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11 **The Effect of Mild Depression on Time Discrimination**

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Abstract

Depressed mood states affect subjective perceptions of time but it is not clear whether this is due to changes in the underlying timing mechanisms, such as the speed of the internal clock. In order to study depression effects on time perception, two experiments using time discrimination methods with short (<300 ms) and long (>1000 ms) durations were conducted. Student participants who were categorised as mildly depressed by their scores on the Beck Depression Inventory were less able than controls to discriminate between two longer durations but were equally able to discriminate shorter intervals. The results suggest that mildly depressed or dysphoric mood do not affect pacemaker speed. It is more likely that depression affects the ability to maintain attention to elapsing duration.

Keywords: Time perception, depression, dysphoria, discrimination, timing, internal clock

The Effect of Mild Depression on Time Discrimination

“Time is a necessary representation, lying at the foundation of all our intuitions” (Kant, 1787/1982). In other words, there is a basic temporal component to all human experience. For example, timing processes are intimately linked to the perception that events are simultaneous or occur in succession, with implications for learning and perceived causality (e.g., Eagleman & Holcombe, 2002; Michotte, 1963; Vallee Tourangeau, Murphy, & Baker, 2005). Indeed, functions as simple as crossing a busy road, driving or waiting for a reply all depend upon judging time in one form or another (Zakay & Block, 1997). In spite of its centrality, time perception is affected by individual differences (e.g., Hancock & Rausch, 2010) and psychopathology (Lehmann, 1967; A. Lewis, 1932). For example, mood states have been shown to influence time perception (e.g., Bschor et al., 2004; Sévigny, Everett & Grondin, 2003). Exploring how changes in mood affect timing processes may be useful in terms of understanding the underlying timing processes themselves (Meck, 2005) but also in terms of understanding how moods and cognitions interact and how mood states are exacerbated by these changes.

Clinical levels of depressed mood have long been associated with disturbances in time experience (e.g., A. Lewis, 1932) which is usually experienced as a feeling of time passing more slowly than usual (e.g., Hoffer & Osmond, 1962; Mezey & Cohen, 1961). Evidence suggests that such subjective changes in time experience may be linked to changes in objective time judgements (e.g., Bschor, et al., 2004; and see Meck, 2005 for a discussion). There is considerable confusion within the time perception and depression literature in relation to terminology (Bschor et al., 2004) and it is therefore important to define these terms clearly. Here, the term *objective* time judgement refers to “The objectively measurable capacity of a subject to judge the

length of a given time span” (Bschor, et al., 2004, p. 223). For example, participants might be asked to make a verbal estimate (VE) of the duration of a signalled time interval or to produce a time interval of a given duration (production estimate: PE), using a key press for instance. Many studies examining the effects of depression on objective time judgement have used versions of these methods. Usefully, a comparison of VE and PE performance can be used to make theoretical inferences about the state of the underlying timing processes.

In particular, some theories of time perception postulate the existence of an internal clock process. This is composed of a pacemaker that produces pulses in an analogous manner to ticks on a chronometric clock (e.g., Gibbon, 1981; Treisman, 1963; see Allan, 1998 and Grondin 2010 for a discussion). Pulses are thought to be gated to an accumulator via an attentional switch. When an elapsed duration has finished, the switch opens preventing more pulses from entering the accumulator, the contents of which represent perceived duration of an interval(see Figure 1, adapted from Allan, 1998). That representation is copied to a short-term memory store and can be compared to previously stored durations via a comparison process; then a judgement or decision about the interval can be made.

Insert Figure 1 here

One idea is that a pacemaker running at a different pace, relative to non-depressed mood, could produce a slowed perception of time. This would also result in a specific pattern of findings on VE and PE tasks. For example, with a faster clock, more pulses would be accumulated in a given VE interval resulting in higher estimates of the presented duration. Conversely, in the PE task, more pulses would be produced in a shorter time period, meaning that the produced duration would be

