Effect of chronotype on emotional processing and risk taking.

Journal:	*Chronobiology International*
Manuscript ID	LCBI-2015-0107.R3
Manuscript Type:	Original Reports
Date Submitted by the Author:	22-Jan-2016
Complete List of Authors:	Berdynaj, Donjeta; University of Roehampton, Psychology Boudissa, Sarah; University of Roehampton, Psychology Grieg, Magnus; University of Roehampton, Psychology Hope, Charlotte; University of Roehampton, Psychology Mahamed, Sacdiya; University of Roehampton, Psychology Norbury, Ray; University of Roehampton, Psychology
Keywords:	Chronotype, Depression, Negative bias, Cognition

SCHOLARONE™
Manuscripts

1   Chronotype

Effect of chronotype on emotional processing and risk taking.

Donjeta Berdynaj[1*], Sarah N. Boudissa[1*], Magnus S. Grieg[1*], Charlotte Hope[1*], Sacdiya H.

Mahamed[1*] & Ray Norbury[1,2]

[*] Authors are listed in alphabetical order with the exception of the corresponding author

[1] University of Roehampton

Psychology Department

London, UK

[2] Address for correspondence:

Ray Norbury

University of Roehampton

Psychology Department

Whitelands College

London

SW15 4JD

E:ray.norbury@roehampton.ac.uk

2   Chronotype

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.

3   Chronotype

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

4   Chronotype

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.

5   Chronotype

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

7   Chronotype

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

8   Chronotype

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

9

Chronotype

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

12   Chronotype

£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 → infinity as

D → 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

15   Chronotype

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(q₁)* 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

17   Chronotype

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

18   Chronotype

<.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.

19   Chronotype

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

21   Chronotype

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.

23

Chronotype

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Chronotype

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.

25   Chronotype

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.

Chronotype

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

27   Chronotype

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

28   Chronotype

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

29   Chronotype

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*

30 Chronotype

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.

31

Chronotype

Declaration of interest

The authors report no conflicts of interest.

32

Chronotype

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

33   Chronotype

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

34   Chronotype

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).

35   Chronotype

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(q₁)	-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(q₁)*) for EIC and LC separately.

36   Chronotype
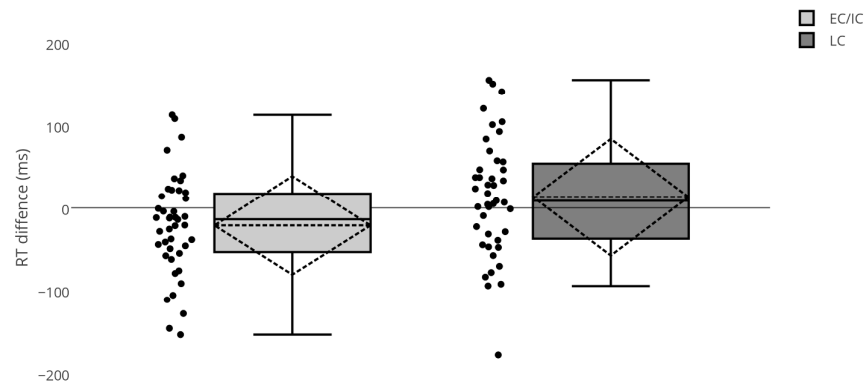

Figure 1. Emotional recognition. Displayed are reaction time difference scores (latency to agreeable – latency to disagreeable words). EIC shown in light grey, LC dark grey. Boxes show interquartile range, solid line median value, dotted line mean and standard deviation, whiskers +/- 1.5 x the interquartile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

37   Chronotype
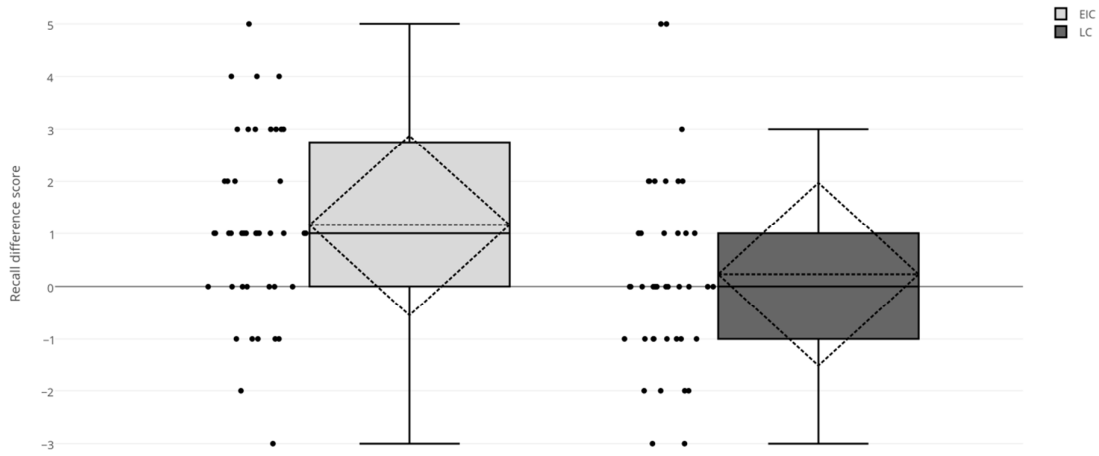

Figure 2. Emotional recall. Displayed are recall difference scores (recall accuracy to agreeable – recall accuracy to disagreeable words). Boxplot details as in Figure 1.

