Before you know it: cognitive changes in depression

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Declaration

This thesis is submitted to The Australian National University in fulfilment of the Doctorate of Philosophy (Clinical Psychology) degree. Chapters 1, 2 and 7 are my own work apart from the usual contributions of my supervisors. Chapters 3-6 are published articles or manuscripts prepared for submission of which I am the first author; the contributions of co-authors are detailed at the start of each chapter. All ideas that are not my own have been properly acknowledged and referenced.

Michael David Corke

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I would like to thank my supervisory panel for their support in helping me through this journey. They have been inspiring, patient, forgiving, stimulating and challenging – thank you Mark, Stephanie, Rhonda and Jason. I would also like to thank my lovely partner Clare for supporting me throughout my PhD., Clare, you are the best.

Table of contents

Abstract

Depression is a common mental disorder affecting an estimated 350 million people globally (World Health Organization, 2016). Despite the global prevalence and impact of depression, the main treatments, including antidepressant drugs and psychotherapy, are only partly effective (Arroll et al., 2009; Bschor & Kilarski, 2016; Churchill et al., 2013; Churchill et al., 2010) and further research is therefore required to better understand and treat this illness. Although the symptoms of depression are heterogeneous, two specific cognitive symptoms appear to be relatively ubiquitous: (a) an impaired ability to disengage from negative material (Armstrong & Olatunji, 2012; Donaldson, Lam, & Mathews, 2007; Gotlib & Joormann, 2010; Koster, De Lissnyder, Derakshan, & De Raedt, 2011; Koster, De Raedt, Goeleven, Franck, & Crombez, 2005); and (b) a distortion in the processing of temporal intervals, leading to a sensation that time is dragging (Bschor et al., 2004; Kitamura & Kumar, 1982; A. Lewis, 1932; Sévigny, Everett, & Grondin, 2003; Wyrick & Wyrick, 1977).

The specific aims of this thesis were to investigate, using psychophysical methodologies, whether the impairment in disengagement from negative material and the distortions in temporal processing occur at ‘shorter durations’ (less than one second). If this is the case, it might suggest that the impairments are related to changes in the underlying mechanisms associated with attention, cognition, and temporal processing, rather than, or in addition to, the typical ruminative thinking of depression that takes place over ‘longer durations’.

We investigated the relationship between depression symptoms and impaired disengagement from negative and positive emotional material (Chapter 4) using an emotion-induced blindness (EIB) paradigm, which tested stimulus durations of 200ms and 800ms. No evidence was found of any relationship between depressive symptoms

and impaired disengagement from negative or positive emotion stimuli. We also investigated the relationship between depression symptoms and impairments and distortions in temporal processing (Chapter 6). The study used a two-alternative forced choice (2AFC) paradigm to compare the duration of two images, neutral-neutral and neutral-negative. The reference duration was 200ms and the measures of impairment and distortion were point of subjective equality (PSE) shift and Weber fraction (WF). Once again, no evidence was found of any relationship between depressive symptoms and the impairments or distortions.

Together, the findings suggest that depression symptoms were unrelated to an impaired temporal processing mechanism or impaired mechanisms responsible for the disengagement from emotion stimuli. Instead, the findings were more consistent with the cognitive models of depression. Specifically: (a) the impaired disengagement from negative material in depression was more likely to be related to rumination and its effects on attentional control rather than earlier cognitive processes (Donaldson et al., 2007; Koster et al., 2011), and, (b) the perception of time slowing in depressed individuals was likely to be related to the cognitive impairments in sustained attention – especially that people with depression tend to focus on the passage of time (Gallagher, 2012; Msetfi, Murphy, & Kornbrot, 2012).

Chapter 1. Introduction

1.1 Rationale and aims for thesis

Depression is a common mental disorder affecting an estimated 350 million people globally. Most suicides are linked to the experience of depression and more than 800,000 people die from suicide each year. The incidence of depression is increasing and it is estimated that by 2030, depression will be the largest contributor to worldwide disease burden (World Health Organization, 2016).

In the literature, the term *depression* may have either a clinical definition or be defined by a score on a psychometric instrument. A clinical diagnosis of Major Depressive Disorder (MDD) requires a clinical interview such as the SCID-5 (American Psychiatric Association, 2018) and follows the DSM-5 (American Psychiatric Association, 2013) criteria for MDD. The criteria are the individual must be experiencing five or more of the following symptoms during the same two-week period and at least one of the symptoms should be either (1) depressed mood or (2) loss of interest or pleasure:

1. Depressed mood most of the day, nearly every day;
2. Markedly diminished interest or pleasure in all, or almost all, activities most of the day, nearly every day;
3. Significant weight loss when not dieting or weight gain, or decrease or increase in appetite nearly every day;
4. A slowing down of thought and a reduction of physical movement;
5. Fatigue or loss of energy nearly every day;
6. Feelings of worthlessness or excessive or inappropriate guilt nearly every day;
7. Diminished ability to think or concentrate, or indecisiveness, nearly every day; and
8. Recurrent thoughts of death, recurrent suicidal ideation with or without a specific plan.

In addition, these symptoms must cause the individual clinically-significant distress or impairment in social, occupational, or other important areas of functioning. Also, the symptoms must not result from substance abuse or another medical condition.

For convenience, both clinically and in research, psychometric instruments are often used to measure depressive symptoms. Some of these instruments, for example the Beck Depression Inventory - Second Edition (BDI-II) (A.T. Beck, Steer, & Brown, 1996), have cut-off scores that are proposed to equate to a clinical diagnosis of depression. The studies in this thesis have used the BDI-II as a measure of depressive symptoms.

Despite the global prevalence and impact of depression, the main treatments, including antidepressant drugs and psychotherapy, are only partly effective (Arroll et al., 2009; Bschor & Kilarski, 2016; Churchill et al., 2013; Churchill et al., 2010); and neither the biological nor cognitive models of depression fully explain the development and perpetuation of the disorder (Dunn et al., 2015; Gotlib & Joormann, 2010; Koster et al., 2011; Willner, Scheel-Krüger, & Belzung, 2013).

The dominant cognitive model of psychopathology was originally formulated by Aaron Beck to explain depressive illness and it was then generalized to include other psychological disorders. According to Beck, “the processing of external events or internal stimuli is biased and therefore systematically distorts the individual’s construction of his or her experiences” (A. T. Beck, 1967, 2005). In depression, this distortion can result in the typically-negative cognitions, rumination, and low mood (A. T. Beck, 2005; Haaga, Dyck, & Ernst, 1991; Hollon, Kendall, & Lumry, 1986).

Beck’s model is supported by 40 years of research (A. T. Beck, 2005; Haaga et al., 1991; Hollon et al., 1986) and it forms the basis of Cognitive Behavior Therapy (CBT), which is the most widely used psychological treatment for depression (Churchill et al., 2010; Cuijpers et al., 2013). However, CBT to treat depression is only effective in approximately

50% of cases (Churchill et al., 2010; Cuijpers et al., 2013). Thus, it is essential that we critically examine the areas in which Beck's model requires refinement and then integrate the findings into tailored CBT protocols and other psychotherapies to treat depression.

To date, research has focused around the symptoms of depression at longer durations, typically minutes or hours, with few studies investigating symptoms that occur at durations of less than one second. A duration of less than one second is relevant as the cognitive models of depression suggests that the distortions and impairments in depression are linked to rumination and therefore thoughts that are within conscious awareness (Koster et al., 2011). Durations of less than one second do not provide time for rumination to occur. Consistent with this research, modifying these thoughts is a core component of CBT (J. S. Beck, 2011).

However, few studies have examined whether depression is linked to an alteration/s in early cognitive processing. Thus, the characteristic impairments and distortions in depression in the early stages of stimulus processing have received limited research attention, and the timing of onset of the processes is unknown. Although the symptoms of depression are heterogeneous, two specific cognitive symptoms appear to be relatively ubiquitous: (a) an impaired ability to disengage from negative material (Armstrong & Olatunji, 2012; Donaldson et al., 2007; Gotlib & Joormann, 2010; Koster et al., 2011; Koster et al., 2005); and (b) a distortion in the processing of temporal intervals, leading to a sensation that time is dragging (Bschor et al., 2004; Kitamura & Kumar, 1982; A. Lewis, 1932; Sévigny et al., 2003; Wyrick & Wyrick, 1977).

The specific aims of this thesis were to investigate whether the impairment in disengagement from negative material and the distortions in temporal processing occur at shorter durations of less than one-second. If this is the case, it might suggest that the impairments are related to changes in the underlying mechanisms associated with attention, cognition, and temporal processing, rather than, or in addition to, the typical ruminative thinking of depression. In other words, is it the case that the cognitive impairments and distortions are occurring “before you know it”.

As detailed below, the studies in this thesis used psychophysical methodologies to measure disengagement from negative material and temporal processing. Established psychometric scales were used to measure the symptoms of depression and the typical participants were young adults studying at the Australian National University.

1.2 Thesis structure

There are seven chapters in this thesis. Chapter 2 explains the relevant theoretical models of depression and reviews the literature relevant to our understanding of the cognitive distortions and impairments associated with depression. It highlights how the majority of studies in the psychological literature have tested longer durations (typically seconds, minutes or hours) and it compares the findings at these longer durations to findings at very short durations (<1000ms). The chapter is structured to lead directly into the study covered by the manuscript in Chapter 3 of the thesis. Manuscripts in Chapters 4, 5 and 6 of the thesis include summaries of the literature pertaining to the relevant study in each chapter. The chapters build upon the base provided by Chapter 2 and to avoid duplication, the literature was not repeated in Chapter 2.

Chapter 3 (Study 1) investigates a technical aspect of the EIB task. During a pilot experiment for Study 2, it was noted that the EIB effect appeared to be reduced when negative and positive distractors were mixed, within the same experimental block. This effect was investigated and the finding informed the methodology used in Study 1.

Chapter 4 (Study 2) investigates the hypothesis that impaired disengagement from negative material in people with depression symptoms is related to rumination. If this hypothesis is correct, we would not expect to see an effect of the distortion at very short durations (< 1000ms), before rumination is thought to commence. An emotion-induced blindness (EIB) paradigm was used in this study to measure disengagement from emotional images at 200ms and 800ms and to analyse the relationship between disengagement and depression symptoms.

Chapter 5 (Study 3) investigates the effect of emotionally-valenced stimuli on the perception of duration. A series of intervals from 50-1000ms was utilised. This study was employed to determine the appropriate duration to utilise when investigating the relationship between depression symptoms and the perception of duration.

Chapter 6 (Study 4) investigates the hypothesis that distortions in temporal processing associated with depressive symptoms are related to attentional deficits and not to changes in the underlying temporal mechanism. If the impaired temporal mechanism hypothesis is correct, we would expect to see the effects of the distortion at all durations, including very short durations (< 1000ms). The investigation utilised a two-alternative fixed-choice (2AFC) method to compare the duration of two images, and the relationship between duration distortions and depression symptoms was analysed.

Chapter 7 outlines a summary of the findings and a discussion regarding the cognitive theories of depression. The discussion includes the general implications of the study findings that are not covered in detail in the individual chapters and directions for future research.

1.3 Thesis format and publication details

Studies 1-4 were prepared as individual manuscripts for journal publication. The contents of these chapters are identical to the published or submitted-for-publication manuscripts, except that the page numbering has been changed to be consistent with the overall thesis and references have been consolidated at the end of the thesis.

At the time of writing, publication details for each chapter are:

Study 1

Corke, M., Goodhew, S. C., Bell, J., Brown, R. & Edwards, M. (2018). The Influence of Prior Images on Emotion-Induced-Blindness. Unpublished.

Study 2

Corke, M., Goodhew, S. C., Bell, J., Brown, R. & Edwards, M. (2017). Depressive symptoms are associated with impaired disengagment from briefly-presented emotional images. Unpublised.

Study 3

Corke, M., Bell, J., Goodhew, S. C., Smithson, M., & Edwards, M. (2016). Perceived time slows during fleeting fun or fear. *The Quarterly Journal of Experimental Psychology*, 1-22.

Study 4

Corke, M., Goodhew, S. C., Bell, J., Brown, R. & Edwards, M. (2017). Time slows in depression but only when attentional limits are exceeded. Unpublished.

Chapter 2. Literature review: cognitive impairments and biases in depression

2.1 Chapter overview

This chapter provides a brief summary of the current state of research into the causes, symptoms, maintaining factors and treatment of depression. It then provides a more detailed review of the literature covering the cognitive impairments and biases that are associated with depression. It explains the relevant cognitive models of depression and how they are related to studies in this thesis. The chapter highlights how the majority of relevant studies use longer durations (typically seconds, minutes or hours) and how the findings at longer durations are different from the findings at very short durations (<1000ms). It then focuses on the literature underpinning the first of the two specific cognitive symptoms of depression covered by this thesis – impaired disengagement from negative material at short intervals.

2.2 Definitions

The term *depression* may have either a formal clinical definition or be defined by a score on a psychometric instrument. A formal clinical diagnosis of Major Depressive Disorder (MDD) requires a clinical interview such as the SCID-5 (American Psychiatric Association, 2018) and follows the DSM-5 (American Psychiatric Association, 2013) criteria for Major Depressive Disorder. A diagnosis of MDD under the DSM-V (American Psychiatric Association, 2013) requires:

A. Five or more of the following symptoms to have been present for at least two weeks and at least one of the symptoms to have been either a depressed mood or a loss of interest or pleasure:

    1. Depressed mood most of the day, nearly every day;
    2. Markedly diminished interest or pleasure in all or most activities;
    3. Significant weight loss or gain;

4. Insomnia or hypersomnia;
5. Psychomotor agitation or retardation;
6. Fatigue or loss of energy;
7. Feelings of worthlessness or excessive guilt;
8. Diminished ability to think or concentrate; and
9. Recurrent thoughts of death or suicidal ideation.

B. The symptoms must cause clinically-significant distress.

C. The episode must not be attributable to the physiological effects of a substance or another medical condition.

D. The occurrence of the episode must not be better explained by a psychotic disorder.

E. There must never have been a manic episode.

Criteria A–C represent a Major Depressive Episode and the DSM-V provides additional specifiers for the severity and course of the illness.

For convenience, both clinically and in research, psychometric instruments are often used to measure depressive symptoms. In some cases instruments have cut-off scores that are proposed to equate to a clinical diagnosis of depression, for example the Beck Depression Inventory - Second Edition (BDI-II) (A.T. Beck et al., 1996). The studies in the literature that are covered in this thesis typically use either a diagnosis of MDD or a cut-off score on a psychometric instrument to define either depression or depression symptoms. In some cases, particularly with meta-analyses, they may use mixed definitions. Where relevant, the definition method has been included in the description of the study from section 2.6 onwards.

2.3 Individual and societal impacts of depression

Depression is a common mental disorder affecting an estimated 350 million people globally. The incidence of depression is increasing and it is estimated that by 2030, depression will be the largest contributor to worldwide disease burden. Most suicides are linked to the experience of depression and over 800,000 people die from suicide each year (World Health Organization, 2017). The most recent Australian Bureau of Statistics figures show that 8.9% of the Australian population reported experiencing depression in 2014-15 (Australian Bureau of Statistics, 2015).

2.4 Depression treatment

Despite the extraordinary individual and societal impacts of depression, the two main broad-based treatments, antidepressant drugs and psychotherapy, are only partly effective. Results vary between the studies but typically only 20-50% of individuals receiving drug treatment or psychological therapy will experience remission after a single course of treatment, and approximately 75% will experience a relapse (Arroll et al., 2009; Bschor & Kilarski, 2016; Churchill et al., 2013; Churchill et al., 2010). Reasons underpinning the poor responses to therapy relate to the heterogeneous nature of the illness and a limitation in our understanding of the illness and its treatments (Bschor & Kilarski, 2016; Churchill et al., 2010; Dunn et al., 2015). In fact, there have only been two major breakthroughs in the treatment of depression in the past 50 years: the development of CBT and antidepressant drugs. The most common and efficacious therapy, CBT, was introduced in the 1960s (A. T. Beck, 1967), whereas the current generation of selective serotonin reuptake inhibitor (SSRI) antidepressants was first approved for use in 1987 (Carlsson, 1999). As neither treatment is effective for one-half of the depression patients, it is essential for research to continue into all aspects of depression, in order to permit a comprehensive understanding of the disorder and to refine existing treatments and develop new more effective treatments.

2.5 Models of depression

Depression can be conceptualised from the perspective of a diathesis-stress model (Monroe & Simons, 1991). That is, an individual’s diatheses or vulnerabilities (e.g. high stress-reactivity) can interact with stressors in their life, which may lead to depression. One key vulnerability is likely to be genetics; as people with depression are three-times more likely to have a close relative with depression than those without depression (Sullivan, Neale, & Kendler, 2000); and twin studies suggest that approximately 40% of the risk of experiencing depression is genetically based (Rice, Harold, & Thapar, 2002). The second key vulnerability is thought to be environmental factors during childhood, including abuse, poverty, negative family relationships, divorce, and generally stressful events (Dunn et al., 2015; Heim & Binder, 2012). These childhood factors are associated with an increased depression risk during childhood and this risk is maintained throughout later life (Dunn et al., 2015; Kim Park, Garber, Ciesla, & Ellis, 2008). Additionally, certain stressors in later life are likely to be associated with an increased depression risk, including difficulties with relationships, finances, health, housing and employment (Caspi et al., 2003; Monroe & Simons, 1991). Importantly, it is not the stressor itself that is thought to be responsible for the development of depression, rather the individual's reaction to the stressor. For example, the way in which a person cognitively appraises a stressor and its consequences and/or the manner in which they cope with it can increase the risk of depression, more so than the intensity of the stressor itself (Willner et al., 2013).