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3 shorter (e.g., Bindra & Waksberg, 1956) compared with non-depressed people.
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6 Therefore, a distinct pattern of over-estimates on the VE task and under-estimates on
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8 the PE task could be suggestive of a rapidly pulsing internal clock resulting in the
9
10 subjective experience of time elapsing slower than usual in depression (Kitamura &
11
12 Kumar, 1983).
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15 A brief review of published studies examining depression and time perception
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17 using VE and PE methods, shown in Table 1, is suggestive of this pattern though
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19 there are inconsistencies in the findings. Note that Table 1 does not include (i) studies
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21 where people's performance were compared during a depressive episode and in
22
23 recovery (e.g., Mezey & Cohen, 1961); or (ii) studies including people with
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25 depression and some other health issue, such as migraine (e.g., Anagnostou &
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27 Mitsikostas, 2004). The review includes sample sizes, details of the specific tasks
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29 used and the durations tested.
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36 Insert Table 1 here
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40 Overall, participants in these studies made time estimates of durations ranging
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42 from 1s to 60 minutes. Verbal estimates involving longer durations in the minutes
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44 range were obtained retrospectively such that participants were not warned in advance
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46 that an estimate would be required. Shorter durations in the seconds range were
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48 estimated prospectively and participants were informed about the task in advance (see
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50 Grondin, 2010). Five of the 10 studies using the VE procedure reported that depressed
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52 individuals *over-estimated* durations in the seconds to minutes range (Bschor, et al.,
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54 2004; Dilling & Rabin, 1967; Kitamura & Kumar, 1983; Munzel, Gendner, Steinberg,
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56 & Raith, 1988; Wyrick & Wyrick, 1977) while two studies reported that depressed
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58 people *under-estimated* intervals of similar durations (Lehmann, 1967; Tysk, 1984)
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3 and three studies reported no mood effects (Bech, 1975; Hawkins, French, Crawford,
4 & Enzle, 1988; Prabhu, Agarwal, & Teja, 1969). Findings from studies using the PE
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6 procedure were similarly inconsistent. Three studies reported that depressed
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8 participants *under-estimate* durations between 10 and 90 s (Bschor, et al., 2004; Kuhs,
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10 Hermann, Kammer, & Tolle, 1991; Tysk, 1984), another recorded significant
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12 variability in depressed people's estimates (e.g., Sévigny, Everett & Grondin, 2003),
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14 and four studies reported no mood effect at all (Kitamura & Kumar, 1983; Munzel, et
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16 al., 1988; Prabhu, et al., 1969). Thus, while there is some evidence for verbal *over-*
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18 *estimation* and production *under-estimation*, this evidence is inconsistent and some
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20 studies do report contradictory findings.
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27 This inconsistency may, in part, be due to the confounding effects of
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29 medication with clinical samples as well as the experimental methods used. For
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31 example, the neurotransmitter systems implicated in timing (e.g., Ho, Velazquez-
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33 Martinez, Bradshaw, & Szabadi, 2002) are also related to depression itself and
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35 pharmacological antidepressant treatment. In addition to this, and perhaps more
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37 importantly, VE and PE experimental methods must be treated with caution in terms
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39 of pacemaker effects. For appropriate performance, durations experienced within the
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41 experimental setting must be attended to and then compared to remembered durations.
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43 Any aspect of these processes could easily be a source of between group differences.
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45 It has also been noted that experimental manipulations, which have no logical link to
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47 pacemaker speed, can produce pacemaker-like effects in VE tasks (Matthews, 2010,
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49 In press). Moreover, a change in pacemaker speed is thought to produce only transient
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51 changes in time perception in relation to real time as the timing system soon
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53 recalibrates (Killeen, Fetterman, & Bizo, 1997). The final point to make here is that
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55 the inconsistency of the findings summarised in Table 1, certainly do not allow for
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3 any strong theoretical conclusions. The review does show, however, that disturbances
4 in time perception are not simply subjective feelings but can be detected through
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6 objective time judgements.
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10 In recent years, researchers interested in depression have begun to use
11 experimental methods more frequently used in the classical timing literature (Gil &
12 Droit Volet, 2009; Rammsayer, 1990; Sévigny et al., 2003). Temporal discrimination
13 tasks are one example and go some way to accounting for the interpretational
14 problems with VE and PE methods. Participants are exposed to a series of standard
15 and comparison durations in the milliseconds to seconds range, which differ in
16 duration by several hundred milliseconds. They are then simply asked to decide
17 which of the two durations is the longer. After a number of trials, during which the
18 difference between the two stimuli is either reduced or increased depending on
19 performance accuracy, a time discrimination threshold can be calculated which
20 indicates the smallest difference that can reliably be perceived which corresponds to
21 around 75% correct (Wetherill, Chen, & Vasudeva, 1966). The rationale for using this
22 task is that if the internal clock is running at a faster pace, producing more pulses per
23 second, it provides relatively finely tuned temporal discrimination (Rammsayer,
24 Hennig, Haag, & Lange, 2001). A clock running at a slower pace would produce the
25 opposite effect and the individual would be less able to discriminate between two
26 similar intervals. Importantly, such effects would not be influenced by any
27 recalibration of timing processes in relation to chronometric time.
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53 Two currently published studies have reported depression effects on temporal
54 discrimination performance. For example, Rammsayer (1990) found that patients with
55 major depression with melancholia displayed impaired performance in comparison to
56 controls on a time discrimination task where the standard duration was 1000 ms.
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3 Sévigny, Everett and Grondin (2003) used a non-clinical, analogue sample and a
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5 different variant of the discrimination task. Their participants were asked to judge
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7 whether each standard stimulus was short or long; duration was not adjusted during
8
9 the procedure. The percentage of correct responses did not differ between groups
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11 when stimuli were in the 80 to 120ms or 450 to 550 ms range. However, Sévigny et
12
13 al., found that depressed participants made fewer correct responses when stimuli were
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15 in the 1120 to 1280 ms range. Taken together these two studies provide some
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17 indication that depression is associated with worse time discrimination when
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19 durations are greater than 1000 ms but that performance is unaffected with shorter
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21 durations.
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27 This distinction between short and long discrimination is interesting because
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29 there are implications for the underlying processes affected by depression. This is
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31 because evidence from numerous sources suggests that distinct processes involving
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33 sensory memory underpin the processing of millisecond durations in comparison to
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35 those in the seconds range that involve attention and short term memory (see
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37 Rammsayer et al., 2001 for a discussion). Therefore any differences between the
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39 ability to discriminate between millisecond and seconds durations could indicate
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41 attentional (P. A. Lewis & Miall, 2003a, 2003b) or cognitive causes (Sévigny et al.,
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43 2003)of the effect of depression on timing(but see also Rammsayer & Ulrich, 2005)
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45 rather than an effect related to the speed of a pacemaker.
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51 However, this requires further experimentation. Sévigny et al.,'s study, which
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53 provides the only direct short versus long comparison, used a sample of student
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55 participants categorised as scoring low or high on the Beck Depression Inventory.
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57 Although this procedure involves non-random group assignment, they did not control
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59 for other potentially confounding between group differences. For example, temporal
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3 discrimination performance has been linked to general intelligence (Rammsayer &
4 Brandler, 2007) suggesting that this is an important variable to control.
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8 In the present study we used short and long versions of the same temporal
9 discrimination procedure with mildly depressed and non-depressed students as
10 categorised by their scores on the Beck Depression Inventory. We attempted to
11 control for pre-existing between group differences by taking measures of IQ,
12 education and working memory capacity. The durations and procedural details of the
13 discrimination tasks used in Experiment 1 have been used in other similar
14 experiments (Rammsayer, et al., 2001). Durations were either 'long' in the seconds
15 range (>1000 ms in Experiment 1a) or were 'short' in the milliseconds range (<300
16 ms in Experiment 1b). Where possible, methodological details are combined to avoid
17 repetition.
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31 Experiment 1

