylor, M. J., Cowen, P. J., & Goodwin, G. M. (2003). Toward a neuropsychological theory of antidepressant drug action: increase in positive emotional bias after potentiation of norepinephrine activity. *The American Journal of Psychiatry*, *160*(5), 990–992.

Hayward, G., Goodwin, G. M., Cowen, P. J., & Harmer, C. J. (2005). Low-dose tryptophan depletion in recovered depressed patients induces changes in cognitive processing without depressive symptoms. *Biological Psychiatry*, *57*(5), 517–524. http://doi.org/10.1016/j.biopsych.2004.11.016

Hidalgo, M. P., Caumo, W., Posser, M., Coccaro, S. B., Camozzato, A. L., & Chaves, M. L. F. (2009). Relationship between depressive mood and chronotype in healthy subjects. *Psychiatry and Clinical Neurosciences*, *63*(3), 283–290. http://doi.org/10.1111/j.1440-1819.2009.01965.x

Horne, J. A., & Östberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. *International Journal of Chronobiology*, *4*(2), 97–110.

Joormann, J., Talbot, L., & Gotlib, I. H. (2007). Biased processing of emotional information in girls at risk for depression. *Journal of Abnormal Psychology*, *116*(1), 135–143. http://doi.org/10.1037/0021-843X.116.1.135

Kilgore, W. D. S. (2007). Effects of sleep deprivation and morningness-eveningness traits on risk-taking. *Psychological Reports*, *100*, 613–626.

Lara, T., Madrid, J. A., & Correa, Á. (2014). The Vigilance Decrement in Executive Function Is Attenuated When Individual Chronotypes Perform at Their Optimal Time of Day. *PLoS ONE*, *9*(2), e88820. http://doi.org/10.1371/journal.pone.0088820

Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., … Brown, R. A. (2002). Evaluation of a behavioral measure of risk taking: the Balloon Analogue Risk Task (BART). *J Exp Psychol Appl.*, *8*(2), 75–84.

Levandovski, R., Dantas, G., Fernandes, L. C., Caumo, W., Torres, I., Roenneberg, T., … Allebrandt, K. V. (2011). Depression Scores Associate With Chronotype and Social Jetlag in a Rural Population. *Chronobiology International*, *28*(9), 771–778. http://doi.org/10.3109/07420528.2011.602445

Levandovski, R., Sasso, E., & Hidalgo, M. P. (2013). Chronotype: a review of the advances, limits and applicability of the main instruments used in the literature to assess human phenotype. *Trends in Psychiatry and Psychotherapy*, *31*(1). http://doi.org/10.1590/S2237-60892013000100002

Manly, T., Lewis, G. H., Robertson, I. H., Watson, P. C., & Datta, A. (2002). Coffee in the cornflakes: time-of-day as a modulator of executive response control. *Neuropsychologia*, *40*(1), 1–6.

Mannie, Z. N., Bristow, G. C., Harmer, C. J., & Cowen, P. J. (2007). Impaired emotional categorisation in young people at increased familial risk of depression. *Neuropsychologia*, *45*(13), 2975–2980. http://doi.org/10.1016/j.neuropsychologia.2007.05.016

Mannie, Z. N., Williams, C., Browning, M., & Cowen, P. J. (2015). Decision making in young people at familial risk of depression. *Psychological Medicine*, *45*(02), 375–380. http://doi.org/10.1017/S0033291714001482

Mehroof, M., & Griffiths, M. D. (2010). Online gaming addiction: the role of sensation seeking, self-control, neuroticism, aggression, state anxiety, and trait anxiety. *Cyberpsychology, Behavior and Social Networking*, *13*(3), 313–316.

Merikanto, I., Lahti, T., Kronholm, E., Peltonen, M., Laatikainen, T., Vartiainen, E., … Partonen, T. (2013). Evening types are prone to depression. *Chronobiology International*, *30*(5), 719–725. http://doi.org/10.3109/07420528.2013.784770

Peckham, A. D., McHugh, R. K., & Otto, M. W. (2010). A meta-analysis of the magnitude of biased attention in depression. *Depression and Anxiety*, *27*(12), 1135–1142. http://doi.org/10.1002/da.20755

Pulcu, E., Trotter, P. D., Thomas, E. J., McFarquhar, M., Juhasz, G., Sahakian, B. J., … Elliott, R. (2014). Temporal discounting in major depressive disorder. *Psychological Medicine*, *44*(09), 1825–1834. http://doi.org/10.1017/S0033291713002584

Reske, M., Rosenberg, J., Plapp, S., Kellermann, T., & Jon Shah, N. (2015). fMRI identifies chronotype-specific brain activation associated with attention to motion — Why we need to know when subjects go to bed. *NeuroImage*. http://doi.org/10.1016/j.neuroimage.2015.02.013