In addition, current theory suggests that the link between environmental stressors and the biology of depression is the inflammatory response system (e.g. cytokine theory of depression; (Maes et al., 2016; Slavich & Irwin, 2014; Willner et al., 2013)). The inflammatory response system is thought to have evolved to respond to short-term physical threats such as infection and predators. However, in the case of persistent high stress, an inflammatory response (e.g. release of interleukin-1 and related cytokines) may occur that involves the brain, which may lead to an alteration in blood flow and brain structure and functioning, potentially leading to depression (Maes et al., 2016; Slavich & Irwin, 2014).

Structural brain changes include a reduction in hippocampus connectivity, and atrophy and a loss of neurons and glial cells in the limbic system (Arnold et al., 2012; Banasr, Dwyer, & Duman, 2011). Neural changes include an increase in the influence of sub-cortical emotional processing regions, with an attenuation in top-down control from the pre-frontal cortex (Disner, Beevers, Haigh, & Beck, 2011). As with all mental illnesses, biological models of depression may be supplemented with a parallel cognitive model. Ultimately, the two models should be integrated to provide a comprehensive understanding of the aetiology, maintenance and successful treatment of the illness; although such an approach has rarely been used.

Several cognitive models of depression also exist, with the best-established being Aaron Beck's model. According to Beck's *cognitive model of psychopathology*, "the processing of external events or internal stimuli is biased and therefore systematically distorts the individual's construction of his or her experiences" (A. T. Beck, 1967, 2005). In people with depressed mood, the model suggests that the distortion results in typical negative cognitions, depressive-rumination and low mood, and the symptoms of depression (e.g. distress) contribute to a positive-feedback loop that reinforces the cognitive distortions and maintains the biological stressor.

Cognitive impairments and distortions of depression are therefore a part of a complex system of interactions between the depressive cognitions, genetics, stressors, individual responses to stressors, and the biology of neural mechanisms and inflammation. Thus, given the level of complexity of the interactions, it is not surprising that there are few comprehensive psycho-biological models of depression causation (Dunn et al., 2015; Wittenborn, 2016). Nonetheless, it is clear that a better understanding of the cognitive impairments and distortions occurring in depressed individuals is required in order to optimize depression treatment.

2.6 Cognitive impairments and biases in depression

There is extensive literature covering many decades of research on the cognitive impairments and biases associated with depression – for a comprehensive review see Gotlib & Joorman (2010) (both MDD and depression symptoms). Depression is typically associated with a general cognitive deficit across most aspects of memory and concentration; however, people with depression find it easy to concentrate on negative, self-focused thoughts and they display enhanced recall of negative material (Burt, Zembar, & Niederehe, 1995; Mathews & MacLeod, 2005) (both MDD and depression symptoms).

Specifically, a meta-analysis of cognitive deficits in depression cases identified significant deficits with small-to-medium effect sizes for psychomotor speed, attention, visual learning and memory, and executive functioning; however, working memory, verbal learning and memory were not significantly affected (Lee, Hermens, Porter, & Redoblado-Hodge, 2012) (MDD). Memory impairments are reported to be typically greater when attention is not constrained by the task, when increased cognitive effort is required, or when attention is easily allocated to personal concerns (Gotlib & Joormann, 2010) (MDD). In addition to memory impairments, there is a negativity bias to memories, with a preferential recall of negative material (Mathews & MacLeod, 2005; Matt, Vázquez, & Campbell, 1992) (both MDD and depression symptoms).

Another feature of depression is biased attention. A meta-analysis of dot-probe (k=12, n=937) and Stroop studies (k=16, n=863) showed consistent attentional biases to negative stimuli in depression with a medium effect size in the dot-probe studies (d=.52, p<.001) and a small non-significant effect in the Stroop studies (d=.17, p=.06) (Peckham, McHugh, & Otto, 2010) (both MDD and depression symptoms). Most of the research into attentional biases has been based on paradigms that measure changes in response time. While this is of some value, it fails to capture the information that is related to the duration of eye-gaze, which is a key component of visual attention; although eye-tracking technology has subsequently permitted this supplementary information to be collected. A recent meta-analysis of studies (*k*=33, *n*=1579) showed that during free vision, relative to controls, depressed individuals showed no increase in vigilance to threat, but they did show a shorter engagement with positive material and a longer engagement with negative material (Armstrong & Olatunji, 2012) (both MDD and depression symptoms). Thus, when reviewed as a whole, the body of evidence suggests that people with depression do not preferentially direct their attention to negative information but are impaired in disengaging from the information (Gotlib & Joormann, 2010).

2.7 Links to rumination

Studies suggest that depressive-rumination is closely related to cognitive impairments in depression (Donaldson et al., 2007; Koster et al., 2011; Koster et al., 2005) (both MDD and depression symptoms). Rumination in this context can be defined as a person focusing their thoughts on their depressive symptoms, often with the intention of trying to understand the implications and meaning of the symptoms. (Koster et al., 2011). The impaired disengagement hypothesis suggests that impaired disengagement from negative, self-related material, causes and maintains rumination in depressed individuals (Koster et al., 2011). Rumination is thought to be a key part of a positive-feedback loop that reinforces and maintains the cognitive impairments and biases. Other supporting evidence for the relationship between rumination and depression comes from the finding that removing the opportunity to ruminate can reduce the level of impairment in depression (Gotlib & Joormann, 2010), suggesting that people with depression retain the ability to concentrate and remember but they are distracted by their personal concerns.

2.8 Implications for depression-related cognitive impairments and biases at shorter intervals

Rumination is by definition a conscious process that occurs within a timeframe that permits awareness, processing, and the reprocessing of thoughts, which is expected to take at least seconds to minutes. If the depression-related cognitive impairments and biases are only related to rumination, then they should not exist at shorter durations (before rumination has commenced). So far, the depression-related biases and impairments have typically only been found when the stimuli were presented for longer durations (>1000ms), supporting the rumination hypothesis; whereas when the stimuli were processed for shorter durations, there was less evidence of any impairments (Gotlib & Joormann, 2010).

2.9 Findings of impaired disengagement from negative material at shorter intervals

In contrast to the many hundreds of published studies investigating cognitive impairments and distortions at longer durations, there are few studies that demonstrate impairments at shorter durations (<1000ms). Only four studies appear to have provided supporting evidence, including a dot-probe study showing impaired disengagement from depression-related words presented for 500ms (Bradley, Mogg, & Lee, 1997) (depression symptoms); impaired disengagement from sad faces presented for 100ms (Sanchez, Vazquez, Marker, LeMoult, & Joormann, 2013) (MDD); an increase in emotion-induced blindness at 100ms (Onie & Most, 2017) (depression symptoms); and a larger and longer attentional blink at 180ms (Rokke, Arnell, Koch, & Andrews, 2002) (depression symptoms). These studies are discussed in more detail below.

The Bradley, Mogg and Lee (1997) dot-probe study is often cited as an example of impaired disengagement that is associated with depression. In their study, they simultaneously presented a pair of words on the screen, one neutral and one depression-related. After the words disappeared a dot was presented at the location of one of the words and the participant had to select the location as quickly as possible. The difference between the response time for neutral and depression-related words provided a measure of the change in selective attention towards the spatial location of the depression-related word. In Study 1, they found a significant effect, but this only occurred after a depressed mood induction, not the participants with depression symptoms, as measured by a psychometric instrument. In Study 2, they did not find an effect in the participants with naturally-occurring depression symptoms, as measured by the BDI. Therefore, this study does not provide evidence of a relationship between impaired disengagement from negative material and depression, at shorter intervals.

Sanchez et al. (2013) used an eye-tracking study and found impaired disengagement from sad faces after 100ms of presentation in participants diagnosed with MDD. Their methodology simultaneously presented sad and neutral faces on the screen and measured the disengagement time from the sad to the neutral face using eye-tracking. However, their paradigm included a 3,000ms naturalistic viewing of the face prior to disengagement testing, providing time for the later stages of processing to occur, which may have influenced the disengagement process after the 100ms fixation; and this aspect of the study limits the value of the evidence.

Onie and Most (2017) found a significant positive relationship between ‘negative affect’ and impaired disengagement from emotive images at 100ms, using an emotion-induced blindness (EIB) paradigm (Most, Chun, Widders, & Zald, 2005). (Note: this paradigm has been used in studies in this thesis and is explained further below). However, their measure of ‘negative affect’ was based on a combined score of the three subscales of the DASS-21 (Lovibond & Lovibond, 1995), which indexes depression, anxiety and stress symptoms. Therefore, although their findings are relevant and related to depression, as there is a high correlation between the DASS21 total and BDI score (Henry & Crawford, 2005), further direct evidence of a relationship between impaired disengagement and the symptoms of depression would be valuable.

Rokke, Arnell, Koch, and Andrews (2002) found impaired early-stage processing in participants with symptoms of depression, using an 'attentional blink' paradigm (AB) (Raymond, Shapiro, & Arnell, 1992). The AB paradigm is a rapid serial visual presentation (RSVP) task that involves a stream of images being presented at approximately 100ms durations. The paradigm can either be single or dual task. In the single task version, participants made decisions about one image – for example, the presence of a letter – whereas in the dual task version, they reported on two targets – for example, the identity of a white letter (T1) in a stream of black letters and the presence of a specific black letter (T2) following the white letter. If T2 was presented more than 500ms after T1, then their accuracy approached that of the single task version; however, if T2 was presented within 500ms of T1, their accuracy was impaired. This impairment is the referred 'attentional blink' and it is hypothesised to reflect attentional processing limitations (Raymond et al., 1992). Rokke et al (2002) found a deeper attentional blink in severely-depressed participants, but only in the more demanding dual task condition. They hypothesised that this was caused by a limitation on the encoding of stimuli into conscious awareness. If this is the case, the impairment may be associated with a general reduction in cognitive capacity in depressed individuals but not a specific impairment in disengagement from negative material (Gotlib & Joormann, 2010; Rokke et al., 2002).

In summary, none of the four studies discussed here provides strong evidence of a relationship between depression symptoms and impaired disengagement from negative material, at short durations. Identifying impaired disengagement from negative material requires an experimental paradigm that can differentiate between a specific depression-related disengagement impairment and a more general cognitive impairment (e.g. cognitive slowing) that occurs in depressed individuals. The EIB paradigm, as used by Onie and Most (Onie & Most, 2017), is an experimental method that can measure disengagement from emotional visual stimuli that are displayed for short durations, typically in the hundreds of milliseconds (McHugo, Olatunji, & Zald, 2013; Most et al., 2005). Importantly, EIB includes a control condition that provides a comparison of performance between emotional images and neutral images. Therefore, any general impairment in disengagement caused by depression will be evident in the neutral condition and any additional effects caused by the negative images can be isolated.

In the EIB paradigm, a series of neutral images – typically landscape images – are rapidly presented (100ms each) and during the series a single emotional distractor image is presented. Emotional distractors can be positive (e.g. erotica, scenes of excitement or achievement) or negative (e.g. attacks, weapons, disfigurement or scenes with disgusting content). A target image (i.e. rotated landscape) is then presented at one of two durations (either lag 2, 200ms or lag 8, 800ms) after the distractor image, and the participant is required to make judgments about the image. The participant's accuracy after an emotional distractor image is then compared to their accuracy after a neutral distractor image. A study of healthy participants found that when the target image was shown at lag 2 after a neutral distractor image, participant accuracy was 91%; however, when the target image was shown at lag 2 after a negative distractor image, accuracy dropped to 83% (Most et al., 2005). Additionally, when the target image was shown at lag 8 after either of the distractor images, their accuracy was over 90%.

The details of exactly how and where in the early stages of the attentional process impaired disengagement and a resulting drop in accuracy occurs in EIB are still being investigated (McHugo et al., 2013; Wang, Kennedy, & Most, 2012). However, the end result is clearly a reduced ability to disengage from an emotional visual stimulus and process a subsequent stimulus. EIB is therefore an ideal experimental paradigm to investigate any impaired disengagement from negative material at the early stages of attention and cognition in people with depression symptoms. It targets a relevant duration (100-200ms); it provides a quantitative measure of disengagement; it can utilize depression-relevant (negative) images; and it provides a control measure of any reduced overall cognitive capacity or cognitive speed.

Study 2 uses an EIB paradigm to investigate the relationship between impaired disengagement from negative material and the symptoms of depression. Previous studies have confirmed that people with depression have difficulty disengaging from negative stimuli after relatively long durations (>1000ms); however, this impairment has not been fully investigated at shorter intervals (<1000ms). In particular, we were interested in understanding if the impairment identified by Rokke et al. (2002), using an AB paradigm, was the result of a general cognitive impairment caused by depression, or a specific impairment related to the processing of negative material.

Chapter 3. Study 1, technical aspects of the EIB task

3.1 Chapter overview

This chapter investigates the technical aspects of the EIB task. During a pilot study for Study 2, it was noted that the EIB effect appeared to be reduced when negative and positive distractors were mixed in the same experimental trial block. When using the EIB paradigm, conclusions are typically drawn based only on the relationship between the features of the distractor image and the magnitude of the EIB impairment. However, a key influence that has not been explored in the literature is the effect of images that are shown in earlier trials. We therefore investigated this influence by comparing the results of the two experiments: In Experiment 1, we blocked the trials by valence, with each block of trials comparing the effect of neutral distractors to either positive or negative distractors, but not both. In Experiment 2, we mixed the trials containing positive, negative and neutral distractors in each block.

We found that the magnitude of the EIB effect in Experiment 1, where trials were blocked, was larger than it was in Experiment 2, where the trials containing positive and negative distractors were mixed. A follow-up analysis showed that the smaller effect size in Experiment 2 was driven by a habituation effect that only occurred with the mixed valence blocks. Our findings likely demonstrate that the magnitude of the EIB effect was influenced by previous images and in particular, habituation to the images. Further studies are suggested to evaluate and confirm this effect further.

Our findings demonstrate that the magnitude of the EIB effect was likely influenced by previous images. This finding informed our use of blocked trials in Study 2 and it is important for users of the EIB paradigm to consider this when designing future studies.

3.2 Publication status

This manuscript has not been published to date.

3.3 Manuscript

The Influence of Prior Images on Emotion-Induced-Blindness

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Abstract

The Emotion-Induced Blindness (EIB) task provides a robust method of measuring the ability of emotionally-valenced stimuli to capture attention and it provides a temporal measure of disengagement from emotionally-valenced stimuli. However, in order to maximize the information obtained when using the paradigm, factors that can affect the magnitude of the EIB impairment need to be fully understood. When using the paradigm, conclusions are typically drawn based only on the relationship between the features of the distractor image and the magnitude of the EIB impairment. However, one key influence that has not been explored is the effect of the images shown in earlier trials. We therefore investigated this influence by comparing the results of two experiments. In Experiment 1, we blocked the trials by valence, with each block of trials comparing the effect of neutral distractors to either positive or negative distractors, but not both. In Experiment 2, we mixed the trials containing positive, negative, and neutral distractors in each block. We found that the magnitude of the EIB effect in Experiment 1, where the trials were blocked by valence, was larger than that in Experiment 2, where the trials containing positive and negative distractors were mixed. Follow-up analysis showed that the smaller effect size in Experiment 2 was driven by a habituation to stimulus effect that only occurred in the mixed valence blocks. Our findings demonstrate that the magnitude of the EIB effect is influenced by previous images and in particular habituation to a mix of negative and positive distractors. Further studies are required to more fully evaluate and confirm this effect.

The Influence of Prior Images on Emotion-Induced-Blindness

Prioritising emotional stimuli is an adaptive process in humans. However, this prioritisation comes at the cost of processing other stimuli that are presented in close temporal proximity to the emotion stimulus. Several tasks have been used to study this interaction, although each task taps into different aspects of the attentional process. In this study, we employed the emotion-induced blindness or EIB task (Most et al., 2005). In this task, the presentation of an emotional stimulus briefly impairs the observer's ability to process subsequent stimuli. The task provides a robust method of measuring the ability of emotional stimuli to capture attention and it provides a temporal measure of disengagement from emotional stimuli (McHugo et al., 2013; Most et al., 2005). The paradigm has been used to study a diverse range of areas including attention (Most & Wang, 2011) perception (Gupta, Hur, & Lavie, 2016), memory (Flaisch, Steinhauser, & Schupp, 2016), negative affect (Onie & Most, 2017), and obsessive compulsive disorder (Olatunji, Ciesielski, & Zald, 2011).

Prior to the development of the EIB task, the most commonly used experimental method used to investigate the time course of emotional attentional bias was the dot-probe task (Bar-Haim, Lamy, Pergamin, Bakermans-Kranenburg, & Van Ijzendoorn, 2007; MacLeod, Mathews, & Tata, 1986). In this task, two images are displayed on the screen for a short period of time, followed by a probe in one of their locations. The participant is required to indicate the location of the probe. Emotional attentional bias is shown when response times are different between probes in the location of an emotive image compared to those in the location of a neutral image. One of the main advantages of this task is the ability to display the emotional images for very short periods of time (in the millisecond range), in order to test the time course of emotional bias from the earliest stages of exposure, including subliminally. A limitation of the dot-probe task is that it is by nature related to shifts in spatial attention. Although this feature is useful, the development of alternative paradigms that relate to other attention mechanisms provides researchers with the ability to access and compare the different attentional mechanisms. For an example comparing the dot-probe to the EIB task, see Onie and Most (2017).

The mechanisms underlying the EIB effect have been researched since the effect was first documented by Most et al. (2005), who likened it to “attentional rubbernecking.” The EIB paradigm utilises a rapid serial visual presentation (RSVP) stream, in which a series of neutral images (typically landscape images) are rapidly presented (100ms each) and during the series, a single emotional distractor image is presented. Emotional distractors can be positive (e.g. erotica, scenes of excitement or achievement) or negative (e.g. attacks, weapons, disfigurement or scenes with disgusting content). A target image (i.e. rotated landscape) is then presented at one of two durations (either lag 2 or lag 8) after the distractor image, and participants are required to make judgments about this image (see Figure 1). The participant’s accuracy in detecting the direction of rotation after an emotional distractor image is compared to their accuracy after a neutral distractor image.