32 Method

33 Participants

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38 University students were asked to complete the Beck Depression Inventory
39 (BDI: Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) as part of a mass screening
40 procedure in order to volunteer for participation. Thirty-six students, who were
41 invited to participate, completed the BDI a second time during participation to ensure
42 a stable BDI score. No participants were excluded at this point on the basis of an
43 inconsistent or too high BDI score. Participants were then assigned to the depressed
44 ($n = 18$) and non-depressed ($n = 18$) groups on the basis of their scores on the Beck
45 Depression Inventory (BDI: Beck, et al., 1961). Participants with BDI scores of 9 or
46 above were categorised as mildly depressed while those with scores of 8 or below
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3 were assigned to the non-depressed group with the constraint that half the participants
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5 in each group were female. We collected data on a range of relevant variables
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7 including age, digit span scores(Lezak, 1995), premorbid IQ as measured by the
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9 National Adult Reading Test (Nelson, 1982) and years of education in order to be
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11 aware of any pre-existing between group differences. In Experiment 1a, groups were
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13 matched on these variables (all $t < 1.97$) and differed on BDI scores ($M = 17.2$, $SE =$
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15 1.8 and $M = 4.7$, $SE = .5$) for the depressed and non-depressed group respectively:
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17 $t(34) = 6.61$, $p < .001$). BDI scores in the depressed group ranged from 9 to 40, with 7
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19 of those 18 participants scoring in the moderate range. However, in Experiment 1b,
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21 although groups were matched on age and education, all $t < 1$, the depressed group
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23 produced lower digit span ($M = 6.3$, $SE = .2$) and NART scores ($M = 25.8$, $SE = 1.9$)
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25 than the non-depressed group (digit: $M = 7.3$, $SE = .2$, $t(34) = 2.94$, $p < .001$; NART:
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27 $M = 31.3$, $SE = 1.9$, $t(34) = 2.05$, $p < .05$). The mood groups in Experiment 1b also
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29 differed on BDI scores ($M = 15.2$, $SE = 1.1$ and $M = 4.9$, $SE = .7$ for the depressed and
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31 non-depressed group respectively: $t(34) = 7.81$, $p < .001$). BDI scores in the depressed
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33 group ranged from 9 to 29, and of those 7 participants fell into the moderately
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35 depressed range.
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43 44 45 **Apparatus**

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47 The visual stimuli consisted of a 10cm diameter red circle and a 10 cm blue
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49 square presented on the computer screen. The two auditory stimuli were created
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51 using RealBasic NotePlayer, instruments 57 and 58. Both were played at middle C
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53 (pitch 60 in RealBasic) at the same velocity of 127 (this refers to the intensity or
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55 loudness of the sound stimulus which could vary from 0 to a maximum of 127) and
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57 were presented through headphones. On 50% of trials, the circle and instrument 57
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59 signalled the standard duration, and on the other 50% of trials, the square and
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3 instrument 58 signalled the standard duration. Auditory and visual stimuli were
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5 presented simultaneously. This simultaneous presentation of auditory and
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7 visualstimuli is relatively unusual but identical to that used by Smith and colleagues
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9 (Smith, Taylor, Rogers, Newman, & Rubia, 2002) in their work with children with
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11 ADHD. Their concern, shared here, was to make the task suitable for participants who
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13 may have some difficulty in maintaining attention. We also wanted to use a suitable
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15 variant of the time discrimination task that has detected differences between controls
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17 and relatively high functioning diagnostic categories.
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23 **Procedure**