Ridout, N., Astell, A., Reid, I., Glen, T., & O'Carroll, R. (2003). Memory bias for emotional facial expressions in major depression. *Cognition & Emotion*, *17*(1), 101–122. http://doi.org/10.1080/02699930302272

Schmidt, C., Collette, F., Cajochen, C., & Peigneux, P. (2007). A time to think: Circadian rhythms in human cognition. *Cognitive Neuropsychology*, *24*(7), 755–789. http://doi.org/10.1080/02643290701754158

Śmieja, M., Orzechowski, J., & Stolarski, M. S. (2014). TIE: An Ability Test of Emotional Intelligence. *PLoS ONE*, *9*(7), e103484. http://doi.org/10.1371/journal.pone.0103484

Spielberger, C. ., Gorsuch, R. ., & Lushene, R. . (1970). *STAI Manual for the State-Trait Anxiety Inventory*. Palo Alto, CA: Consulting Psychologists Press.

Stolarski, M., & Jankowski, K. S. (2015). Morningness–eveningness and performance-based emotional intelligence. *Biological Rhythm Research*, *46*(3), 417–423. http://doi.org/10.1080/09291016.2015.1020199

Stolarski, M., Ledzinska, M., & Matthews, G. (2012). Morning is tomorrow, evening is today: Relationships between chronotype and time perspective. *Biological Rhythm Research - BIOL RHYTHM RES*, *44*(2), 1–16. http://doi.org/10.1080/09291016.2012.656248

Sundqvist, K., & Wennberg, P. (2014). Risk Gambling and Personality: Results from a Representative Swedish Sample. *Journal of Gambling Studies / Co-Sponsored by the*

National Council on Problem Gambling and Institute for the Study of Gambling and Commercial Gaming. http://doi.org/10.1007/s10899-014-9473-2

Surguladze, S. A., Young, A. W., Senior, C., Brébion, G., Travis, M. J., & Phillips, M. L. (2004). Recognition accuracy and response bias to happy and sad facial expressions in patients with major depression. *Neuropsychology*, *18*(2), 212–218. http://doi.org/10.1037/0894-4105.18.2.212

Tottenham, N., Tanaka, J. W., Leon, A. C., McCarry, T., Nurse, M., Hare, T. A., … Nelson, C. (2009). The NimStim set of facial expressions: Judgments from untrained research participants. *Psychiatry Research*, *168*(3), 242–249. http://doi.org/10.1016/j.psychres.2008.05.006

Wallsten, T. S., Pleskac, T. J., & Lejuez, C. W. (2005). Modeling Behavior in a Clinically Diagnostic Sequential Risk-Taking Task. *Psychological Review*, *112*(4), 862–880. http://doi.org/10.1037/0033-295X.112.4.862

Wang, L., & Chartrand, T. L. (2015). Morningness–Eveningness and Risk Taking. *The Journal of Psychology*, *149*(4), 394–411. http://doi.org/10.1080/00223980.2014.885874

Weber, E. U., Blais, A.-R., & Betz, N. (2002). A domain-specific risk-attitude scale: Measuring risk perceptions and risk behaviors. *Journal of Behavoioural Decision Making*, *15*, 263–290.

Declaration of interest

The authors report no conflicts of interest.

Task	DV	Description	Interpretation
Balloon analogue risk task (BART)	Adjusted pumps	The average number of pumps on each balloon that did not explode	A larger value represents greater risk taking behaviour
	γ^{+}	Reward sensitivity	How a participant adjusts their estimate of risk based on experience during the task. Higher values indicate increased reward sensitivity
	β	Behavioural consistency	Higher values represent great behavioural consistency
	$Var(q_1)$	Confidence in the initial perception of risk	Larger values indicate greater uncertainty in the initial estimate of risk
Visual probe task	Vigilance score	Median response time to incongruent trials (probe replaces neutral stimulus) minus response time to congruent trials (probe replaces emotional stimulus)	The higher the vigilance score the greater the bias to the emotional stimulus
	Facilitation score	Response time to congruent trials minus response time neutral pairs	Faster response time to congruent trials indicates a facilitation of attentional resources to that emotion (e.g. faster response times to happy congruent trials vs neutral-neutral pairs would suggest a facilitation of attentional resources to positive facial expressions)
	Disengagement score	Response time to incongruent trials minus response time neutral pairs	Slower responses to incongruent trials reflects increased difficult in disengagement
Delayed discounting	k	Indifference point	Estimated from the following equation V=A/(1+kD). If k is large the effect of delay (D) on degrading value is bigger thatn if k is small. That is, a larger k reflects greater delay discounting

Table 1. Task details. Shown are outcome variables for the BART, visual probe and delayed discounting tasks are their interpretation.