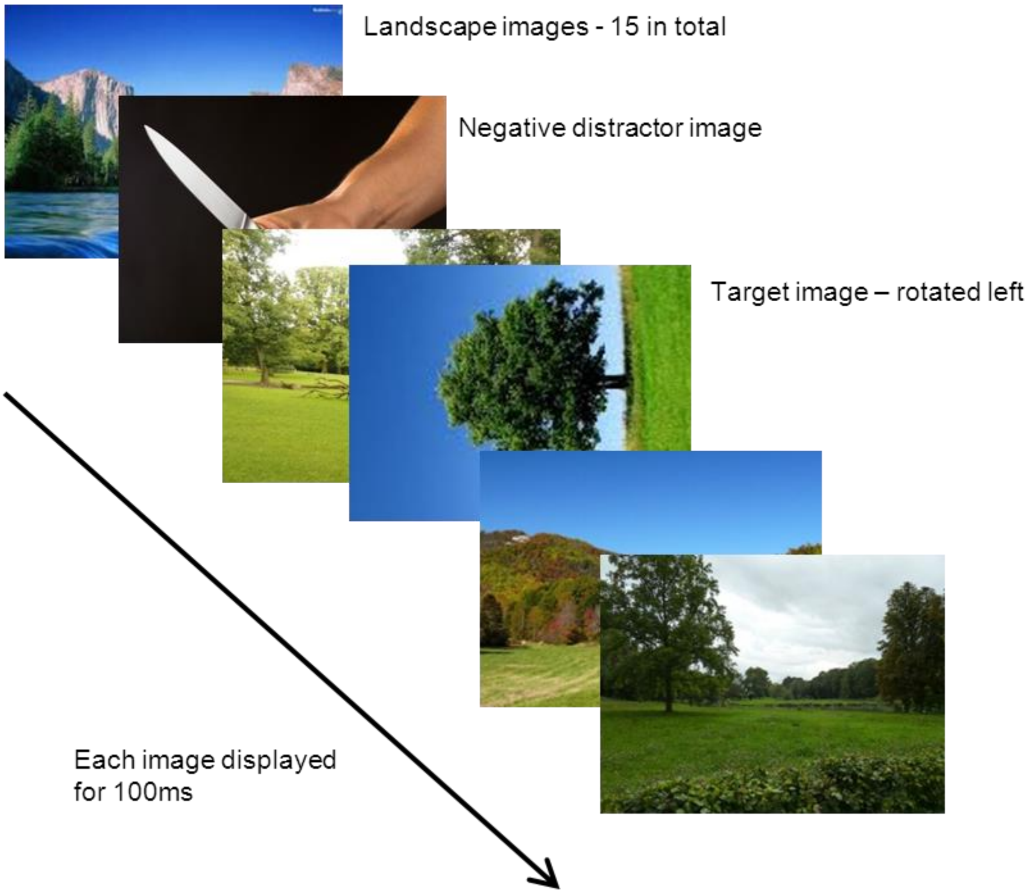

Figure 1. *Example of part of an EIB trial. The distractor is the knife and the target image (at T2) is the tree rotated left.*

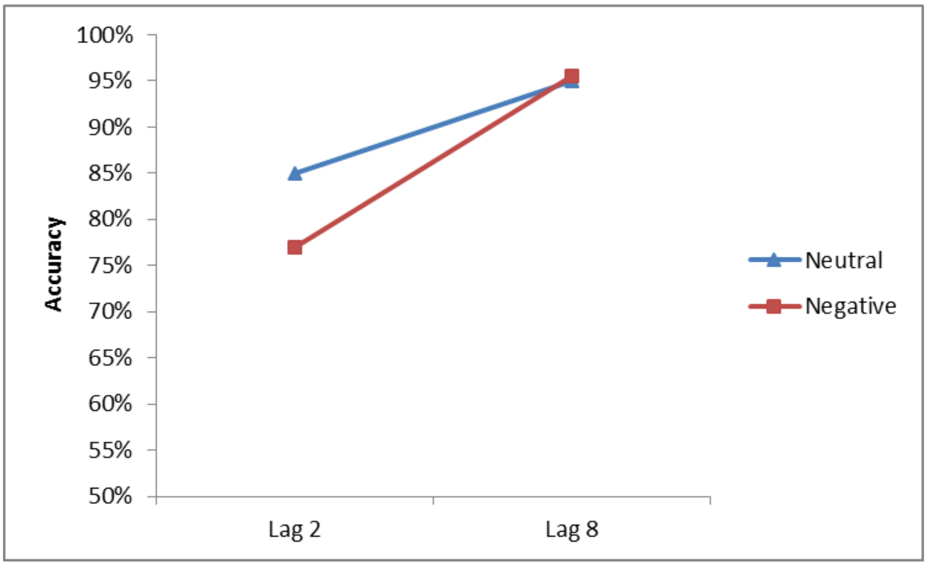

Figure 2. *Example EIB results showing lower accuracy for negative distractors at lag 2, with a recovery in performance by lag 8. Data from a pilot study.*

Most et al. (2005) found that when the target image was shown at lag 2 after a neutral distractor image, participant accuracy was 91%; however, when the target image was shown at lag 2 after a negative distractor image, accuracy dropped to 83%. When the target image was shown at lag 8 after either of the distractor images, accuracy was over 90% (see Figure 2 for a similar example using data from our pilot study). Other studies have consistently replicated these findings (McHugo et al., 2013) and also they have shown that positively valenced, highly-arousing stimuli can create a larger EIB effect than negatively valenced stimuli (Most, Smith, Cooter, Levy, & Zald, 2007). To date, the conclusions from these studies are typically based on the relationship between the valence of the distractor image and the magnitude of the EIB impairment at lag 2 and lag 8.

However, one key influence that has not been directly explored is the effect of the images shown in earlier trials. If previously displayed distractor images can influence the magnitude of this effect, it has the potential to introduce noise or even confound the results of the study.

This may not represent a problem in typical studies that compare only one type of emotionally-valenced stimulus to a neutral stimulus. However, in studies that include several types of emotionally valenced stimuli within the same block of trials, for example, studies by Ciesielski, Armstrong, Zald, and Olatunji, (2010) and Olatunji et al., (2011), this may be an issue. Therefore, we investigated the influence by comparing the results of two experiments. In Experiment 1, trials were blocked by valence and each block of trials compared the effect of neutral distractors to either positive or negative distractors, but not both. In Experiment 2, the trials containing positive, negative and neutral distractors were mixed.

We hypothesised that if EIB effects are driven only by the distractor image, then the magnitude of the effects would be similar in each experiment, with positively-valenced distractors creating a larger EIB effect than negatively-valenced distractors. However, if EIB effects were influenced by previous images, then the magnitude of the effects in Experiment 2 (mixed condition) would be affected by the interspersed distractors of the opposite valence. In particular, we hypothesised that a very large EIB effect created by positively-valenced distractors may be attenuated by the interspersed negatively-valenced distractors which had smaller EIB effects - an averaging effect of the two stimuli. In contrast, the smaller EIB effect of negatively-valenced distractors would be increased by the interspersed positively-valenced distractors which had a larger EIB effect.

Method

Participants

Participants were recruited from an undergraduate ANU Research School of Psychology psychology course Student Research Participation Scheme. First- and second-year ANU psychology students could receive course credit for their participation or they were paid for their time. Study inclusion criteria were: 18-years or older and a Canberra, Australia resident. Due to the strong aversive nature of some of EIB images, people were excluded if they had ever been diagnosed with Post Traumatic Stress Disorder. Participants in Experiments 1 and 2 were recruited from the same student research pool, using similar advertising strategies; however; they were carried out in different semesters.

Participants in Experiment 1 were 40 undergraduate students from the Australian National University (ANU) including 5 males and 35 females, with a mean age of 19.9 years (range 18-36 years). Participants in Experiment 2 were 40 undergraduate students from the ANU including 7 males and 33 females, with a mean age of 20.1 years (range 18-35 years). Each participant took part in only one of the experiments.

Apparatus and stimuli

Stimuli were color images taken from the International Affective Picture Systems (IAPS) database (Lang, Bradley, & Cuthbert, 2005) and landscape (city and natural) images were taken from the internet. There were 20 neutral-valence, low-arousal IAPS images, 20 negative-valence, high-arousal images, and 20 positive-valence, high-arousal images. IAPS images were taken from multiple subsets to avoid a systematic bias in spatial frequency content. Spatial frequency content has the potential to influence visual perception and biases have previously been identified when using single subsets of IAPS images (Delplanque, N'diaye, Scherer, & Grandjean, 2007). Valence and arousal classifications were based on the ratings provided in the IAPS database, as shown in Table 1. Mean arousal ratings, using ratings obtained using Likert-type scales ranging from 1 (*low*) to 9 (*high*) for high-arousal negative and high-arousal positive distractors were similar. Stimulus size was 448 x 336 pixels, presented at a distance of 0.5m with a visual angle of 17.3 x 12.8 degrees. Stimuli were presented on a Sony Multiscan G400 CRT monitor at 100Hz driven by Cambridge Research Systems Visage hardware and software (Version 1.26) and a Dell Precision T3400 PC. The experiment was programmed using Matlab (Version R2012b) and Psychtoolbox-3.

Table 1

Valence and Arousal Ratings for Stimuli

Stimulus	Valence Mean	Arousal Mean
Neutral-valence, low-arousal	4.51	2.89
Negative-valence, high-arousal	1.81	6.81
Positive-valence, high-arousal	6.68	6.67

Design and procedure

An EIB paradigm (Most et al., 2005; Most et al., 2007) was used in both experiments. Each trial consisted of a rapid serial visual presentation of 17 images for 100ms each, with no inter-stimulus interval. The images, with the exception of two, were upright landscapes, either a cityscape or natural landscape. The remaining two images were the distractor and the target. The distractor was either a neutral or a valenced image and the target was a landscape (city or natural) image rotated 90 degrees either left or right. The distractor was positioned at either the 4th, 6th or 8th position and the target appeared at either two (lag 2=100ms onset of image, 200ms offset of image) or eight (lag 8=700ms onset of image, 800ms offset of image) items after the distractor, see Figure 1 for an example. Participants used the **z** and **?** keys to indicate the direction of the rotation of the target.

Experiment 1 consisted of four blocks of 96 trials in each block. Two blocks utilized half neutral and half negative distractors and two utilized half neutral and half positive distractors. The valence of the first block presented was randomized across the participants and the valence of each following block was alternated. Experiment 2 consisted of three blocks of 96 trials in each block. Each block included equal numbers of neutral, negative and positive distractors, presented in random order.

Data analysis

Responses were captured in Matlab and transferred to Microsoft Excel for collation, accuracy calculations, and presentation, and then to SPSS for statistical analysis.

Results

Experiment 1 – blocked trials

Raw accuracy scores are shown in Figure 3 and the EIB effect (EIB = valenced accuracy score - neutral accuracy score) is shown in Table 2.

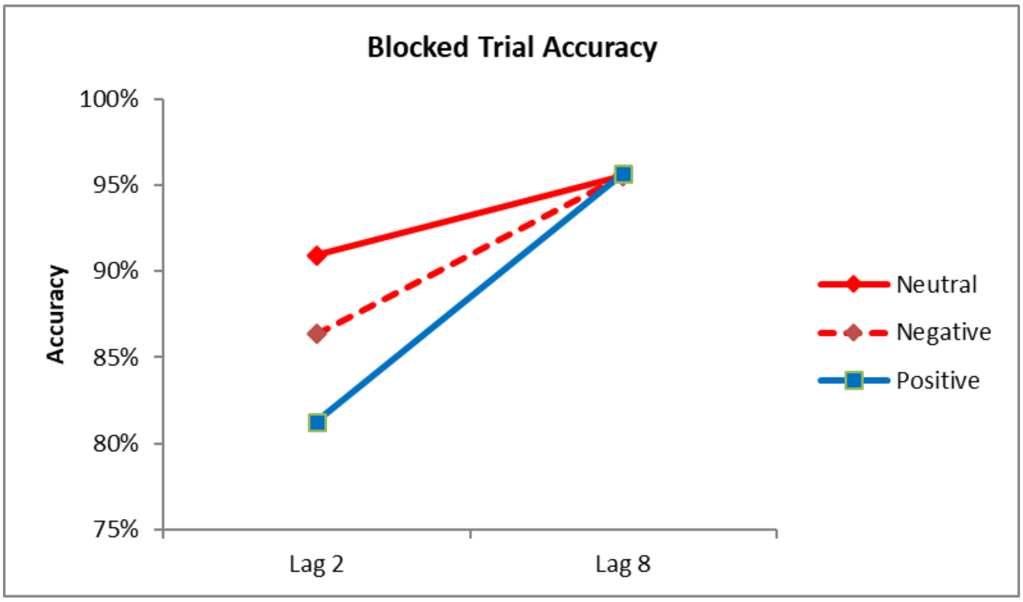

Figure 3. Results showing mean accuracy for blocked trials. The EIB effect is shown by the difference between valenced and neutral scores. Error bars omitted due to overlaps of multiple lines/colours which are unreadable.

Table 2

EIB effect, blocked trials – percentage impairment (valenced accuracy- neutral accuracy)

	Mean	Std. Dev.
Lag 2 negative	-4.55%	7.42%
Lag 2 positive	-9.24%	12.20%
Lag 8 negative	0.08%	4.60%
Lag 8 positive	0.08%	4.20%

Statistical analysis was performed using two separate repeated measures 2 (valence) x 2 (lag) ANOVAs comparing: (a) the effects of negatively-valenced distractors with neutral distractors (negative condition); and (b) positively-valenced distractors with neutral distractors (positive condition). Two separate ANOVAs were used to avoid incorrectly comparing more than one neutral condition. For the negative condition, there was a significant main effect of lag, F (1, 39)=20.35, p=<.001, partial η^2=.343, a significant main effect of valence, F (1, 39)=7.52, p=<.001, partial η^2=.162, and a significant interaction effect of lag x valence, F (1, 39)=14.61, p=<.001, partial η^2=.273. For the positive condition, there was a significant main effect of lag, F (1, 39)=43.98, p=<.001, partial η^2=.530 a significant main effect of valence, F (1, 39)=23.61, p=<.001, partial η^2 = .377, and a significant interaction effect of lag x valence, F (1, 39)=51.27, p=<.001, partial η^2=.568. The results show a classic EIB effect with an increased impairment in accuracy at Lag 2 for valenced distractors compared to neutral distractors. The increased impairment was 4.55% for the negative condition and 9.24% for the positive condition, and there was a recovery in impairment for all conditions at Lag 8.

Experiment 2 – mixed trials

Raw accuracy scores are shown in Figure 4 and the EIB effect (EIB = valenced accuracy score - neutral accuracy score) is shown in Table 3.

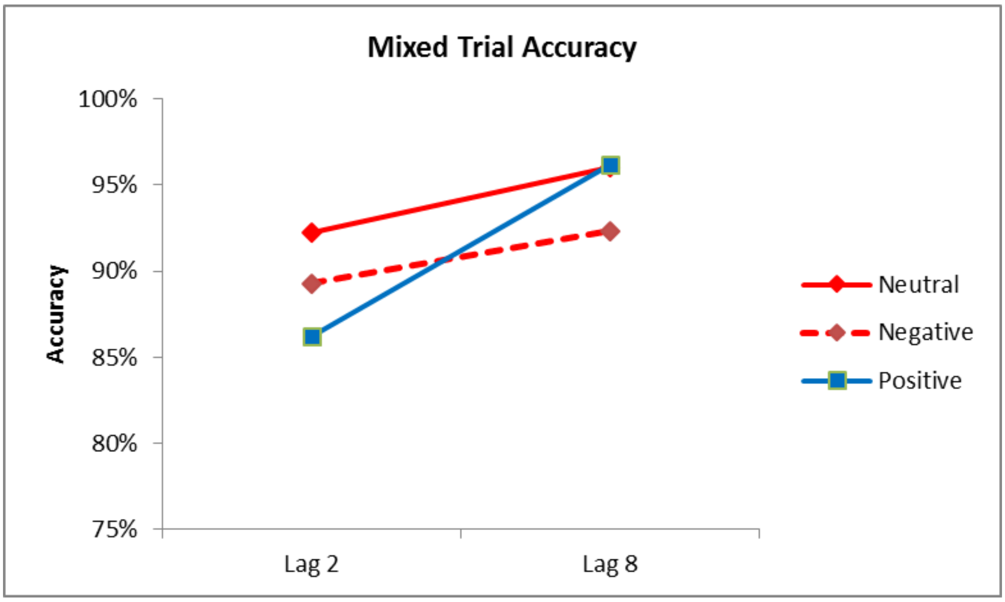

Figure 4. Results showing mean accuracy for mixed trials. The EIB effect is shown by the difference between valenced and neutral scores.

Table 3

EIB effect, mixed trials – percentage impairment (valenced accuracy - neutral accuracy)

	Mean	Std. Dev.
Lag 2 negative	-2.97%	5.72%
Lag 2 positive	-5.99%	5.68%
Lag 8 negative	-3.69%	4.67%
Lag 8 positive	0.10%	4.49%

Statistical analysis was performed using two separate repeated measures 2 (valence) x 2 (lag) ANOVAs comparing: (a) the effects of negatively-valenced distractors with neutral distractors (negative condition); and (b) positively-valenced distractors with neutral distractors (positive condition). For the negative condition, there was a significant main effect of lag, F (1, 39)=23.00, p=<.001, partial η^2=.371, a significant main effect of valence F, (1, 39)=38.73, p<.001, partial η^2=.498, and a non-significant interaction effect of lag x valence, p=.57. For the positive condition, there was a significant main effect of lag F, (1, 39)=75.62, p=<.001, partial η^2=.660, a significant main effect of valence, F (1, 39)=35.19,

$p<.001$, partial $\eta^2=.996$, and a significant interaction effect of lag x valence, F (1, 39)=22.59, $p= <.001$, partial $\eta^2=.367$. The results show a classic EIB effect with an impairment of accuracy at Lag 2 of 3.44% for the negative condition, and 7.29% for the positive condition. However, the expected recovery in impairment at Lag 8 occurred only for positive distractors but not negative distractors.