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26 Participants arrived in the lab and completed the BDI. They were then given
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28 instructions for the time discrimination task which involved participants being asked
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30 to judge the difference between standard and variable comparison durations presented
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32 sequentially. On each of 32 trials, both durations were marked by the simultaneous
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34 presentation of both an auditory and visual stimulus. The visual stimuli were a red
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36 square or blue circle presented on the computer screen, accompanied by a sound of
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38 the same duration. In order to avoid time order error (the finding that the presentation
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40 order of standard and comparison intervals biases discrimination judgements, see
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42 Allan, 1977; Eisler, Eisler, & Hellstrom, 2008), presentation order was partially
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44 randomised with the constraint that the standard interval should be presented first on
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46 50% of trials. In all conditions, the standard duration remained the same throughout
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48 the procedure and the comparison duration was reduced by a factor of X for each
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50 correct answer, and increased by 3X for each incorrect answer.
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Experiment 1a.

In the long version of the task, the standard duration was always 1000 ms and the variable comparison duration was initially set to 1400 ms. For trials 1 to 4, the downward 'step' was 100 ms, while the upward step was 300 ms. For trials 5 to 32, the downward step was 25 ms and the upward step was 75 ms.

Experiment 1b.

In the short version of the task, the standard duration was 50 ms and the variable comparison duration started at 75 ms. For trials 1 to 4, the downward step was 3 ms, while the upward step was 9 ms. For trials 5 to 32, the downward step was 2 ms and the upward step was 6 ms.

Participants initiated each trial by clicking on the 'start button' located at the centre of the computer screen. After a 900 ms delay, the first interval was presented, followed, after a 900 ms inter-stimulus-interval (ISI), by the second interval. After the termination of the second interval, a message appeared on the screen asking participants to indicate which stimulus was on the screen for the longer period. Once the judgement was made, the start button returned to the screen so that participants could initiate the next trial. The procedure results in a series of 'runs' of successive correct and incorrect responses. After an incorrect response, the comparison duration was increased with the relevant upward step and after a correct response the comparison duration was decreased by the relevant downward step. Once the procedure was complete, participants were thanked, paid a nominal sum for participation and debriefed.

Data Analysis

Discrimination performance was measured by calculating a mean time discrimination threshold, using the mid-run estimates of the last 20 trials, for each

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3 participant (Rammsayer, et al., 2001). Here, the term run refers to series of correct
4 responses, whereeach mid-run estimate is equivalent to the average difference
5 between the standard and comparison durations judged correctly. The threshold is
6 then averaged over the ‘runs’ generated by each participant. This measure has been
7 shown to be a reliable estimate of the difference duration at which participants are
8 75% correct (Wetherill, et al., 1966). The mid point of the last run was only included
9 in each participant’s average, if it was an unbiased end to the run, rather than a run
10 artificially terminated by the end of the procedure.
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23 Results and Discussion

24 Experiment 1a

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29 The mean discrimination thresholds calculated for each mood group were
30 lower for the non-depressed ($M = 105.7$, $SE = 8.5$) than for the depressed participants
31 ($M = 161.4$, $SE = 20.4$). As these data were not normally distributed, $W(36) = .83$,
32 $p < .001$, thresholds were converted to natural logarithms after which the distribution
33 approximated normality, $W(36) = .984$, $p = .866$. The transformed data were then
34 analysed using an independent samples t-test with mood group (depressed, non-
35 depressed) as the between subjects factor¹. Consistent with observations, the
36 depressed group produced a significantly higher discrimination threshold than the
37 non-depressed group, $t(34) = 2.51$, $p = .017$.
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51 Experiment 1b

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54 The mean discrimination thresholds calculated for each mood group were very
55 similar. Non-depressed participants were able to discriminate reliably between
56 durations that differed by 30.1 ms ($SE = 2.5$), whereas depressed participants were
57 able to discriminate between differences of 27.0 ms ($SE = 2.8$). Raw threshold data
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3 were normally distributed, $W(36) = .957, p = .175$, and were analysed using an
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5 independent samples t-test with mood group (depressed, non-depressed) as the
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7 between subjects factor. The small difference between the depressed and non-
8
9 depressed groups was not reliable, $t(34) = .82, ns$.