38   Chronotype
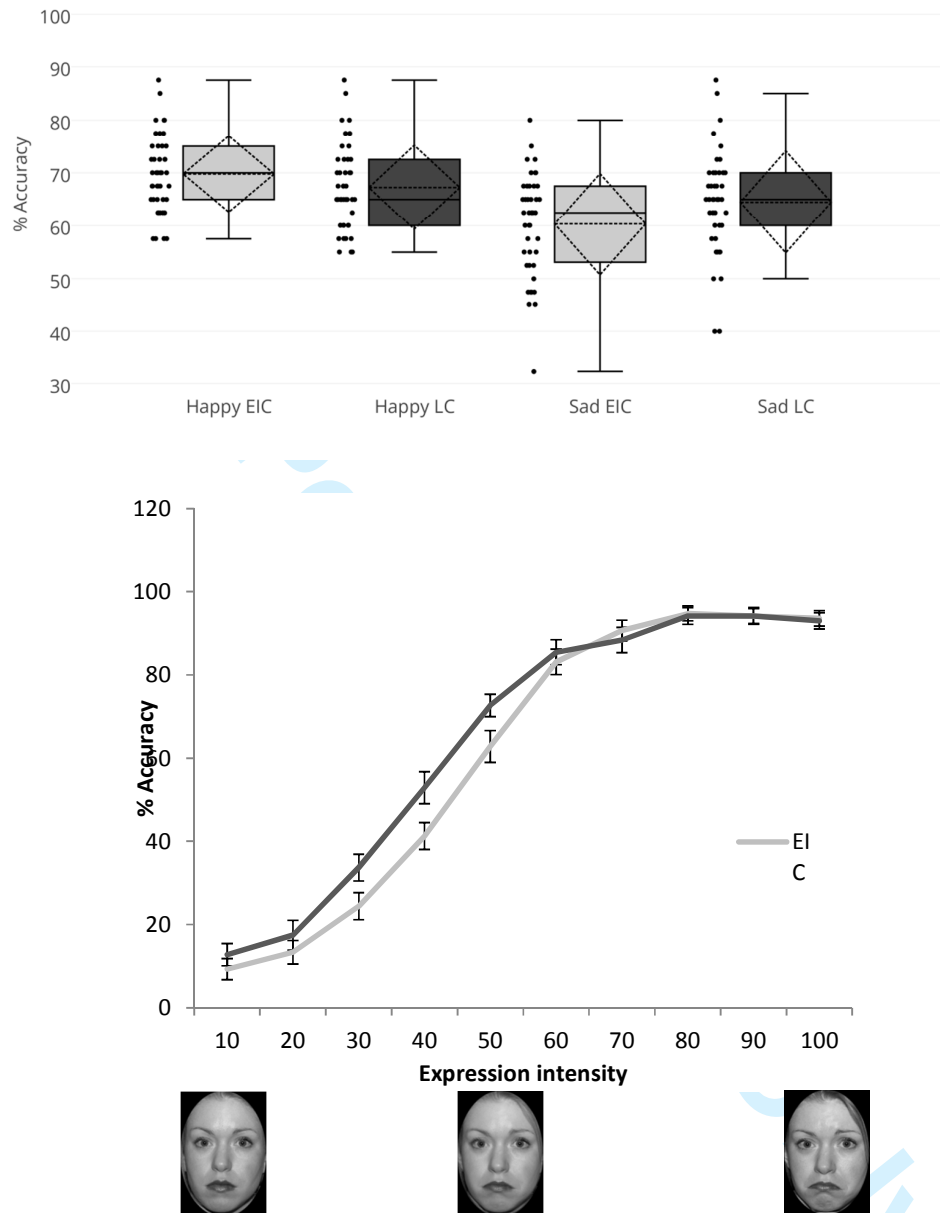

Figure 3. Facial expression recognition. 3A. Displayed are percentage accuracy. It can be seen that EIC show reduced recognition accuracy to sad faces as compared to LC. Boxplot details as in Figure 1. 3B. Intensity-accuracy response curves for LC as compared to EIC. A clear shift to the left (i.e. increased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

39   Chronotype

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.