Comparison of Experiments 1 and 2

The size of the EIB effects in Experiments 1 and 2 was compared to determine if there was a difference caused by blocking vs. mixing valenced distractors. Statistical analysis was performed using two separate repeated measures 2 (valence) x 2 (lag) ANOVAs with the experiment as a between-subjects factor, comparing: (a) the effects of negatively-valenced distractors with neutral distractors (negative condition); and (b) positively-valenced distractors with neutral distractors (positive condition). For the negative condition, there was a significant main effect of lag, F (1, 78)=7.42, $p=.008$, partial $\eta^2=.087$, a non-significant main effect of valence F, (1, 78)=1.19, $p=.278$, partial $\eta^2 = .015$, a significant interaction effect of lag x experiment F (1, 78)=9.45, $p=.003$, partial $\eta^2 = .108$, a significant interaction effect of valence x experiment F (1, 78)=55.51, $p<.001$, partial $\eta^2=.416$, and a significant interaction effect of lag x valence x experiment, F (1, 78)=36.23, $p=<.001$, partial $\eta^2=.317$. The main effects are consistent with the EIB paradigm and the interaction effects confirm a statistical difference between experiments.

For the positive condition, there was a significant main effect of lag F (1, 78)= 100.76, $p<.001$, partial $\eta^2=.564$, a significant main effect of valence F (1, 78)=83.56, $p= <.001$, partial $\eta^2=.517$, a non-significant interaction effect of lag x experiment F (1, 78)= 2.40, $p=.125$, partial $\eta^2=.03$, a non-significant interaction effect of lag x experiment F (1, 78) =2.40, $p=.05$, partial $\eta^2 = .048$, and a non-significant interaction effect of lag x valence x experiment *F* (1, 78)=3.37, *p*=<.07, partial η^2=.041. The main effects are consistent with the EIB paradigm and the interaction effects confirm a statistical difference between experiments.

The results confirm that a statistical difference exists between the two experiments, although they do not provide a simple way to compare the EIB effects. Therefore, a follow-up analysis comparing EIB effects (EIB = neutral accuracy score - valenced accuracy score) for Experiments 1 and 2 was performed. The results are shown in Figure 5 and Table 4.

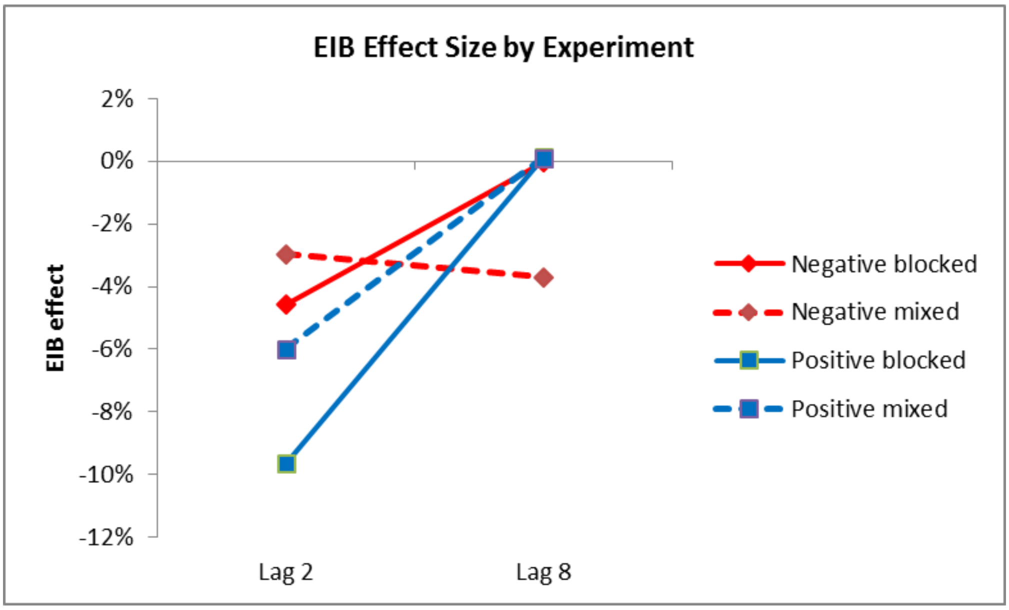

Figure 5. Results showing EIB effect – the difference between valenced and neutral scores.

Table 4

EIB effect – percentage impairment (valenced accuracy - neutral accuracy)

	Lag 2	Lag 8
Negative blocked	-4.56%	0.08%
Negative mixed	-2.97%	-3.70%
Positive blocked	-9.24%	0.08%
Positive mixed	-5.99%	0.10%

A statistical analysis was performed comparing the EIB effects, using a mixed ANOVA with repeated measures 2 (valence) x 2 (lag) and with experiment (blocked versus mixed) as a between-subjects factor. There was a significant interaction effect of lag x experiment, F (1, 78)=8.32, p=.005, partial η^2=.096, a significant interaction effect of valence x experiment F (1, 78)=8.31, p=.005, partial η^2=.096, and a non-significant interaction effect of lag x valence x experiment F (1, 78)=1.07, p=.304, partial η^2=.014.

The results demonstrated that at Lag 2, mixed positive and negative stimuli reduced the size of the EIB effect in comparison to presenting the negative and positive stimuli in separate blocks. The results also show that for negative stimuli, the stimulus mixing impaired the classic EIB recovery at Lag 8. As the magnitude of impairment was reduced by the experimental order (blocked vs. mixed valence), the EIB effect appears to have been influenced by the valence of previous distractors, and not simply the valence of the distractor within each trial.

Further follow-up and analysis

One possible explanation for the discrepant effect size between Experiment 1 and 2 is a difference in the habituation to valenced stimuli caused by the experimental order. We investigated this possibility by, analyzing the progressive changes in EIB effect size for each experimental block.

Experiment 1 follow-up by block

The EIB effects by block for Experiment 1 are shown in Figure 6 and Table 5.

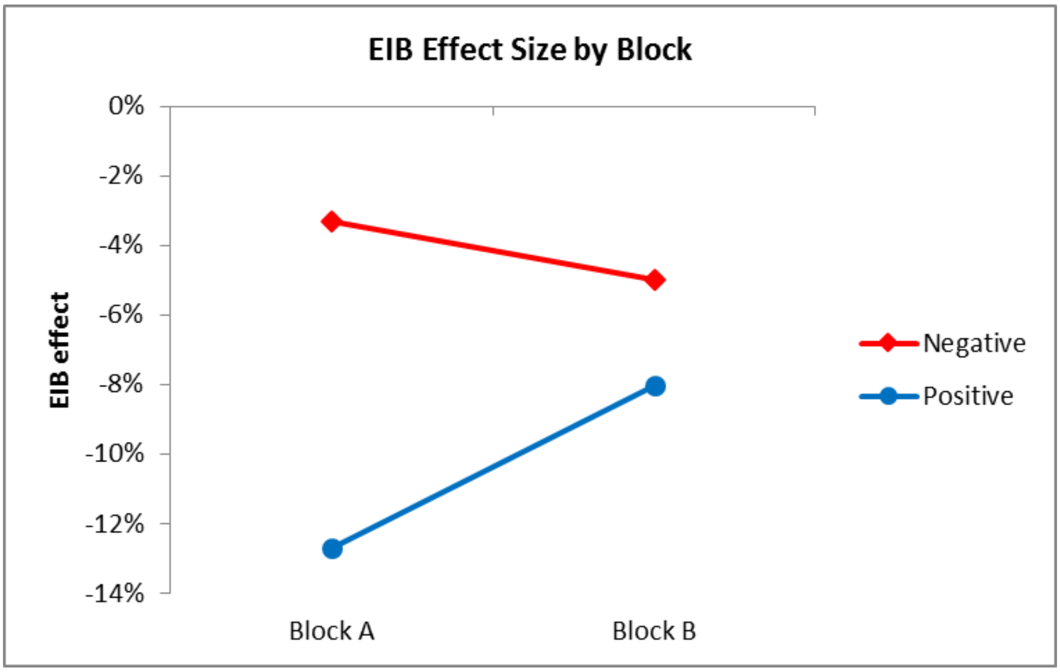

Figure 6. Results showing EIB effect by block for Experiment 1.

Table 5

EIB effect – percentage impairment (valenced accuracy - neutral accuracy)

	Block A	Block B
Negative	-3.33%	-5.00%
Positive	-12.71%	-8.02%

Statistical analysis was performed on the Experiment 2 data, using a repeated measures 2 (valence) x 2 (block) ANOVA in order to compare the EIB effects by block. There was a significant main effect of valence F (1, 38)=15.59, p<.001, partial η^2=.286, but no significant main effect of block, F (1, 39)=1.23, p=.275, partial η^2=.031, and no significant interaction effect of block x valence, F (1, 38)=.03, p=.864, partial η^2=.001. The results suggest that there was no significant habituation effect occurring in Experiment 1.

Experiment 2 follow-up by block

The EIB effects by block for Experiment 2 are shown in Figure 6 and Table 6.

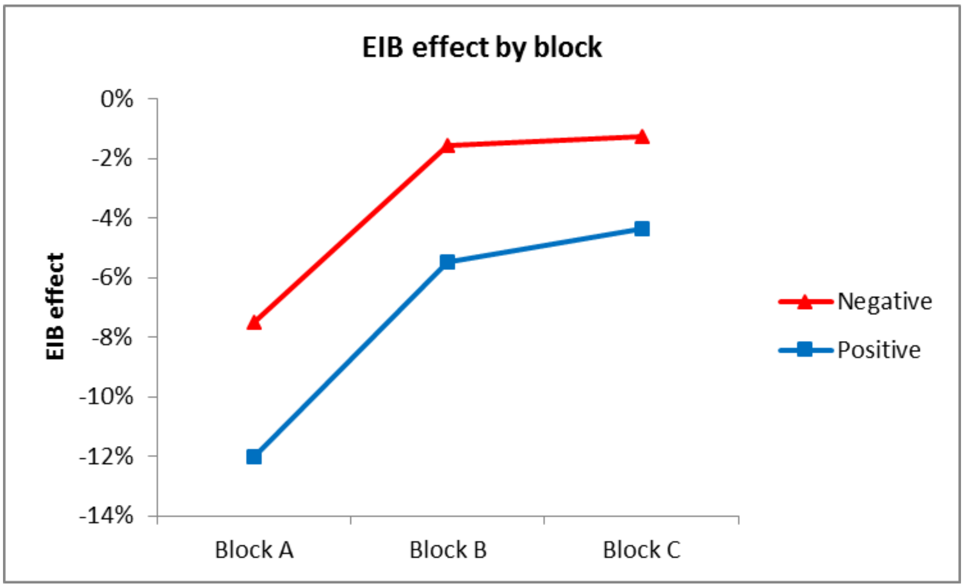

Figure 7. Results showing EIB effect by block for Experiment 2.

Table 6

EIB effect – percentage impairment (valenced accuracy - neutral accuracy)

	Block A	Block B	Block C
Negative	-7.56%	-1.56%	-1.25%
Positive	-12.0%	-5.47%	-4.38%

Statistical analysis was performed for Experiment 2, using a repeated measures 2 (valence) x 3 (block) ANOVA in order to compare the EIB effects by block. There was a significant main effect of block F (1, 38)=5.20, p=.01, partial η^2=.215, a significant main effect of valence, F (1, 39)=13.74, p=.001, partial η^2=.261, and a significant interaction effect of block x valence, F (1, 38)=5.13, p=.011, partial η^2=.273. Visually, the main drop appeared to be between Block A and Block B. Follow-up *t* tests were performed to confirm that this was the case.

Paired samples *t*-test results showed a significant difference for negative stimuli between Block A and Block B, t(39)=2.72, p=.01, with a medium effect size (d=.51). There was a non-significant difference between Block B and Block C, t(39)=.833, p=.41. There was a similar result for positive stimuli with a significant difference between Block A and Block B, $t(39)=2.69$, $p=.011$, with a medium effect size ($d=.61$); and there was a non-significant difference between Block B and Block C, $t(39)=1.51$, $p=.139$. The results suggest that a habituation effect to the valenced stimulus occurred after Block A.

General discussion

Studies using the EIB paradigm have typically drawn conclusions based on the relationship between the features of the distractor image and the magnitude of the EIB impairment. However, one key influence that has not been explored is the potential effect of images shown in earlier trials. We therefore investigated the influence by comparing the results of two experiments. In Experiment 1, the trials were blocked by valence, with each block of trials comparing the effect of neutral distractors to either positive or negative distractors, but not both. In Experiment 2, we mixed the trials containing positive, negative, and neutral distractors in each block. The results of Experiment 1 were consistent with other studies in the literature (Most et al., 2005; Most et al., 2007) showing a large EIB effect (9.2%) for positive emotional distractors and a smaller but still significant effect (4.6%) for negative distractors. However, in Experiment 2, when the trials containing positive and negative distractors were mixed, there was a smaller EIB effect for positive (6.0%) and negative distractors (3.0%). In both experiments the effect size for positive distractors was double that for negative.

Follow-up analysis showed a significant drop in the EIB effect after the first block in Experiment 2 (mixed condition) but not in Experiment 1 (blocked condition), suggesting that there was a differential habituation effect caused by the block order in the experiment. Other studies have also failed to detect habituation effects when using the EIB paradigm in a blocked format. Most et al. (2005) did not find any evidence of habituation using 168 trials of negative emotional images and comparing the effect between the first and second half of blocked trials within the experiment; and an unpublished experiment from this lab failed to detect any evidence of habituation on 120 trials of negative emotional images and comparing experimental halves. Given the results, it is possible that our finding of a habituation effect in the mixed condition was anomalous based on this particular sample, or alternatively that there may be another explanation. One hypothesis is that in the mixed condition, positive and negative distractors in close temporal proximity reduces the perceived valence and therefore the participants' arousal level. Anecdotal evidence supporting such an effect was obtained when the information statement was provided to participants, which showed examples of negatively- and positively-valenced images on a single page, in close spatial proximity. Several participants remarked that this juxtaposition was disagreeable (as opposed to either positively or negatively arousing) and the authors agreed with this perception, viewing scenes of violence (negative valence) and sexuality (positive valence) in close temporal proximity may have had the same effect, reducing overall arousal and changing the EIB effect. By the end of the first block, participants were expected to be aware that the positive and negative blocks were mixed in the experiment, and as a consequence, their arousal levels may have dropped. Although this hypothesis is plausible, there was a strong EIB effect in the first block, so the reduction in EIB effect appears to have required some level of habituation.

The hypothesis that mixing the valence of images is disagreeable but not arousing is consistent with findings related to context effects during emotion perception. In a review, Barrett, Mesquita, and Gendron (2011) suggest that the perception of a facial expression's valence and arousal can be influenced by images of the overall scene and also by other faces paired with the scene. One example they provide is of a tennis star, her facial expression in isolation appears in extreme pain but a full body shot shows a triumphant fist-pump and the valence of her facial expression is then interpreted as positive instead of negative. Based on ERP recordings. these effects appear to occur early and automatically during visual processing (Righart & De Gelder, 2008) and they may therefore influence the perception of images shown in rapid succession, such as during an RSVP stream.

Another relevant study is Kennedy, Newman, and Most (2017). This study examined the effect of proactive control on the EIB effect. In some trials, participants were warned about the nature of the distractor and asked to try and ignore it. Provision of this information reduced the EIB effect. They included blocks of single valence (8 trials) and mixed valence (32 trials) and found a small increase in EIB effect in mixed valence blocks compared to single valence blocks. Their finding was in the opposite direction to our study, however, this may have been influenced by the smaller number of mixed trials compared to our study (96 trials). In addition, their study included conditions warning participants of the type of image to be displayed and although relevant, is not directly comparable to our results.

Future research is therefore required to investigate the hypotheses by conducting an experiment using blocks of mixed and single valences for each participant. Analysis of possible habituation effects could then confirm if the habituation effect was greater for the mixed valence blocks compared to the single valence blocks.

(Note for thesis purposes: prior to identifying the habituation effect and in order to confirm the results of this study by ruling out individual differences between samples, an experiment was commenced using similar methodology but with participants randomly allocated to blocked or mixed trials. This experiment was not continued once the habituation effect above was identified, as the habituation effect suggested a completely different direction for future investigation. Future studies could focus on within-subjects effects to limit the number of participants required and directly compare the habituation effects for mixed and blocked trials within the same experimental sitting.

Future studies should also consider the number of images used in each category. This study used 20 each of neutral, positive and negative images. In blocks of 96 trials this will result in multiple presentations of the same image. Prior to commencing the mixed study, this was not considered to be an issue as we found no evidence of any habituation. Future studies looking at habituation effects may need to increase the number of valenced *stimuli. However, maintaining a small number of neutral stimuli has the advantage of limiting the influence of differences between neutral stimuli.)*

An unexpected finding from this study was the lack of recovery at Lag 8 for negative distractors in the mixed trials, and the reasons for this are unclear, although this may be explained by a context effect. Future research should therefore investigate this phenomenon by measuring participants' accuracy at varying intervals (for example lags 8-12) to determine the actual timing of the recovery in this condition. Combining this information with the results obtained from varying the number of trials between changes in valence might increase our understanding of the EIB effect.

The EIB task provides a robust method of measuring the ability of emotional stimuli to capture attention. It provides a temporal measure of disengagement from emotional stimuli and it has been used to study a diverse range of process. However, studies using the EIB paradigm have typically drawn conclusions based solely on the relationship between the features of the proximal distractor image and the magnitude of the EIB impairment. We found that the magnitude of the EIB effect in Experiment 1, where trials were blocked, was larger than that obtained in Experiment 2, where the trials containing positive and negative distractors were mixed. Our findings demonstrate that the magnitude of the EIB effect can be influenced by images in previous trials. Specifically, there appears to be a habituation effect in the EIB paradigm, but only for blocks of mixed valence trials. This influence of prior images should therefore be considered when future EIB studies are designed and interpreted. In particular, the valence of the distractor images should not be mixed during the trial blocks until follow-up studies have clarified the effects.