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12 The findings of Experiment 1 suggest that discrimination performance is
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14 impaired in depression with durations of over 1000 ms but unaffected with shorter
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16 durations of less than 300 ms. In this experiment, we used relatively unusual
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18 simultaneous presentations of visual and auditory stimuli in order to define the
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20 durations. In spite of this, our findings are consistent with Sévigny et al., (2003) who
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22 also noted a distinction between short and long discrimination performance. However,
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24 in Experiment 1, short and long time discriminations were studied in different samples
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26 and the possibility is that uncontrolled between sample differences are responsible for
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28 the distinction. Depressed participants who participated in the 'short' task had
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30 marginally lower BDI scores ($M = 15.2, SE = 1.1$) than those who completed the long
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32 task ($M = 17.2, SE = 1.8$). This difference, though small, does span the published cut
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34 off scores for mild (BDI = 9 to 15) and moderate depression (BDI = 16+) using this
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36 version of the BDI and could have influenced the difference between the two sets of
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38 findings. A stronger test of the short versus long discrimination distinction requires a
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40 within participants comparison of short and long discrimination performance with a
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42 larger sample. Moreover it is important to include a dependent measure, such as the
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44 Weber fraction, which allows direct comparisons of timing sensitivity across short
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46 and long durations.
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55 Experiment 2

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Method

Participants

Eighty-eight university students were recruited for this experiment and assigned to the depressed ($n = 40$) and non-depressed ($n = 48$) groups using the same criteria as previous experiments. No participants were excluded on the basis of an inconsistent or too high BDI score. In this experiment, we also collected handedness data through participant self report and found that the 3 of the depressed and 6 of the non-depressed participants were left handed, all other participants were right handed. In our initial analyses, we found that left handedness, albeit with only 9 participants, seemed to have a significant influence on the effect of duration on discrimination performance, $F(1, 72) = 4.13, p = .04, \eta^2 = .05$, with those who were left-handers producing higher long thresholds ($M = 203.5$ ms, $SE = 28.4$) than right-handers ($M = 140.8$ ms, $SE = 9.9$) but not short thresholds. Given that there is some evidence that laterality has an influence on time perception with the right hemisphere being related to visual information processing and left hemisphere to specialised timing processes (see Grondin & Girard, 2005; Grondin, Voyer, & Bisson, 2010, In press; Polzella, DaPolito, & Hinsman, 1977), we decided to exclude data provided by left handed participants from further analysis in order to reduce this noise in the data rather than attempt to account for the added variability statistically.

Therefore, the final sample was 79 participants, 42 of whom were assigned to the depressed group (Male: $n = 22$, female: $n = 20$) and 37 participants who were categorised as non-depressed (Male: $n = 20$, female: $n = 17$). The depressed and non-depressed groups were matched on age and education (all $t < 1.16$) but not NART and digit span scores. Depressed participants scored lower on the digit span task ($M = 6.7, SE = .2$) and NART ($M = 25.6, SE = 1.0$) than their non-depressed counterparts

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3 (digit: $M = 7.4$, $SE = .3$, $t(77) = 1.93$, $p < .05$; NART: $M = 31.8$, $SE = 1.0$, $t(77) = 4.47$,
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6 $p < .05$). Depressed participants also scored reliably higher on the BDI ($M = 17.43$,
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8 $SE = .45$) than their non-depressed counterparts ($M = 3.86$, $SE = 1.04$), $t(49.14) =$
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10 11.94, $p < .001$, equal variances not assumed. BDI scores in the depressed group
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12 ranged from 9 to 31, with 20 of the participants scoring in the moderately depressed
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14 range.
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17 18 **Apparatus and procedure**

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21 Apparatus, stimuli and procedures were the same as Experiment 1. As
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23 participants would be completing both the short and long versions of the time
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25 discrimination task, the order of presentation was counterbalanced, with
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27 approximately half of the participants in each mood group completing the short
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29 discrimination first and the others completing the long discrimination first. One
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31 further difference in procedures was that three experimenters were involved in
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33 running the experiment, with HS running 38 participants, GB 17 and RM running 24
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35 participants.
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40 41 **Data analysis**

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43 The aim of this experiment was to replicate the findings of Experiment 1, and
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45 make direct comparisons between short and long duration discrimination
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47 performance. Although short and long discrimination thresholds are both calculated
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49 using the same millisecond scale, they are not directly comparable as the ‘step width’
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51 and parameters used in the procedure and the available variability are quite
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53 different. Therefore, Weber fractions, which are a classical psychophysical measure of
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55 timing sensitivity, were calculated by taking the ratio of the threshold on the standard
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57 duration for each condition (see Grondin, Ouellet & Roussel, 2001 for a discussion).
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Standard natural log transformations were required (see Table 2), as the raw data did not approximate normality. Following successful transformations, the data were analysed using mixed Analysis of Variance, with mood (depressed, non-depressed) as a between subjects factor and duration (short, long) as the within subjects factor. 'Experimenter' and 'counterbalancing order' variables, as well as age and education covariates, were included in the analyses.