Measure	EIC (*n* = 43)	LC (*n* = 43)	*p value*
Age	21.63 (4.43)	20.26 (1.91)	.068
Age range	18-43	18-27	
Gender (F/M)	31/12	36/7	.299
PSQI	6.19 (3.16)	6.70 (2.86)	.434
BDI	2.47 (1.30)	2.86 (1.88)	.260
STAI- trait index	33.98 (6.78)	35.51 (6.91)	.388
EPQ-R	2.65 (0.97)	3.00 (1.09)	.121
Cigarettes smoked (per day)	1.38 (3.19)	1.00 (2.73)	.747
Units of alcohol (per week)	4.40 (6.46)	3.18 (3.78)	.389

Table 2. Group characteristics. PSQI - Pittsburgh Sleep Quality Index; BDI - Beck Depression Inventory; EPQ-R - Eysenck Personality Questionnaire Revised (neuroticism subsection only).

Measure	EIC (n = 43)	LC (n = 43)	*p value*
Adjusted pumps	15.23 (6.49)	16.33 (7.88)	.48
β	0.40 (0.42)	0.28 (0.17)	.09
γ^{+}	0.53 (0.34)	0.57 (0.39)	.60
$LnVar(q_1)$	-9.97 (2.22)	-10.02 (1.93)	.91

Table 3. Balloon Analogue Risk Task (BART). Displayed are mean and (SD) for adjusted pumps and model parameters estimated from the data (β, γ^{+} and $LnVar(q_1)$) for EIC and LC separately.

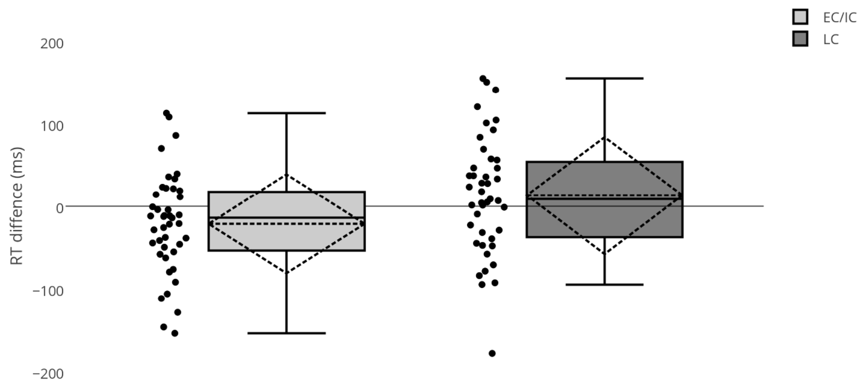

Figure 1. Emotional recognition. Displayed are reaction time difference scores (latency to agreeable – latency to disagreeable words). EIC shown in light grey, LC dark grey. Boxes show interquartile range, solid line median value, dotted line mean and standard deviation, whiskers +/- 1.5 x the interquartile range. Black circles show individual data points.

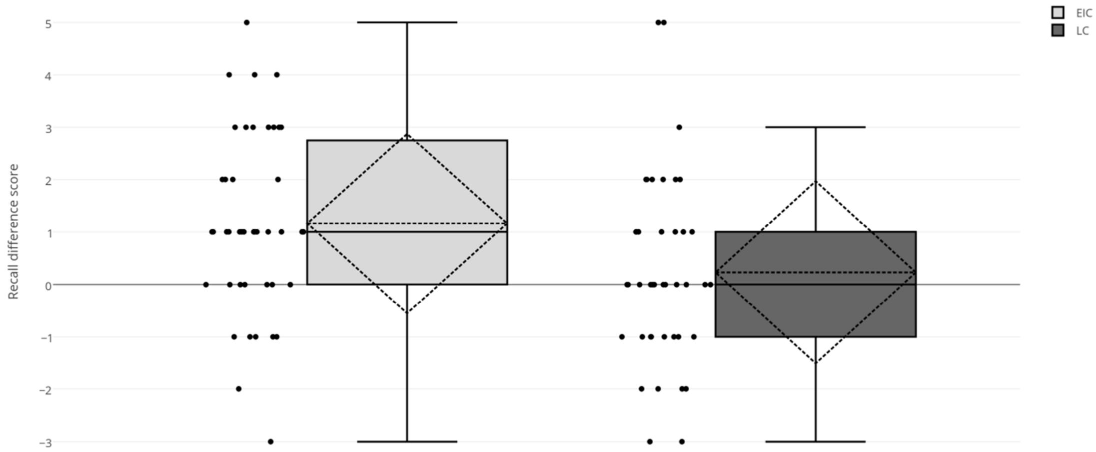

Figure 2. Emotional recall. Displayed are recall difference scores (recall accuracy to agreeable – recall accuracy to disagreeable words). Boxplot details as in Figure 1.