Chapter 4. Study 2, impaired disengagement from negative material

4.1 Chapter overview

This chapter investigates the hypothesis that impaired disengagement from negative material in people with high depression scores is related to rumination. If this hypothesis is correct, we would not expect to see the effects of a distortion at very short durations (< 1000ms), before rumination has had time to commence. The investigation utilised an EIB paradigm to measure disengagement from emotional images at 200ms and 800ms and to analyse the relationship between disengagement and depression symptoms. Cognitive theories of depression suggest that it is the negative valence of stimuli that is related to depression symptoms; and the theories will tested by including positive images with arousal levels that are matched to the negative images to determine if the depression impairments are specifically related to negative valence or changes in arousal response. No evidence was found of a relationship between impaired disengagement from negative material at short intervals and depressive symptoms. Our findings are consistent with the cognitive theories of depression which suggest that a causal relationship exists between the difficulties in disengagement from negative material, rumination, and depression.

4.2 Publication status

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4.3 Manuscript

Depressive Symptoms and Impaired Disengagement from Briefly-presented Emotional Images

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Abstract

Impaired disengagement from negative material is one of the key characteristics of depression. This study investigated the relationship between symptoms of depression, using Beck's Depression Inventory (BDI), and impaired disengagement from negative and positive emotional material, using an emotionally-induced blindness (EIB) paradigm. Participants were Australian National University students (n=130). Previous studies have confirmed that people with depression symptoms have difficulty disengaging from negative stimuli after relatively long exposure durations (typically seconds to minutes). A prior study found evidence suggesting that this impairment may also occur during disengagement from briefly-presented (< 1000ms) negatively-valenced material. In addition, some cognitive bias modification (CBM) treatments for depression have targeted disengagement from negative material at shorter intervals. Our study found no evidence of any relationship between impaired disengagement from negative material at short intervals and depressive symptoms. Our findings are consistent with cognitive theories of depression that suggest a causal relationship between difficulties in disengagement from negative material, rumination, and depression. Our results have implications for the understanding, diagnosis, and treatment of depression and in particular the use of cognitive bias modification (CBM) treatments for depression.

Depressive Symptoms and Impaired Disengagement from Briefly-presented Emotional Images

Depression[1] affects 350 million people each year and is the leading cause of disability globally (World Health Organization, 2016). Despite these statistics, the primary frontline treatments for depression, antidepressant drugs and psychotherapy, are only partly effective (Arroll et al., 2009; Bschor & Kilarski, 2016; Churchill et al., 2013; Churchill et al., 2010); and the causes of depression are still not fully understood. The dominant cognitive model of depression was originally formulated by Aaron Beck. According to Beck, "the processing of external events or internal stimuli is biased and therefore systematically distorts the individual's construction of his or her experiences" (A. T. Beck, 1967, 2005); and this distortion is thought to result in negative cognitions, rumination and low mood. Beck's model is supported by 40 years of research (A. T. Beck, 2005; Haaga et al., 1991; Hollon et al., 1986) and it forms the basis of Cognitive Behavior Therapy (CBT), which is the most widely used psychological treatment for depression (Churchill et al., 2010; Cuijpers et al., 2013). However, CBT for depression is only effective in approximately 50% of cases

[1] For the purposes of this paper, when discussing population statistics, depression models and treatments, 'depression' is defined in its generic form and includes people with a clinically-diagnosed major depressive episode or major depressive disorder (American Psychiatric Association, 2013), as well as those meeting a clinically-accepted cut-off number on a depression instrument such as the Beck Depression Inventory II (BDI-II) (A.T. Beck et al., 1996). This use of the generic 'depression' is common in the literature due to the large number of studies in the area, the many different criteria used to differentiate between depressed and control participants (Gotlib & Joormann, 2010; Peckham et al., 2010) and the changing diagnostic criteria for depression over the decades (American Psychiatric Association, 2016). Where specific studies of cognitive deficits are discussed, their definition (MDD or depressive symptoms) has been included.

(Churchill et al., 2010; Cuijpers et al., 2013), thus, it is essential to continue to investigate the cognitive symptoms of depression and build upon the findings to improve future iterations of CBT and other psychotherapies.

Studies suggest that depression is characterized by three cognitive features: (a) an increase in the elaboration of negative information; (b) difficulties in disengaging from negative material; and (c) deficits in cognitive control during the processing of negative information (for review, see Gotlib & Joorman, 2010) (both MDD and depression symptoms). These studies provide strong support for Beck's model using stimuli that are processed for longer durations (>1000ms). Examples include a negative bias towards a preferential recall for negative material (Mathews & MacLeod, 2005; Matt et al., 1992) (MDD and depression symptoms); and eye-tracking studies show a longer glance duration for negative images within 10-second and 30-second presentation durations (Eizenman et al., 2003) (depression symptoms), (Kellough, Beevers, Ellis, & Wells, 2008) (MDD). A meta-analysis of previous dot-probe (k=12, n=937) and Stroop studies (k=16, n=863) detected consistent attentional biases to negative stimuli that was related to depression symptoms (Peckham et al., 2010) (MDD and depression symptoms), with a medium effect size in the dot-probe studies (d=.52, p <.001), but a non-significant effect in the Stroop studies (d=.17, p =.06). Finally, there is consistently strong research support indicating that an excessive level of rumination on negative material occurs with related difficulties in disengaging from negative material at longer durations, typically in the range of seconds to minutes (Donaldson et al., 2007; Koster et al., 2011; Koster et al., 2005) (MDD and depression symptoms).

When reviewed as a whole, the body of evidence strongly supports that a broad range of cognitive biases and impairments occur in depression, when the stimuli are presented for longer durations (>1000ms) (Gotlib & Joormann, 2010). However, when the stimuli are processed for shorter durations (<1000ms) there is less evidence of impairment related to depression (Mathews & MacLeod, 2005). Thus, the presence of negative biases at longer (but not shorter) durations, combined with increased rumination, suggests that depression is characterized by a difficulty in disengaging from negative material during the later stages of cognitive processing; specifically at stimulus durations of 1000ms or longer. The results support the clinical focus of CBT on cognitions such that the therapist helps the client to work through their negative thoughts (J. S. Beck, 2011; Simmons & Griffiths, 2009). However, if impaired disengagement from negative material does commence at an earlier stage of processing, then CBT may not be addressing a critical stage in the cognitive processing sequence.

Rokke, Arnell, Koch, and Andrews (2002) found evidence of impaired early stage processing related to depression symptoms, using an ‘attentional blink’ paradigm (AB) (Raymond et al., 1992). The AB paradigm is a rapid serial visual processing (RSVP) task in which a stream of images is presented at approximately 100ms durations. The paradigm can either involve a single or dual task. In the single task version, participants make decisions about one image; for example, the presence of a letter; whereas in the dual task version, participants report on two targets; for example, the identity of a white letter (T1) in a stream of black letters and the presence of a specific black letter (T2) following the white letter. If T2 is presented more than 500ms after T1, then the accuracy approaches that of the single task version; however, if T2 is presented within 500ms of T1, the accuracy is impaired. This impairment is referred to as attentional blink and it is hypothesized to reflect attentional processing limitations (Raymond et al., 1992). Rokke et al (2002) found a deeper attentional blink in severely depressed participants, but only in the more demanding dual task condition. They hypothesized that this was caused by a limitation in the encoding of the stimuli into conscious awareness. If this is correct, then the impairment may be related to an overall reduction in cognitive capacity in depression cases, but not a specific impaired disengagement from depression-related negative material (Gotlib & Joormann, 2010; Rokke et al., 2002).

However, identifying impaired disengagement from negative material requires an experimental paradigm that can differentiate between a specific depression-related impairment in disengagement and a more general cognitive impairment (e.g. cognitive slowing) that can occur in depressed individuals. Emotionally-induced blindness (EIB) is an experimental paradigm that can measure disengagement from emotional visual stimuli displayed for short durations, typically in the hundreds of milliseconds (McHugo et al., 2013; Most et al., 2005). Importantly, EIB includes a control condition that provides a comparison of participants' performance between the emotional and neutral images. Therefore, the general impaired disengagement caused by depression should also be evident in the neutral condition and any additional effects caused by emotional images can be isolated.

In the EIB paradigm, a series of neutral images (typically landscape images) are rapidly presented (100ms each) and during the series, a single emotional distractor image is presented. Emotional distractors can be positive (e.g. erotica, scenes of excitement or achievement) or negative (e.g. attacks, weapons, disfigurement or scenes with disgusting content). A target image (i.e. rotated landscape) is then presented at one of two durations (either lag 2 or lag 8) after the distractor image and participant are required to make judgments about this image (see Figure 1). Participant's accuracy after an emotional distractor image is then compared to their accuracy after a neutral distractor image.

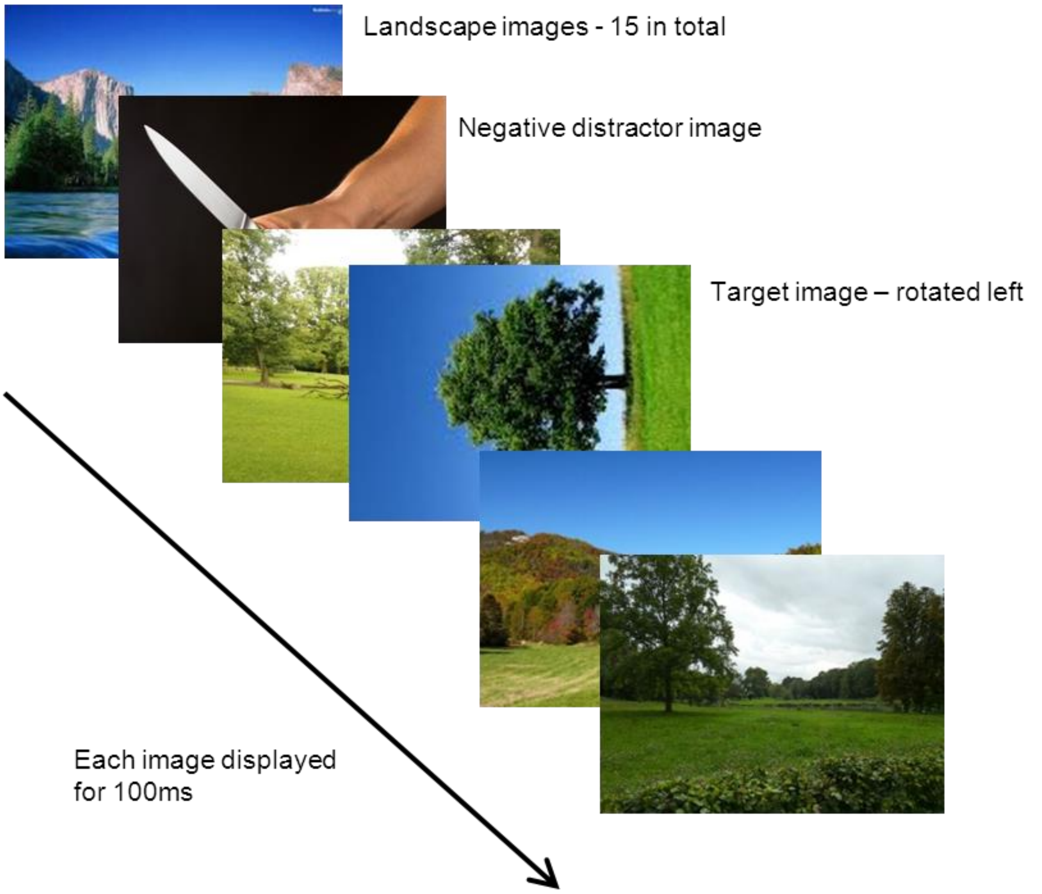

Figure 1. Example of part of an EIB trial. The distractor is the knife and the target image (at T2) is the tree rotated to the left.

Using EIB, Most et al. (2005) found that when the target image was shown at lag 2 after a neutral distractor image, participant accuracy was 91%; however, when the target image was shown at lag 2 after a negative distractor image, their accuracy dropped to 83%. When the target image was shown at lag 8 after either of the distractor images, accuracy was over 90% (see Figure 2 for a similar example based on data from a pilot study).

Figure 2. Typical EIB results showing lower accuracy for negative distractors at lag 2, with a recovery in performance by lag 8. Data from a pilot study.

The details of how and where in the early stages of attentional processing this impaired disengagement and the resulting drop in accuracy occurs is still being investigated (McHugo et al., 2013; Wang et al., 2012). However, the end result is a delay in disengagement from an emotional visual stimulus and processing of the following stimulus. Even though an impairment in engagement processes cannot be completely ruled out, the end result is still a delay in disengagement. EIB is therefore an ideal experimental paradigm for investigating impaired disengagement from negative material at the early stages of attentional and cognitive processing in relation to depression symptoms. It targets a relevant duration (200-800ms); provides a quantitative measure of disengagement; can utilize depression-relevant (negative) images; and it provides a control measure for any reduced overall cognitive capacity or cognitive speed.

Therefore, this study used an EIB paradigm to investigate the relationship between impaired disengagement from negatively-valenced emotional material and the symptoms of depression. We also included positively-valenced emotional material with similar arousal levels to the negatively-valenced emotional material; and by including positively-valenced emotional material, this permitted the effects of arousal to be differentiated from the effects of negative material.

Previous EIB studies have confirmed that people with depression have difficulty disengaging from negative stimuli after relatively long durations (>1000ms); however, this impairment has not been fully investigated at shorter intervals <1000ms). In particular, we were interested in understanding whether the impairment identified by Rokke et al. (2002), using an AB paradigm, was the result of general cognitive impairment caused by depression or a specific impairment related to the processing of negative material. Better understanding this impairment will further our understanding of the cognitive nature of depression.

Method

Participants

Participants were recruited from an undergraduate ANU Research School of Psychology psychology course Student Research Participation Scheme. First- and second-year ANU psychology students could receive course credit for their participation or they were paid for their time. Study inclusion criteria were: 18-years or older and a Canberra, Australia resident. Due to the strong aversive nature of some of EIB images, people were excluded if they had ever been diagnosed with Post Traumatic Stress Disorder.

A large sample of 130 ANU undergraduate students participated in the study including 34 males and 96 females, with a mean age of 20.3-years (range 18-42 years). Data from eight participants was excluded due to them not achieving an acceptable level of task accuracy for the neutral stimuli (> 60%). Mean depression scores for this group were not statistically different from those of the result of the sample.

Apparatus and stimuli

Stimuli were color images taken from the International Affective Picture Systems (IAPS) database (Lang et al., 2005) and the landscape (city and natural) images were downloaded from the internet. There were 20 neutrally-valenced, low arousal IAPS images, 20 negatively-valenced, high-arousal images and 20 landscape images. IAPS images were taken from multiple subsets to avoid a systematic bias in spatial frequency (Delplanque et al., 2007). Valence and arousal classifications were based on the ratings (using Likert type scales ranging from 1 (*low*) to 9 (*high*) included in the IAPS database, which are shown in Table 1. Stimulus size was 448 x 336 pixels, presented at a distance of 0.5m with a visual angle of 17.3 x 12.8 degrees. Stimuli were presented on a Sony Multiscan G400 CRT monitor at 100Hz driven by Cambridge Research Systems Visage hardware and software (Version 1.26) and a Dell Precision T3400 PC. The experiment was programmed using Matlab (Version R2012b) and Psychtoolbox-3.

Table 1

Valence and Arousal Ratings for Stimuli

Stimulus	Valence Mean	Arousal Mean
Neutrally-valenced, low-arousal	4.51	2.89
Negatively-valenced, high arousal	1.81	6.81
Positively-valenced, high arousal	6.68	6.67

Psychometric testing

The BDI-II (A.T. Beck et al., 1996) was used as a primary measure of depression symptoms. The BDI-II has a high level of reliability and validity, and a cut-off score of 20 can be used to indicate clinically-relevant levels of depressive symptoms (Dozois, Dobson, & Ahnberg, 1998). Depression and anxiety symptoms are highly concurrent with each other (Grant et al., 2005) and the cognitive models explaining them are similar (e.g. role played by unhelpful cognitions) (A. T. Beck, 2005). As a result, some studies include measures of anxiety and depression, in order to examine similarities or differences between the disorders in the studies' results. In this study, the Depression Anxiety Stress Scales-21 (DASS21) (Lovibond & Lovibond, 1995) assessed the symptoms of depression as well as anxiety (including cognitive symptoms) and stress (including autonomic arousal symptoms). The DASS21 has high reliability, and high convergent validity with other measures of anxiety and depression (Henry & Crawford, 2005).

Design and procedure

An EIB paradigm (Most et al., 2005; Most et al., 2007) was used as the basis for the study. Each trial consisted of a rapid serial visual presentation of 17 images for 100ms each, with no inter-stimulus interval. All the images, with the exception of two, were upright landscapes, either natural or cities. The remaining two images were the distractor and the target. The distractor was either a neutral or emotional image and the target was a landscape image rotated either 90 degrees left or right. The distractor was positioned at either the 4th, 6th or 8th position and the target appeared either two (lag 2=100-200ms) or eight (lag 8=700-800ms) items after the distractor[2] (see Figure 1 for an example). Participants used either the **z** key or **?** key to indicate the direction of the rotation of the target. There were four blocks that included 96 trials in each block. Two blocks utilized half neutral and half negative distractors and two utilized half neutral and half positive distractors. The valence of the first block presented was randomized across participants and the valence of each following block was then alternated.

Data analysis

Responses were captured in Matlab and transferred to Microsoft Excel for collation, accuracy calculations, and presentation, and then to SPSS for statistical analysis. Statistical power was calculated using G* Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007).