Results and discussion

Discrimination thresholds and Weber fractions for short and long discriminations are shown in Table 2. Non-depressed participants produced lower thresholds than depressed participants for long durations but not short. In fact, for short discriminative stimuli, depressed participants performed marginally better than non-depressed. Weber fractions mirrored this pattern, although timing sensitivity was better for all participants with longer durations.

Insert Table 2 here

The Analyses of Variance carried out on the threshold and Weber fraction data supported these observations. Here we report only the analysis of Weber fractions but note where there were differences between the two analyses. The duration by mood interaction was significant, $F(1, 68) = 5.18, p = .026, \eta^2 = .07$. The main effect of duration failed to reach the significance level for Weber fraction data, $F(1, 68) = 3.64, p = .06, \eta^2 = .05$, but as expected long thresholds were reliably longer than short thresholds, $F(1, 68) = 17.58, p < .001, \eta^2 = .21$. The duration by counterbalancing order interaction was also reliable, $F(1, 68) = 6.88, p = .011, \eta^2 = .09$, although as the

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3 interaction involving the counterbalancing variable did not involve mood, it will be
4
5 not be discussed further. Planned comparisons showed that the effect of mood on the
6
7 long discrimination thresholds was relatively small and of borderline significance,
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9 $F(1, 68) = 3.89, p = .053, \eta^2 = .054$, whereas there was clearly no difference
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11 attributable to mood with short durations, $F < 1$. In addition, for both non-depressed
12
13 and depressed participants, the Weber fractions derived from long discriminations
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15 were significantly smaller than from short discriminations (both $F_s > 171$, both
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17 $p_s < .001$). However, the size of these effects was greater for depressed ($\eta^2 = .83$) than
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19 non-depressed ($\eta^2 = .72$) participants.
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25 These data replicate the effects of mood on discrimination performance
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27 identified in Experiment 1. All participants performed similarly on the short time
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29 discrimination task. However, people categorised as depressed were less able than
30
31 the non-depressed to discriminate between durations in the region of 1000 ms. The
32
33 distinction between short and long discrimination performance noted in Experiment 1
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35 is replicated in Experiment 2 in which all participants completed both short and long
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37 conditions.
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41 General Discussion

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43 The data from the two experiments reported here provide evidence for
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45 differences in objective time judgement related to depression but little evidence for
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47 changes in clock speed. In the present study, where mood differences emerged, the
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49 depressed groups were less able to discriminate durations than the non-depressed
50
51 group. At first glance, this might be thought of as consistent with a slower pacemaker,
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53 except that between group differences were restricted to longer durations of over 1000
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55 ms. This finding is consistent with Sévigny et al., (2003) who reported that their
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57 depressed participants were less likely to answer correctly when durations were long
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3 but not short. A change in pacemaker speed should affect both short and long time
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5 discrimination performance. If other aspects of timing, such as the accumulator,
6
7 comparator and decision processes, were affected by depression then those effects
8
9 should also be evident in short and long conditions. This suggests that depression
10
11 affects the remaining components of the model, either attention or memory, and that
12
13 these effects come into play with longer durations.
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17 For example, an attentionally mediated ‘flicker’ in the switch, which provides
18
19 the pacemaker accumulator connection (also see Lejeune, 1998; Meck, 2005 for a
20
21 discussion), would likely be more evident with longer durations. This would reduce
22
23 the number of pulses accrued in a given interval giving the appearance of a slowed
24
25 clock with longer durations and making it more difficult for participants to
26
27 discriminate between those durations. Interestingly, this explanation is also consistent
28
29 with more recent findings from an interval bisection task.
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34 Interval bisection tasks involve the presentation of what are termed ‘short’ and
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36 ‘long’ reference durations. Participants are then presented with a series of
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38 intermediate probe durations and are asked to categorise them as short or long. Gil
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40 and Droit-Volet (2009) found that their moderately depressed participants were less
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42 likely than controls to judge probe stimuli that varied between 600 and 1400 ms as
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44 long. In other words, there was a tendency, correlated with BDI scores, to
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46 underestimate these durations. This effect was interpreted as indicating a reduction in
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48 clock speed whilst also acknowledging that the findings did not exclude an attentional
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50 explanation. It seems then that there is converging evidence which points to attention
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52 as a source of depression related differences in time perception.
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57 However, memory should also be considered in relation to these effects.
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59 During time discrimination and temporal bisection tasks, current durations must be
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3 maintained in working memory (see Figure 1) in order to be compared to the previous
4 duration stored in reference memory. As the role of reference memory has been called
5 into question in temporal bisection due to preserved performance in roving or
6 partition conditions (Allan, 2002; Droit Volet & Rattat, 2007), working memory is the
7 focus here. If working memory capacity or duration were compromised in depression,
8 this could potentially explain the short versus long distinction we have observed.
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18 This does not seem likely for several reasons although there is some evidence
19 of working memory impairment in depression (Channon, 1993; Rose & Ebmeier,
20 2006; and see Gotlib & Hammen, 2009 for a discussion). Firstly, the inter-stimulus
21 interval between standard and comparison durations was the same (900 ms) in both
22 short and long discrimination conditions. Therefore, the WM requirements for
23 maintaining the first stimulus until the second stimulus was presented were the same
24 across short and long conditions. Moreover, in terms of maintaining information over
25 time to ensure appropriate performance, a previous study showed that analogue
26 depressed participants showed no disadvantage when ISIs were 1000 ms long (Msetfi,
27 Murphy, Kornbrot, & Simpson, 2009).
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42 WM capacity requirements did differ across the long and short conditions,
43 however, because longer durations would require more pulses to be maintained until
44 the comparison and decision process. This is unlikely to be the source of the mood
45 differences at longer durations because the performance of depressed participants
46 started with the longest durations being discriminated correctly (1000 to 1400 ms
47 comparison) and only deteriorated as durations and differences decreased (1000 versus
48 around 1160 ms). Impaired WM capacity would presumably mean that shorter
49 durations in this range were more likely to be maintained and therefore discriminated
50 correctly over longer durations. This was not the case in this study and it therefore
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3 seems that attentional, rather than working memory, processes are more likely to
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6 underlie the effects of depression on time discrimination performance.
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8 The key conclusion of the present study is that depression effects on time
9
10 discrimination are not related to changes in clock speed. Depression effects may be
11
12 linked to attention because the attentional switch linking pacemaker and accumulator
13
14 flickers open and closed during elapsing duration (Lejeune, 1998). Or, it might be that
15
16 an attentional gate that channels pulses through to the switch is not optimally wide
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18 open, allowing fewer pulses to pass through (Zakay & Block, 1997). Reduced arousal
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20 in depressive states or attention lapses due to intrusive ruminative thoughts could
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22 produce such effects. In other words, depression effects are probably not specific to
23
24 timing mechanisms but are secondary effects of more general processes.
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29 However, as many other cognitive processes rely on and interact with the
30
31 perception of time, any, albeit general, impairment which impacts on time perception
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33 is likely to have consequences reaching further than the discrimination of short
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35 durations in an experimental task. Consider the potential effect of fewer time pulses
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37 entering the accumulator during short intervals. For example, events separated in time
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39 could appear closer together resulting in an erroneous perception of causality. Waiting
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41 times in between actions, behaviours and subsequent outcomes might appear to be
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43 shorter than usual, inducing passivity rather than activity. Even simple situations like
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45 those we have just described, which occur repeatedly, could potentially result in
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47 feelings of self-blame and helplessness respectively, eventually exacerbating
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49 depressed mood.
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54 People who took part in this study were students scoring low or high on the
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56 BDI and this could be thought of as a limitation. However, our findings of mood
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58 effects on discrimination at intervals of >1000 ms are consistent with findings with
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DEPRESSION AND TIME DISCRIMINATION 22