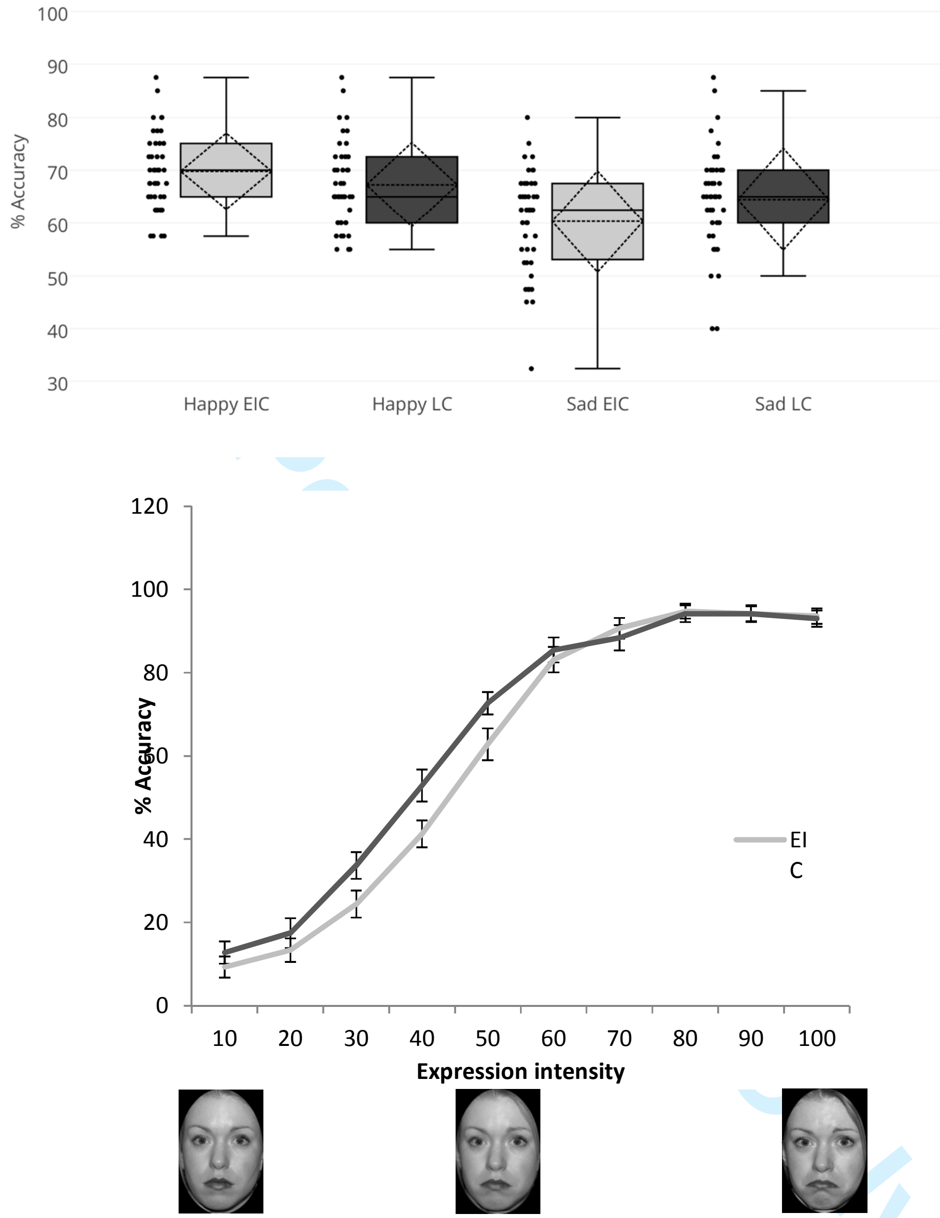

Figure 3. Facial expression recognition. 3A. Displayed are percentage accuracy. It can be seen that EIC show reduced recognition accuracy to sad faces as compared to LC. Boxplot details as in Figure 1. 3B. Intensity-accuracy response curves for LC as compared to EIC. A clear shift to the left (i.e. increased accuracy to sad faces at each intensity level) for all but the highest intensities can be seen in the intensity-accuracy response curve for LC as compared to EIC.

Figure 4. Vigilance scores as measured by the visual probe task. Vigilance was estimated by subtracting median response time when probe replaces emotional face (congruent, or valid, trial) from the response time when the probe appears in the location of the neutral stimulus, referred to as incongruent, or invalid trials. Thus the higher the vigilance score the greater the bias towards the emotional stimulus. Bars show mean, error bars standard error of mean. Early chonotype (EC) shown in light grey, late chronotype (LC) dark grey.