[2] The presentation of left vs right targets was not fully randomized for the first 65 participants. This was not apparent upon viewing the paradigm and it was corrected in the following 65 participants. There was no statistical difference in the accuracy scores between the two data sets, confirming that the participants were not aware of this issue.

Results

DASS21 sample scores ranged from 1-55 (m=16.7), with a possible range of 0-63. BDI-II sample scores ranged from 0-47 (m=13.4), with a possible range of 0-63. Participants with BDI-II scores in excess of 20, suggesting clinical level depression (n=27). Initial analysis was performed using two separate repeated measures 2 (valence) x 2 (lag) ANCOVAs comparing: (a) the effects of negatively-valenced distractors with neutral distractors; and (b) positively-valenced distractors with neutral distractors, with BDI entered as a covariate in order to combine continuous and categorical variables in a form of regression, as opposed to the standard use of ANCOVA. For negatively-valenced distractors, the ANCOVA indicated a non-significant interaction effect of lag x valence x BDI, F (1, 120)=.073, p=.788, partial η^2=.001. For positively-valenced distractors, the ANCOVA indicated a non-significant interaction effect of lag x valence x BDI, F (1, 120)=.475, p=.492, partial η^2=.004. As would be expected with an EIB experiment, the ANOVA showed significant main and interaction effects for lag and valence. For negatively-valenced distractors, there was a significant main effect of lag, F (1, 120)=37.07, p=<.001, partial η^2=.236; a main effect of valence, F (1, 120)=12.51, p=.001, partial η^2=.094 and an interaction effect of lag x valence, F (1, 120)=15.78, p=<.001, partial η^2=.116. This is shown in Figure 4 by the increase in accuracy from Lag 2 to Lag 8 for both valences and a higher level of accuracy at Lag 2 for neutral distractors than valenced distractors but a similar level of accuracy at Lag 8. For positively-valenced distractors, there was a main effect of lag, F (1, 120)=67.51, p=<.001, partial η^2=.360; a main effect of valence, F (1, 120)=41.41, p=<.001, partial η^2=.257 and an interaction effect of lag x valence, F (1, 120)= 51.62, p=<.001, partial η^2 = .301. The effects are similar to those for negative distractors with the exception of the level of accuracy at Lag 2, which is lower for positive distractors than for negative distractors.

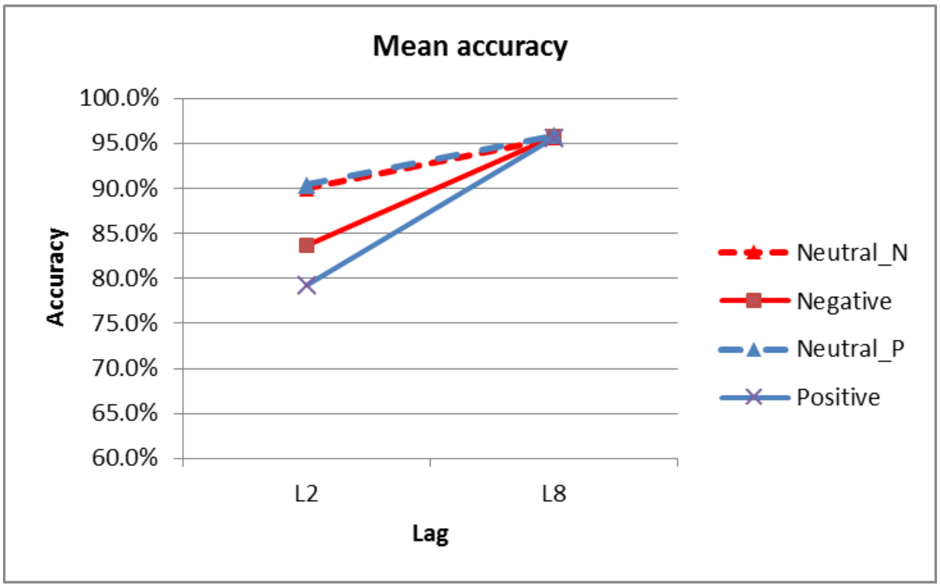

Figure 4. Results showing a classic EIB accuracy pattern, with reduced accuracy at L2 for both negative and positive distractors compared to neutral distractors and a recovery at L8 for all conditions.

The results show that the ability to disengage from emotional material, as measured by the EIB task was unrelated to depression symptoms, as measured by BDI score. To further confirm this finding, a post-hoc partial correlation test was carried out between BDI and DASS21 scores and the EIB effect (neutral – valence accuracy score) , for each lag x valence condition. A partial correlation was used as this test is less conservative than an ANCOVA. There were no statistically significant correlations at L2 for either valence or at L8 for negatively-valenced distractors. However there was a significant but small correlation between BDI scores and EIB effect at L8 for positive distractors, $r(122)=.194$, $p=.032$. A post-hoc power analysis indicated that there was a 93% chance of detecting a medium effect size ($r=.3$) with alpha set at $p<.05$ two-tailed.

General discussion

This study investigated the relationship between depression symptoms and impaired disengagement from emotional material, using an EIB paradigm. ANCOVA detected no evidence of a relationship between BDI score and EIB scores at either L2 or L8, for either the positively or negatively-valenced distractors. Post-hoc correlation tests found a significant but small correlation between BDI score and EIB effects at L8 for the positive distractors; but the effect size was small (r=.194, r^2=3.7%) indicating that the relationship may not have been clinically relevant, even if the test was acceptably conservative.

Our finding is consistent with the ruminative hypothesis of depression (Koster et al., 2011) which posits that a difficulty in disengaging from negative material in depressed individuals occurs only at longer stimulus durations, which is consistent with ruminative processes occurring over longer intervals. Our findings can be compared to those of Rokke et al. (2002) who showed an increased level of attentional blink (AB) in subjects with dysphoria, but only in a demanding dual task condition and not in a less demanding single task condition. They hypothesized that the results were caused by a limitation in encoding stimuli into conscious awareness. The Rokke et al. (2002) single task condition is somewhat similar to the EIB condition in this study in that they are both cognitively undemanding. Therefore, our findings support their conclusion that the effect they found was related to general cognitive impairment related to depression and not a difficulty with disengaging from negative material.

Our findings can also be compared with those of Onie and Most (2017) who investigated the relationship between EIB and ‘negative affect’, which corresponded to total DASS-21 score (i.e. combined measure of depression, anxiety and stress) (Lovibond & Lovibond, 1995). Thus, their measure reflected depressive symptoms to some extent but it was not a direct measure of it. They found that negative affect significantly predicted EIB performance at L1 (p=.007, r2=.118) but not L5. Their findings at L5 are consistent with our study results, but not their findings at L1. One explanation of the discrepant results is that a relationship does exist between EIB score and depressive symptom – but the relationship is small, and given the heterogeneity in depressive symptoms (Dunn et al., 2015; Gotlib & Joormann, 2010; Northoff, Wiebking, Feinberg, & Panksepp, 2011), different studies may or may not find significant results, based on chance and sample size.

Given our null results, there is the possibility of a having made a Type I error, i.e. incorrectly failing to reject the null hypothesis. Apart from the heterogeneity of depression symptoms, another factor increasing the risk of a Type I error, is paradoxically, the reliability of the EIB task. In reliable cognitive tasks with low between-subject variability, reliability for individual differences is low (Hedge, Powell, & Sumner, 2018). Hedge, Powell, and Sumner, (2018) analysed a range of common cognitive tasks, including the dot-probe task when demonstrating this paradox, but not the EIB task. However, another study carried out by Onie and Most (2017) suggested that the the EIB task has higher reliability than the dot-probe task. Future research into the EIB paradigm is required in order to analyse individual difference reliability its effect on statistical power. Our post-hoc power analysis indicated that there was a 93% chance of detecting a medium effect size (r=.3) with alpha set at p<.05 two-tailed, suggesting that our sample size of 130 was sufficiently large.

Another explanation for our null result could be differences in the images used, between our study and that of Onie and Most (2017). We reviewed the images in both studies in order to compare the valence, arousal levels. We were unable to make an objective comparison as many of the images used by (Onie & Most, 2017) were not taken from the IAPS database (Lang et al., 2005). Instead they were similar images obtained from the internet; therefore, they did not have published ratings available. However, our subjective opinion from the review was that there appeared to be no obvious difference between the subject matter, valence or arousal levels of the images used, between the two studies. A further difference between the two studies was the number of images used. In our study, we used 20 images of each valence, whereas (Onie & Most, 2017) used 96. A smaller number of images has the advantage of providing more consistency of images presented between participants. It has the disadvantage of potentially allowing more habituation to occur for each specific image. Previous studies using our image set (*see Chapter 3, Study 1, Experiment 1*) did not find any evidence of habituation with mixed positive and negative valenced images, based on changes in EIB effect in early vs. later blocks, suggesting that the smaller number of images in our study was not problematic. Given our findings and the comparison with the different finding of (Onie & Most, 2017), we suggest that the best explanation of the discrepant results is that a relationship does exist between EIB score and depressive symptom – but the relationship is small.

If the relationship between depressive symptoms and disengagement from negative material at short intervals is indeed weak or non-existent, this may have implications for psychological treatment. Cognitive Bias Modification (CBM) is a recent alternative intervention to CBT. Within CBM, there are two types of intervention: interpretive bias modification (CBM-I) and attention bias modification (CBM-A) (MacLeod, 2012; Mathews & MacLeod, 2002). CBM-I addresses conscious negative thoughts and trains the clients to make more positive interpretations of their thoughts; whereas CBM-A addresses the early stages of attention and cognition, targeting impairments at a similar duration to those investigated in this study.

CBM-A targets attentional and cognitive biases in order to reduce symptoms of mental illness (MacLeod, 2012) and the approach assumes that cognitive biases are either causally related to mental illness or they are part of the maintenance loop of the illness. Early clinical studies were promising with strong research support being provided (MacLeod &

Mathews, 2012). Since then CBM-A studies have proliferated; however, a more recent meta-analysis concluded that there were "no significant clinically-relevant effects" (Cristea, Kok, & Cuijpers, 2015), consistent with the results of this study in which no significant relationship was detected between depression symptoms and BDI.

In summary, our findings suggest that if any impairments in disengagement from positive or negative emotional material occur at short intervals (<1000ms) in people with depression symptoms, they are likely to be very small; consistent with the meta-analytic results of Cristea, Kok, and Cuijpers (2015). Additionally, our findings support the hypothesis of Rokke et al. (2002) that an increase in attentional blink in people with dysphoria was related to a general cognitive deficit and not to a specific impairment in disengagement from negative material. Finally, our findings are consistent with the ruminative theories of depression (Koster et al., 2011) and Beck's cognitive model of depression (A. T. Beck, 1967) which propose that a relationship exists between depressive rumination and a difficulty in disengaging from negative material.

Chapter 5. Study 3, defining short temporal intervals for research purposes

5.1 Chapter overview

Study 3 investigates the second cognitive impairment of depression covered in this thesis – a distortion in the processing of temporal intervals, leading to the sensation that time is dragging. Prior to commencing Study 4, it was necessary to identify a duration that was long enough for initial processing of the stimuli to be completed but short enough to avoid impairments related to rumination. When testing participants' disengagement from emotive stimuli, the EIB experimental paradigm provided a relevant duration (100-200ms). However, when testing the perception of duration, there were fewer constraints. In addition, some studies using durations less than 1,000ms suggest that the perception of duration of emotive images is inconsistent across the temporal range, with the duration of negative images overestimated at 1,000ms but underestimated at 200ms (Smith, McIver, Di Nella, & Crease, 2011). This finding suggested that there may be a change in the temporal processing mechanism at some point across this temporal range. If this is the case, the duration chosen in this experiment should avoid proximity to the transition point between mechanisms as this could produce inconsistent results and increase experimental noise.

In order to determine an appropriate duration, we investigated the effect of emotive images on the perception of durations in healthy subjects, using a range of data points from 50-1000ms. As outlined in this chapter, we found that an increase in the perceived duration of positively and negatively-valenced emotional stimuli at all data points; consistent with studies that used durations longer than 1,000ms. We also confirmed that the Weber fractions, within the range tested, followed the generalised form of Weber's law. Our findings were inconsistent with those of Smith et al. (2011), as discussed above, and we suggest that the experimental method they had used produced noisy data, leading to an anomalous result.

Based on our findings, we selected a duration of 200ms for testing in Study 4 as this was clearly above the participants' threshold of discrimination but still short enough to preclude ruminative processing.

5.2 Publication status

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5.3 Published manuscript:

Perceived Time Slows During Fleeting Fun or Fear

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Abstract

Previous psychophysical studies at durations greater than 1,000ms have confirmed the anecdotal reports of an increase in the perceived duration of both positively and negatively-valenced emotive stimuli; however, the results of studies at durations less than 1,000ms have been inconsistent. This study further investigated the effect of valence on the perception of durations less than 1,000ms. We used both positively and negatively-valenced stimuli in order to compare their effects on the distortion of duration and we tested multiple data points within the sub-one second range. We found an increase in the perceived duration of both positively and negatively-valenced emotional stimuli at all data points. This is consistent with studies at durations longer than 1,000ms and also with models of temporal processing. We also confirmed that Weber fractions, within the range tested, followed the generalised form of Weber's law.

Perceived Time Slows During Fleeting Fun or Fear

"Time stood still" is a common expression describing the perception of time slowing down when exposed to dangerous or emotional stimuli; however, the processes that underlie the perceived duration of emotional stimuli (affective chronometry) are not fully understood (Davidson, 2015). One aspect of affective chronometry that is particularly unclear and has had inconsistent findings is the distortion of duration at intervals less than 1,000ms. Another aspect that is not fully understood is whether the distortions are caused by changes in arousal levels or by changes in attention (Grondin, Laflamme, & Gontier, 2014).

Psychophysical techniques have been used to investigate and quantify the distortion at durations greater than 1,000ms and studies have consistently confirmed anecdotal reports of an increase in the perceived duration of emotive stimuli (Droit-Volet, Brunot, & Niedenthal, 2004; Droit-Volet & Meck, 2007; Tipples, Brattan, & Johnston, 2013). However, studies at durations less than 1,000ms have inconsistent findings. Studies have found an increase in the perception of duration of emotive stimuli, including fear and disgust inducing images (Gil & Droit-Volet, 2012), disgusting mutilation images but not disgusted faces (Grondin et al., 2014) and threatening but not disgust inducing images (Shi, Jia, & Mueller, 2012) .

Another inconsistent finding at durations less than 1,000ms is the effect of the sign of the valence of the stimulus. While studies at durations greater than 1,000ms have consistently found that both positively and negatively-valenced stimuli increase the perceived duration of the stimulus, Smith et al (2011) found that the estimation of duration varied depending on the sign of the emotional valence. At 1,000ms, negative image durations were overestimated and positive image durations were underestimated; however, at 200ms, negative image durations were underestimated but there was no effect on the estimated duration of positive images. These findings are problematic in relation to the dominant theoretical model of human temporal processing. This model suggests that the perception of an increase in the duration of emotive stimuli is caused by an increase in arousal, speeding up the internal clock (Droit-Volet & Meck, 2007). If this is the case, then both positively and negatively-valenced, arousing stimuli should cause an increase in the perception of duration.

The effect of arousal on duration estimates can be explained by Scalar Expectancy Theory (SET) and Attentional Gate Theory (AGT). SET has been the dominant model of human temporal processing at shorter intervals since the late 1970s (Buhusi & Meck, 2005; Gibbon, 1977; Grondin, 2008, 2010a; P. A. Lewis & Miall, 2009; Wearden, Denovan, Fakhri, & Haworth, 1997). In SET, temporal processing occurs using a single pacemaker, or internal clock, that generates 'ticks' that are stored in an accumulator. The number of accumulated ticks in a period is then used for temporal computations. For example, when comparing two intervals, the number of ticks accumulated in the first duration is compared to the number of ticks accumulated in the second duration. Replicating an interval in motor control can be achieved by recreating the number of ticks stored in memory from previous experience. This single internal clock could, at least in theory, be used for processing any duration from milliseconds to hours by accumulating additional ticks – in much the same way as a digital watch accumulates vibrations from a quartz crystal.

AGT is a development on SET and proposes a gate mechanism that regulates the flow of ticks to the accumulator (Zakay & Block, 1996). AGT proposes that increased attention opens the gate mechanism wider, increasing the number of ticks accumulated in a given period, thereby increasing the perceived duration of the period. Studies have attempted to discriminate between the effects of attention and arousal in the perception of an increase in duration. Grondin et al. (2014) suggest that arousal is the most robust explanation for explaining some emotional effects; however, further evidence is required to rule out the involvement of attention.

A further way to test for the effects of arousal would be to compare the effects of positively-valenced images with high levels of arousal to those of negative images with similarly high levels of arousal. If the effects were similar, this would support the arousal theory; however, if the effects were dissimilar, this would suggest that other mechanisms such as attention may be involved.

This study used psychophysical techniques to examine the distortion of duration caused by positive and negative-valenced emotional stimuli, with the metric for systematic distortions or errors being changes in the point of subjective equality (PSE) between the two alternative stimuli. The PSE for duration represents the respective durations at which two stimuli are perceived as equal. The direction and magnitude of any difference between their physical durations at the PSE reveals a temporal distortion, given an experimental manipulation of the second stimulus.

We used a two-alternative, forced-choice (2AFC) paradigm to present the two stimuli. This reduced the chance that differing memory processes across durations could influence the result. One possible explanation for previous inconsistent findings is the extensive use of learned duration methods. For example, in the bisection point version, two reference durations are learnt by the participant. A single test stimulus with a duration between the two learnt durations is then presented and the participant has to choose if the test duration is closer to the longer or shorter learnt duration. This may influence the results due to involving either different memory processes or different levels of memory resources at, for example, 200ms compared to 1,000ms.