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3 clinically depressed participants. It is also the case that the low levels of depression
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5 have an extremely high prevalence (e.g., Barrett, Oxman, & Gerber, 1987;
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7 Salokangas, Poutanen, Stenggard, & Jahi, 1996). Understanding the cognitive and
8
9 experiential changes that happen with low levels of depression will elucidate our
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11 understanding of how those changes can escalate to clinical levels of depression.
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13 Furthermore, the current study implicates the importance of attention in mood
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15 differences observed in normal samples of participants. That is, mood effects on time
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17 perception, as measured by the discrimination of time intervals as short as 50 ms, are
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19 a generic cognitive effect rather than effects related to changes in pacemaker or clock
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21 speed.
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Footnotes

¹All analyses in Experiments 1 and 2 were carried out including sex as a variable. Sex on its own did not have a reliable effect on discrimination threshold or in interaction with mood, all $p > .25$. This variable was not of interest in the present study and was not included in any of the analyses reported here.

Table and Figure Captions

Table 1

Sample and methodology information of studies testing the effects of depression on verbal and production estimation of time.

Table 2

Mean thresholds, Weber fraction and normality tests for short and long time discriminations.

Figure 1. Schematic diagram of scalar timing model with clock, memory and decision stages (adapted from Allan, 1998).

Table 1.

Study	Sample	Task	Temporal orientation	Interval content	Duration	Findings
Prabhu et al., (1969)	Clinical psychotic D (<i>n</i> =32), anxiety (<i>n</i> =32), controls (<i>n</i> =18)	VE	Likely retrospective but unclear	Other time tasks	15 mins	No differences
Bech (1975)	Clinical D (S1: <i>n</i> =17 ^a , E2: <i>n</i> =24 ^a), psychiatric controls (S1: <i>n</i> =6), normal controls (S1: <i>n</i> =8),	VE	Likely retrospective but unclear	Driving task Questionnaire	3 mins 5 mins	No differences
Hawkins et al., (1988)	Mood induction: elated (<i>n</i> =28), neutral	VE	Retrospective	Sorting task	4 & 13 mins	No differences