We used both positively and negatively-valenced stimuli to identify any differences in PSE shift caused by valence. We compared successive durations ranging from 50ms to 1,600ms in order to identify any differences or changes in the effect across the range of durations. Finally, we examined Weber fractions (WFs) at each duration, to measure the resolution of the temporal processing system at that duration and to confirm that our experimental paradigm was providing clean data.

Method

Participants

One of the authors (MC) and four undergraduate students from the Australian National University (ANU) participated in this experiment (three males, two females). The undergraduate students provided written informed consent, as per the ANU Human Research Ethics Committee's requirements, and they were paid for their time.

Apparatus and stimuli

Stimuli were colour images taken from the International Affective Picture Systems (IAPS) database (Lang et al., 2005). There were 20 neutral-valence, low arousal images, 20 positive-valence, high-arousal images and 20 negative-valence, high-arousal images. Images were taken from multiple subsets to avoid systematic biases in spatial frequency (Delplanque et al., 2007). Valence and arousal classifications were based on ratings included in the IAPS database, and are shown in Table 1. Ratings are based on a scale of 1 = low and 9 = high.

Table 1

Valence and Arousal Ratings for Stimuli

Stimulus	Valence Mean	Arousal Mean
Neutral-valence, low-arousal	4.51	2.89
Positive-valence, high-arousal	6.68	6.70
Negative-valence, high arousal	1.81	6.81

Stimulus size was 448 x 336 pixels, presented at a distance of 1.1m with a visual angle of 7.5 x 5.6 degrees. Stimuli were presented on a Sony Multiscan G400 CRT monitor at 100Hz driven by Cambridge Research Systems Visage hardware and software (Version 1.26) and a Dell Precision T3400 PC. The experiment was programmed using Matlab (Version R2012b) and Psychtoolbox-3.

Design and procedure

A temporal two-alternative, forced-choice (2AFC) design was used to compare the duration of two images. The neutral-valence reference image was shown in the first interval and the duration of this image was compared to the varying duration of the second image. The order effect caused by using this method was identified by including blocks comparing the durations of two neutral images.

The experiment consisted of three blocks where the second image had a valence that was neutral, positive or negative, with 135 trials in each block. The 135 trials consisted of nine comparison data points (see Table 2), each presented 15 times, with comparison durations randomised within each block. The order of valence and duration blocks was randomised. Across conditions, the reference durations tested were: 50ms, 100ms, 200ms, 400ms, 800ms and 1,600ms.

Table 2

Comparison Data Points (ms)

Reference Duration	1	2	3	4	5	6	7	8	9
50	10	20	30	40	50	60	70	80	90
100	20	40	60	80	100	120	140	160	180
200	40	80	120	160	200	240	280	320	360
400	80	160	240	320	400	480	560	640	720
800	160	320	480	640	800	960	1,120	1,280	1,440
1,600	320	640	960	1,280	1,600	1,920	2,240	2,560	2,880

A blank, grey screen was shown at the beginning, inter-stimulus interval (0.75s) and end of each trial. Participants were required to indicate which image was presented for the longest duration (first or second). Responses were captured on a keyboard using the left arrow key for the first image and the right arrow key for the second image. The response initiated presentation of the following trial.

Data analysis

Responses were captured in Matlab and then transferred to Prism Graphpad (Version 6.02) and fit to a psychometric curve – a cumulative Gaussian function. This curve was used to calculate the PSE shift and WF for each participant, for each valence-duration combination. PSE shift was calculated by dividing the duration at which the probability was .50 that the test (second) image was perceived to be long, by the reference duration. This provided a proportionate measure of PSE shift to allow comparison between reference durations. WF was calculated using the formula WF = $(D_{.75}-D_{ref})/ D_{ref.}$ $D_{.75}$ was the duration at which the probability of perceiving the test image as being long was .75. D_{ref} was the reference duration. WF may be calculated using the mean of D.75-Dref and Dref-D.25 as a numerator, however we used a proportional scale, therefore our curve was symmetrical and D.75-Dref provides the same numerator. Psychometric curves are typically plotted using a linear X axis. However in this experiment, we used a 2AFC method where the duration was varied above and below the reference duration. In this case, a linear scale would be mathematically incorrect as the shorter duration should always be considered as the reference duration to maintain proportionality. In the reported results, we therefore used an inverse log scale for the X axis as this maintains proportional consistency across the range of durations. The results were analysed using both linear and inverse log scales and no significant difference in outcome was found. Although the inverse log scale is more correct, it is unlikely to produce a different result to the linear scale unless the slope of the psychometric curve is very flat (the WF is large).

Results

The results of primary interest in our study were the PSE shifts and these would typically be reported first. However, the calculation of Weber fractions revealed a threshold effect at the 50ms data point. Therefore this data point was not included in the analysis of PSE shifts. The Weber fraction results have been reported first in order to explain this issue before moving on to the PSE shift results.

Weber fractions

Weber fractions (WFs) are plotted by duration for each valence in Figure 1. WFs between 100ms and 1,600ms were relatively flat with a mean of .17; however, there was a sharp increase at 50ms (M = .33).

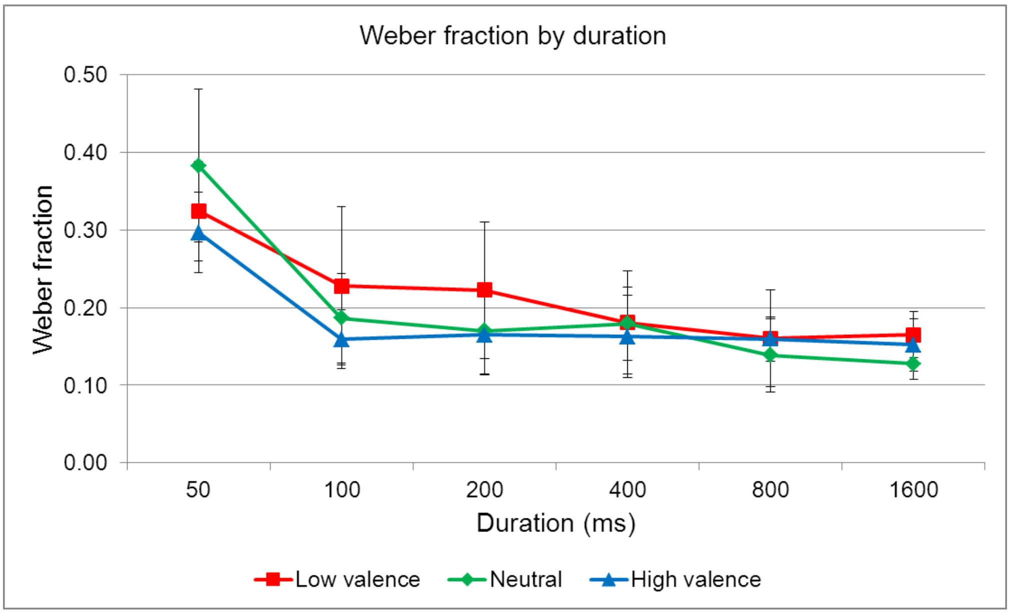

Figure 1. Weber fraction by duration for each valence. Error bars represent standard errors.

The results were analysed with all durations included using an omnibus 3 (Valence) x 6 (Duration) repeated measures ANOVA to determine if valence or duration affected WFs. The effect of duration was significant, F (5, 20) = 11.03, p = <.001, partial η^2 = .734. The effect of valence was not significant, F (2, 8) = 1.13, p = .369, partial η^2 = .221. There was no interaction effect between valence and duration, F (10, 40) = 1.38, p = .225, partial η^2 = .256.

It appeared that the duration effect was driven by the 50ms data point (see Figure 1). To confirm this, an additional 3 (Valence) x 5 (Duration) repeated measures ANOVA was performed, excluding the 50ms data point. Once this result was excluded, the effect of duration was no longer significant, F (4, 16) = 1.11, p = .386, partial η^2 = .217. The effect of valence was still not significant, F (2, 8) = 1.25, p = .337, partial η^2 = .238. There was no interaction effect between valence and duration, F (8, 32) = 0.78, p = .621, partial η^2 = .165.

PSE shift

PSE shifts are plotted in Figure 2. The 50ms data point was excluded due to the threshold effect at 50ms (identified under the WF results, see Fig 1). The PSE shift for the low-valence (negative) and high-valence (positive) images was greater than that for the neutral images, at all durations – that is when they were the same duration, the duration of the valenced images was perceived as longer than the neutral images; however, there was no difference between the PSE shifts for the high-valence and low-valence images. There was an effect of duration; however, this was likely due to the fluctuation in the order effect across durations – theoretically, comparing two neutral images should result in a zero PSE shift; however, time order effects can cause the second image in a sequence to appear to be a different duration to the first image, even if the images and durations are identical (Grondin, 2008). The neutral line represents this order effect at each duration, as both images in the 2AFC comparison were neutral.

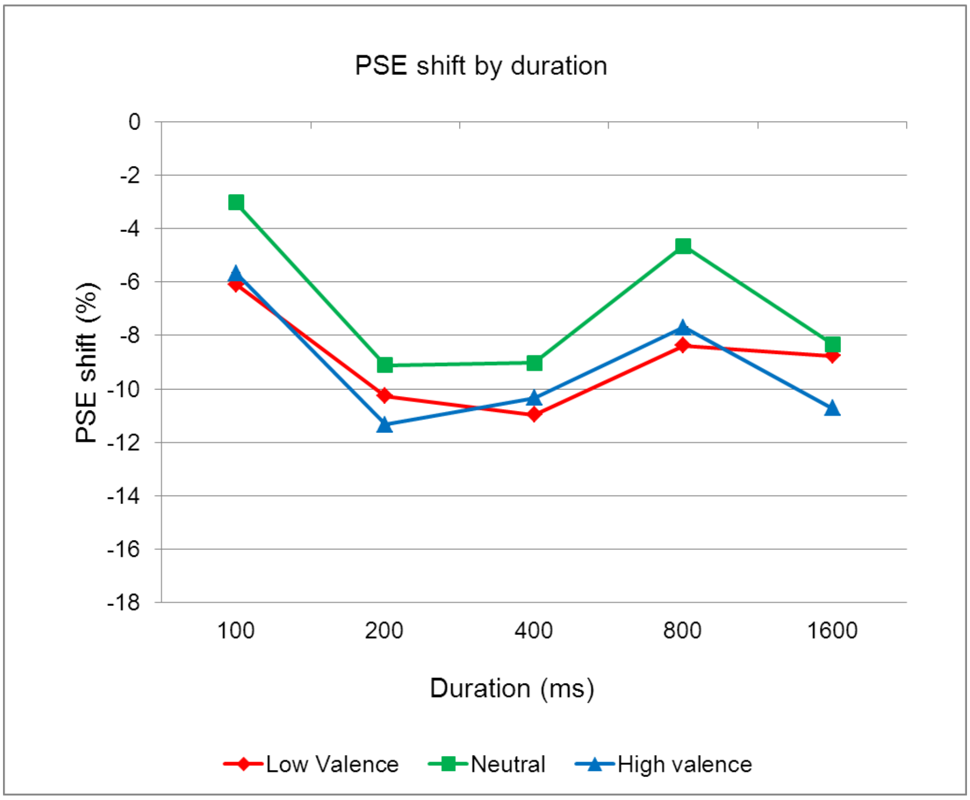

Figure 2. PSE shift for the second image in comparison to the first image. Error bars represent standard errors.

The psychometric functions were tested for goodness of fit which was found to be satisfactory (mean R^2 = .98). Statistical analysis was performed using an omnibus 3 (Valence) x 5 (Duration) ANOVA to determine if valence or duration affected PSE. The effect of duration was significant, F (4, 16) = 4.764, p = .010, partial η^2 = .544. The effect of valence was also significant, F (2, 8) = 5.554, p = .031, partial η^2 = .581. There was no interaction effect between valence and duration, F (8, 32) = 0.59, p = .779, partial η^2 = .128.

Statistical analysis was then performed on the data set after adjusting for the order effects, by subtracting the neutral result from the valence result, at each duration, and using an omnibus 2 (Valence) x 5 (Duration) ANOVA. The effect of duration was no longer significant, F (4, 16) = .080, p = .791, partial η^2 = .020. The effect of valence was also no longer significant, F (1, 4) = .391, p = .812, partial η^2 = .089. There was no interaction effect between valence and duration, F (4, 16) = 0.931, p = .471, partial η^2 = .189.

Discussion

This study used psychophysical techniques to examine the distortion of duration caused by emotional stimuli. Changes in systematic distortions or errors in duration were measured using PSE shifts. We used both positively and negatively-valenced stimuli to identify any differences in distortion caused by valence. We used a 2AFC paradigm to reduce the memory requirements in comparison to the learned duration paradigm. We compared successive durations ranging from to 50ms 1,600ms to identify any differences or changes in the effect within this range. Finally, we examined WFs at each duration, to measure the precision of the temporal processing system and confirm that our experimental paradigm was providing clean data.

We found that both positive and negative images were consistently perceived as lasting longer than neutral images, and we found no effect of duration. These findings are consistent with studies at intervals longer than 1,000ms and confirm that emotional stimuli cause an increase in the perception of duration below 1,000ms. We also found that the increase was independent of emotional valence, suggesting that the effect is more likely to be related to arousal than attention.

We also found an unexpected change in the time-order effect (TOE) between durations. When comparing two neutral images there should be no valence-driven PSE shift; any systematic shift can be attributed to the TOE. The TOE was originally documented by Fechner (1860). During Fechner's experiments with successively-lifted weights, he noted that the ratio of correct to incorrect judgements varied, depending on whether the incremental weight was lifted before or after the reference weight. Our finding that the TOE varied significantly with duration, suggests that some other mechanism/s may be involved that affects the TOE at different durations within this range. One possibility is that this effect is related to differences in memory encoding or retrieval; however, further investigation would be required to confirm this hypothesis.

We did not find a significant difference in the precision of duration comparisons, as measured by WF, between 100ms and 1,600ms, or any difference between positive and negative images. We did find an increase in WF at 50ms; however, this is consistent with the generalised mathematical model of a WF with a constant error, related to the absolute threshold of discrimination (Gescheider, 2013). In temporal processing, this fixed constant may be the effect of a fixed switch latency in a pacemaker-switch-accumulator model (Wearden & Lejeune, 2008). Switch latency can be viewed as a small constant error in the number of accumulated pulses, caused by a delay in the switch opening. The switch latency error, therefore, has a greater proportional effect at very short intervals than at longer intervals. If, for example, the fixed switch latency was 10ms, this would contribute an error of 20% at 50ms, but only 5% at 200ms.

Our findings in relation to PSE shift were consistent with studies at durations greater than 1,000ms that have found an increase in the perception of duration of emotional stimuli, independent of emotional valence (Droit-Volet et al., 2004; Droit-Volet & Meck, 2007; Tipples et al., 2013). However, our findings were inconsistent with Smith et al. (2011).

Smith et al. (2011), found that the durations of highly arousing, negative images were overestimated at 1,000ms but underestimated at 200ms. It is notable that the Weber fractions (WFs) in the Smith et al. (2011) study were relatively high (mean short 0.30, mean long 0.36) compared to other studies using similar visual stimuli and durations, e.g., Grondin (1993) (+-0.10) and our study (mean 0.17). WFs represent the resolution within a system and can increase substantially with external noise (Gescheider, 2013). It is therefore possible that the experimental method used by Smith et al. produced noisy data, leading to an anomalous result. One contribution to this anomaly may have been their randomised presentation of short and long durations within blocks. This appears to have resulted in all short-condition bisection points being consistently reported as shorter than the standard value and all long-condition bisection points being consistently reported as longer than the standard value. It is also unusual that the effect they found in the short block condition was not consistent across the durations within the block.

Another inconsistency between our study and Smith et al. (2011), and also Grondin (2010b), was their finding of a larger WF at 1,000ms compared to 200ms. Their finding does not fit with the generalised form of Weber's law which suggests that WFs should be larger at the lower end of a sensory range. Both of these studies used a learned duration method (note however that the Grondin study used an auditory not a visual stimulus). It is unclear if or why the learned duration method gives different results to the 2AFC method used in this experiment. One hypothesis is that the learned duration method uses more long-term memory resources due to the participant having to learn the reference duration/s earlier and then compare test durations back to them. It is possible that these relatively longer-term memory resources are differentially affected by duration or arousal, unlike the shorter-term memory processes involved in a 2AFC comparison.

In this study, we found that emotional stimuli cause an increase in the perception of duration below 1,000ms and that the increase was independent of emotional valence. This suggests that the effect is more likely to be related to arousal than attention. Our findings were consistent with the dominant models of temporal processing (SET and AGT) and also studies at durations greater than 1,000ms. We also found that WFs within the range tested followed the generalised form of Weber's law. We used a 2AFC method and the inconsistencies between our result and two previous studies (Grondin, 2010b; Smith et al., 2011) suggest that their use of the learned duration method may have influenced their results.

Update for thesis examination

The following study was not included in the literature review of the published manuscript; however, a thesis examiner requested that the study be addressed.

In a related study, Stetson, Fiesta, and Eagleman (2007), found evidence of an increase in duration estimates but not an increase in temporal resolution during a frightening event. Their paradigm involved participants testing their temporal resolution on a wrist-based digital-flicker device, whilst free-falling for approximately 2.5 seconds. Following the event, they were asked to estimate the duration of their fall. The results showed that participants' temporal resolution was unchanged during free-fall, however, participants' estimation of duration was increased by 36%, compared to observers. Although this study was novel and provides an interesting result, their method of measuring temporal resolution extended over the duration of the free-fall (2.5 seconds) and was therefore not limited to a <1000ms duration as in our paradigm.