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	(<i>n</i> =28), depressed					
	(<i>n</i> =28)					
Lehmann (1967)	Clinical D (<i>n</i> =14), controls (<i>n</i> =20), other diagnostic groups	VE	Likely retrospective but unclear	Interview and other experimental tasks	Variable, 20 – 60 mins	Over 90% of Ds categorised as under- estimators
Dilling & Rabin (1967)	Clinical D (<i>n</i> =20), schizophrenics (<i>n</i> =20), controls (<i>n</i> =20)	VE	Likely retrospective but unclear	Other time tasks	14 & 31 mins	More Ds categorised as over-estimators
Wyrick & Wyrick (1977)	Clinical D (<i>n</i> =30), controls (<i>n</i> =30)	VE	Prospective for the durations in s	Other time tasks	5, 10, 20, 80, 160, 240s 15 & 30 mins	Ds over-estimated durations between 160s and 30 mins
Kitamura & Kumar (1983)	Clinical D (<i>n</i> =23), controls (<i>n</i> =23)	VE	Prospective	Empty	5, 10, 20, 80, 160, 240s	Ds over-estimated 10, 20 & 80s.

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7	Tysk (1984)	Clinical D with &	VE	Prospective	Empty (but counting	7.5, 17.5, 27.5s
8		without melancholia			encouraged)	Ds with Melancholia
9		(<i>n</i> =56), controls				under-estimated.
10		(<i>n</i> =60)				
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17	Munzel et al., (1988)	Clinical D (<i>n</i> =47),	VE	Retrospective	Empty, picture	240s
18		controls (<i>n</i> =16)			comparison vs	Ds over-estimated only
19					concentration task	empty & picture
20						comparison intervals.
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24	Bschor et al., (2004)	D (<i>n</i> =32) and Manic	VE	Prospective	Empty	8, 43 & 109s
25		patients (<i>n</i> =30),				D and manic patients
26		controls (<i>n</i> =31)				over-estimated 109s
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31	Lehman (1967)	Clinical D (<i>n</i> =14),	PE		Tapping	15s
32		controls (<i>n</i> =20), other				No differences
33		diagnostic groups				
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5	Prabhu et al., (1969)	Clinical psychotic D	PE	Counting	30s	No differences
6		(<i>n</i> =32), anxiety	PE	Tapping	30s	No differences
7		(<i>n</i> =32), controls				
8		(<i>n</i> =18)				
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14	Munzel et al., (1988)	Clinical D (<i>n</i> =47),	PE	Empty	1, 5 & 10s	No differences
15		controls (<i>n</i> =16)				
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18						
19	Kitamura & Kumar	Clinical D (<i>n</i> =23),	PE	Empty	30s	No differences.
20		controls (<i>n</i> =23)				
21	(1983)					
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24	Newman &	Elderly participants	PE	Empty	40s	Positive correlation with
25		(<i>N</i> =68)				BDI scores.
26	Gaudio (1984)					
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28						
29	Tysk (1984)	Clinical D with &	PE	Empty (but counting	10, 20 & 30s	Ds with melancholia
30		without melancholia		encouraged)		under-estimated.
31		(<i>n</i> =56), controls				
32		(<i>n</i> =60)				
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1						
2						
3						
4						
5	Kuhs et al., (1991)	Clinical D ($n=25$),	PE	Counting	30s	Ds under-estimated.
6		controls ($n=12$)				
7						
8						
9						
10	Sévigny et al.,	Analogue D ($n=15$),	PE	Tapping	1 & 10s	Ds more variability.
11		controls ($n=20$)				
12	(2003)					
13						
14	Bschor et al., (2004)	D ($n=32$) and Manic	PE	Empty (but counting	7, 35 & 90s	Ds & manic patients
15		patients ($n=30$),		not prevented)		under-estimated 35 & 90s
16		controls ($n=31$)				
17						
18						
19						
20						

Note: VE = Verbal estimation, PE = Production estimation, D = depressed; In this table, the terms underestimate and overestimate refer to estimates that are less than or greater than the target value (see Tysk, 1984) relative to estimates made by the control group. For VE tasks, the temporal orientation of the time judgement is noted as retrospective (participants are unaware that a time judgement will be required during the elapsing duration) or prospective (participants are informed about the time task before it commences), see Grondin (2010, p. 563).

^aIn the Bech (1975) study, the depressed groups were split into 3 diagnostic groups of around 6 participants each. Significance tests were based on these smaller *ns*.

Table 2.

Mood	Duration	Discrimination Threshold		Weber Fraction		Shapiro-Wilk <i>p</i>	
		<i>M</i>	<i>SE</i>	<i>M</i>	<i>SE</i>	Raw	Ln
ND	Short	32.60	2.45	.66	.05	.001	.338
D	Short	30.56	2.10	.61	.04		
ND	Long	129.23	15.04	.13	.02	<.001	.294
D	Long	159.21	12.88	.16	.01		

Note: ND = nondepressed; D = depressed; Raw = raw data distributions; Ln = natural log transformed distributions; Shapiro-Wilk tests the normality of the distributions.

Figure 1