Chapter 6. Study 4, distortions in temporal processing

6.1 Chapter overview

Study 4 investigated the hypothesis that the distortions in temporal processing in depressed individuals are related to attentional deficits and not a change in the underlying temporal mechanism. Studies using longer duration (>1,000ms) stimuli, when people with depression show impairments in sustained attention, have consistently identified the perception of time slowing or dragging, which provides support for the attentional hypothesis. An alternative hypothesis is that the temporal mechanism itself is impaired by depression. If the impaired temporal mechanism hypothesis is correct, then we should expect to see the effects of the temporal distortion at all durations, including very short durations (<1000ms). In this study, we utilised a 2AFC method to compare the duration of two images, and the relationship between the duration-distortions, the precision of the mechanism, and depression symptoms was analysed.

We detected no evidence of any changes in the underlying temporal mechanism in people with depression symptoms, based on the measures of temporal distortion and the precision of temporal discrimination. The findings suggest that distortion in the processing of temporal intervals, leading to a sensation that time drags, was not related to changes in the underlying temporal mechanism. Instead, the results support the hypotheses that this symptom was related to cognitive impairments associated with the illness, particularly problems with sustained attention to a task. Results suggest that people with depression tend to focus more on their distress or the passage of time, which may lead to the perception that the duration of the task was longer.

6.2 Publication status

This manuscript is unpublished.

6.3 Manuscript:

Time Slows in Depression but Only When Attentional Limits are Exceeded

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Abstract

This study investigated the hypothesis that distortions in temporal processing in people with depression symptoms will be related to attentional deficits associated with depression; and not to a change in the underlying temporal mechanism. Studies using longer stimulus durations (>1,000ms), at a time when people with depression have impaired sustained attention, have consistently identified temporal distortions, providing support for the attentional hypothesis. An alternative hypothesis is that the temporal mechanism itself is impaired in people with depression. If the impaired temporal mechanism hypothesis is correct, we might expect to see the effects of the impairment at all durations, including very short durations (<1,000ms). However, studies at shorter durations have either generated inconsistent results or they had methodological issues. Thus, an improved methodology was used in this study, which employed a short (200ms) reference duration and compared the effects of neutral and emotional stimuli. No evidence of any changes in the underlying temporal mechanism was detected in people with depression symptoms, based on measures of temporal distortion and the precision of temporal discrimination.

Time Slows in Depression but Only When Attentional Limits are Exceeded

People suffering from depression[1] frequently report that their subjective experience of time slows. This perceptual distortion has been researched for nearly a century, with experimental studies confirming anecdotal accounts (Bschor et al., 2004; Kitamura & Kumar, 1982; A. Lewis, 1932; Sévigny et al., 2003; Wyrick & Wyrick, 1977) (MDD and depression symptoms); however, the mechanisms underpinning this distortion are still unclear (Droit-Volet, 2013; Gallagher, 2012) (MDD and depression symptoms). Given that existing treatments for depression are only partly effective (Arroll et al., 2009; Bschor & Kilarski, 2016; Churchill et al., 2013; Churchill et al., 2010) (MDD and depression symptoms), it is important that the mechanisms which underpin the symptoms are fully researched and understood.

Most hypotheses suggest that the perception of time slowing in individuals with depression is related to cognitive impairments associated with the illness, particularly problems with sustained attention (Gallagher, 2012) (MDD and depression symptoms (Msetfi et al., 2012) (depression symptoms); and the suggested mechanism is a reduced ability to focus on the task. Instead, depressed people are thought to focus on their distress or the

[1] For the purposes of this paper, when discussing population statistics, depression models and treatments, 'depression' is defined in its generic form and includes people with a clinically-diagnosed major depressive episode or Major Depressive Disorder (MDD) (American Psychiatric Association, 2013), as well as those meeting a clinically-accepted cut-off number on a depression instrument such as the Beck Depression Inventory II (BDI-II) (A.T. Beck et al., 1996). This use of the generic 'depression' is common in the literature due to the large number of studies in the area, the many different criteria used to differentiate between depressed and control participants (Gotlib & Joormann, 2010; Peckham et al., 2010) and the changing diagnostic criteria for depression over the decades (American Psychiatric Association, 2016). Where specific studies of cognitive deficits are discussed, their definition (MDD or depressive symptoms) has been included.

passage of time, which leads to the perception that the duration of the task was longer. If this hypothesis is correct, then the distortion should only occur at longer durations (>1000ms) when people with depression experience deficits in sustained attention (Gotlib & Joormann, 2010) (MDD and depression symptoms). An alternative hypothesis is that the temporal mechanism itself is impaired by depression (Gil & Droit-Volet, 2009) (depression symptoms); and if the impaired temporal mechanism hypothesis is correct, then we should expect to see the effects of the impairment at all durations, including very short durations (<1,000ms).

Another related method of measuring distortions in the experience of time is the precision of a person's temporal discrimination, i.e. their ability to discriminate between the duration of two temporal intervals. If the experience of time in a depressed person is distorted due to a deficit in sustained attention related to rumination, then we might expect that the precision of temporal discrimination will be reduced only at longer durations. However, if the distortion was caused by impairments in the temporal processing mechanism, then the precision of temporal discrimination might be reduced at shorter as well as longer durations.

Recent relevant studies using longer durations have consistently confirmed that the perception of time slows in people with depression and they show reduced precision in their duration estimates (Msetfi et al., 2012; Sévigny et al., 2003) (depression symptoms). These findings have been used to support for the impaired attention hypothesis. Three studies have investigated distortions in the temporal processing mechanism and/or precision of duration estimates in relation to depression, at short durations.

The first study, by Gil and Droit-Volet (2009) found a shortening of the perception of duration at 1,000ms, but the findings were the opposite of studies using longer intervals and they require further investigation to explain why this may be the case. The other two studies: Sévigny et al. (2003) and Msetfi et al. (2012) reported findings that were consistent with attentional explanations such that attentional problems tend to affect longer durations

(>1,000ms) but not shorter durations. Sévigny et al. (2003) found evidence of reduced temporal discrimination resolution at 1,140ms but not at 500ms or 100ms; whereas Msetfi et al. (2012) found evidence of reduced temporal discrimination resolution at 1,000ms but not at 50ms.

However, the methodologies used in the two studies were different. Sévigny et al. (2003) used percentage accuracy as the measure of temporal discrimination, but this measure may have concealed small effects at shorter durations. In contrast, typically discrimination ability is measured by constructing a psychometric curve in order to maximise the precision of the psychophysical estimate (Grondin, 2008). Msetfi et al.'s (2012) methodology included an unusual feature that may have influenced the study results, they used simultaneously-presented visual and auditory stimuli to mark the time intervals. However, the temporal discrimination of auditory and visual systems is not equivalent (Rammsayer, 2014). Thus, participants' results may have been influenced by whichever stimulus modality they used when comparing the durations, which in turn may have been affected by depressive symptoms. Another potential issue with Msetfi et al.'s (2012) study is that they used a 50ms duration for their shorter interval, and 50ms is close to the threshold of visual perception, which typically causes a marked decrease in resolution (Corke, Bell, Goodhew, Smithson, & Edwards, 2016). This issue is reflected by Msetfi et al.'s (2012) mean Weber fraction (WF) for healthy participants of .13 at l000ms which increased to .66 at 50ms.

Given the potential methodological issues with these studies, a change in the underlying temporal mechanism cannot be eliminated as a contributor to the distortion in temporal processing or a reduction in the precision of duration estimates, in depressed people. Further investigation is therefore required to confirm or disconfirm the findings of the three existing studies, while also addressing the methodological issues. Confirmation of a distortion in temporal processing or a reduction in the precision of duration estimates at short durations is expected to provide support for the hypothesis that the temporal mechanism is impaired by depression. In contrast, a finding of no distortion or reduced precision at short durations will support the attentional impairment hypothesis, likely indicating that the observed methodological concerns in the previous studies did not compromise the study findings.

In this study, we addressed the objectives by combining four methodological features that were designed to maximise the possibility of identifying changes in the perception of duration or a change in temporal discrimination. First, a short reference duration of 200ms was used, which is well above the threshold of discrimination, thereby, reducing the influence of typical decreases in resolution of perceptions at threshold (Grondin, 2008). In comparison, Msetfi et al. (2012) used a short reference duration of 50ms, which is close to the threshold of discrimination for visual stimuli, whereas Gil and Droit-Volet (2009) used a reference duration of 1000ms and Sévigny et al. (2003) used 1140ms. There is some evidence suggesting that the sub-second human temporal mechanism is different to the supra-second mechanism (Grondin, 2001; P. A. Lewis & Miall, 2003; Rammsayer, Hennig, Haag, & Lange, 2001). Although the exact transition point is unclear, it does appear to be in the region of 1,000ms. If this is the case, then the experimental methodology should ideally avoid reference durations in the vicinity of 1,000ms duration but use durations several hundred milliseconds either side; which should reduce the opportunity for reference and probe durations to be processed by different mechanisms, thus, distorting the results. It also reduces the opportunity for variation to occur between the participants to influence the results; i.e. the reference duration processed by the sub-second mechanism in some participants and the supra-second mechanism in others. Thus, the reference duration of 200ms was chosen in this study, which is well below the proposed transition point.

Second, the reference stimulus was presented first in all trials. The order of the stimulus presentation can affect duration estimates in a phenomenon called the time-order-error (TOE) (see Grondin, (2008) for a detailed review). In order to minimise the TOE, many studies, including Msetfi et al. (2012), randomised the presentation of the first image between the reference and the probe stimuli. While this is effective in minimising the TOE, it also randomizes a systematic distortion, which introduces noise into the results, increasing the WF and decreasing the sensitivity of the experiment. We overcame this drawback by using a 'reminder' method (Rammsayer, 2014) such that the reference image is always presented first, but trials are included with probes of a similar duration to the reference image. Any TOE can then be calculated as a constant and built into the study results.

Third, we used a single stimulus modality (i.e. visual stimuli). Msetfi et al. (2012) used simultaneously-presented visual and auditory stimuli to mark the intervals, but temporal discrimination resolution is typically much higher in the auditory system than in the visual system (Rammsayer, 2014). Thus, participants' results may have been influenced by whichever stimulus modality they used when comparing the durations, which, in turn, may have been affected by depressive symptoms. In contrast, using a single stimulus modality eliminates the possibility of interference or switching between modality mechanisms.

Fourth, a 2AFC paradigm was used, which minimises participants' learning and memory requirements. Many temporal duration studies in the literature, including that conducted by Gil and Droit-Volet (2009), used a bisection point task with learned durations. This task requires the participant to memorize two reference durations (short and long) prior to the presentation of the test probes. However, if the internal clock mechanism is affected by depressed mood, then the effect on learned durations should be proportional to the effect on the test probe duration, with the net effect being zero.

Although the 2AFC paradigm has many advantages, it also has some limitations. One of the experimental challenges in designing a paradigm to measure changes in the perception of duration at short intervals is that the changes are likely to affect the perception of the reference and test stimuli equally, an example of the "El Greco fallacy" (Firestone & Scholl, 2014). For example, Gil and Droit-Volet (2009) used neutrally-valenced stimuli and showed a between-subjects (depressed vs healthy) difference in PSE using a temporal bisection task. However, a between-subjects difference in PSE using a temporal bisection task does not directly measure a difference in the perception of duration. For example, any difference between the measured PSE and true bisection point could be attributed to memory effects, suggesting that a difference between healthy and depressed PSEs were as likely to be driven by memory effects as a change in the perception of duration.

Using a 2AFC paradigm with two neutral stimuli does not fully address this problem. In theory, no PSE shift should occur as there is no change in the condition between the first and second stimulus; and any measured PSE difference is, in fact, a time-order-error (TOE). The mechanisms underlying TOEs are not fully understood; however, they are clearly related to perceptual memory and they are duration and modality specific (see Gondin, 2008 for a detailed discussion). Thus, a difference in PSE (or TOE) between healthy and depressed participants using a 2AFC paradigm with two neutral stimuli should provide evidence for a change in temporal processing or a memory mechanism/s; whereas a finding of no difference would support attentional hypotheses.

However, in designing the study, we were conscious that a finding of no distortion or impairment could be interpreted as providing support for an attentional hypothesis or as a Type II error. Therefore, we used a control condition to demonstrate that the experimental paradigm was effective. To do this, we examined the effect of emotional stimuli on the perception of duration and the precision of temporal estimates. In healthy individuals, at short durations (<1,000ms), emotional stimuli increase the perception of duration, but they exert no effect on the precision of temporal estimates (Corke et al., 2016). Thus, in our study, a within-subjects PSE shift when comparing emotion and neutral stimuli should clearly demonstrate that the paradigm was effective. In addition, a between-subjects effect of depressive symptoms on the PSE shift should support the theory that there are changes in the underlying temporal mechanisms or memory processes in people with depression symptoms.

In summary, our study investigated the hypothesis that distortions in temporal processing in people with depression symptoms will be related to attentional deficits associated with depression, and not changes in the underlying temporal mechanism. Current theory suggests that the perception of time slowing in depressed people is most likely related to attentional deficits. If this theory is correct, then the temporal distortion should only occur at longer durations when depressed people typically experience impaired attention (Gotlib & Joormann, 2010); whereas, if the perceptual distortion is caused by a change in the underlying temporal mechanism, then the change should be detectable at the earliest stages of attention and cognition (Droit-Volet, 2013; Gallagher, 2012). Studies at longer durations (>1,000ms) have consistently identified the perception of time slowing in depressed individuals, providing support for the attentional hypothesis. However, studies at shorter durations have either reported inconsistent results or they had methodological problems that may have confounded the findings. Thus, this study used an improved methodology and compared the effects of neutral and emotional stimuli. If the attentional theory is correct, we predicted that: a) there would be no difference in the PSE (TOE) between healthy participants and those with depression symptoms; b) the PSE shift caused by emotion stimuli would be unrelated to depression symptoms; and c) the precision of temporal estimates (WFs) would be unrelated to depression symptoms.

Method

Participants

Participants were recruited from an undergraduate ANU Research School of Psychology psychology course Student Research Participation Scheme. First- and second-year ANU psychology students could receive course credit for their participation or they were paid for their time. Study inclusion criteria were: 18-years or older and a Canberra, Australia resident. Due to the strong aversive nature of some images, people were excluded if they had ever been diagnosed with Post Traumatic Stress Disorder. Sixty-eight students participated in the study including 26 males and 42 females, with a mean age of 20.3 years (range 17-42 years).

Apparatus and stimuli

Stimuli were color images taken from the International Affective Picture Systems (IAPS) database (Lang et al., 2005) and landscape (both city and natural) images taken from the internet. There were 20 neutral-valence, low-arousal IAPS images and 20 negative-valence, high-arousal images. IAPS images were taken from multiple subsets to avoid systematic biases in spatial frequency (Delplanque et al., 2007). Valence and arousal classifications were based on ratings included in the IAPS database and are shown in Table 1. Ratings are based on a Likert scale of 1 = low and 9 = high. Stimulus size was 448 x 336 pixels, presented at a distance of 0.5m with a visual angle of 17.3 x 12.8 degrees. Stimuli were presented on a Sony Multiscan G400 CRT monitor at 100Hz driven by Cambridge Research Systems Visage hardware and software (Version 1.26) and a Dell Precision T3400 PC. The experiment was programmed using Matlab (Version R2012b) and Psychtoolbox-3.

Table 1

Valence and Arousal Ratings for Stimuli

Stimulus	Valence Mean	Arousal Mean
Neutral-valence, low-arousal	4.51	2.89
Negative-valence, high-arousal	1.81	6.81

Psychometric testing

The BDI-II (A.T. Beck et al., 1996) was used as a primary measure of depression symptoms. The BDI-II has a high level of reliability and validity, and a cut-off score of 20 can be used to indicate clinically-relevant levels of depressive symptoms (Dozois et al., 1998). Depression and anxiety symptoms are highly concurrent with each other (Grant et al., 2005) and the cognitive models explaining them are similar (e.g. role played by unhelpful cognitions) (A. T. Beck, 2005). As a result, some studies include measures of anxiety and depression, in order to examine similarities or differences between the disorders in the studies' results. In this study, the Depression Anxiety Stress Scales-21 (DASS21) (Lovibond & Lovibond, 1995) assessed the symptoms of depression as well as anxiety (including cognitive symptoms) and stress (including autonomic arousal symptoms). The DASS21 has high reliability, and high convergent validity with other measures of anxiety and depression (Henry & Crawford, 2005).

Design and procedure

A temporal two-alternative forced-choice (2AFC) design was used to compare the duration of two images, using a reference duration of 200ms. Comparison durations were 40ms, 80ms, 120ms, 160ms, 200ms, 240ms, 280ms and 360ms. The neutral-valence reference image was shown first and the duration of this image was compared to the varying durations of the second image. In each trial, the second image had a valence that was either neutral or negative. The order effect caused by using this method was identified by analysing the trials comparing the durations of the two neutral images. The experiment consisted of two blocks of 135 trials in each block, one neutral/neutral and the other neutral/negative. The 135 trials consisted of nine comparison duration points, ranging from 40ms to 360ms, each presented 15 times, with the comparison durations randomised within each block. The order of valence and duration blocks was randomised. A blank grey screen was shown at the beginning, during the inter-stimulus interval (0.75s), and at the end of each trial. Participants were required to indicate which of the images was presented for the longest duration (first or second). Responses were captured on a keyboard using the left arrow key for the first image and the right arrow key for the second image. Their response then initiated the commencement of the next trial.

Data analysis

Responses were captured in Matlab and then transferred to Prism Graphpad (Version 6.02) and fit to a psychometric curve (i.e. cumulative Gaussian function). This curve was used to calculate the PSE shift and WF for each participant, for each valence-duration combination. PSE shift was calculated by dividing the duration at which the probability was .50 of the test (second) image being perceived as longer than the reference duration. This provided a proportionate measure of PSE shift to permit a comparison between the reference durations. WF was calculated using the formula WF = $(D_{.75}\text{-}D_{ref})/ D_{ref.}$: $D_{.75}$ was the duration at which the probability of perceiving the test image being longer was .75; whereas $D_{ref.}$ was the mean reference duration for each participant. An inverse log scale was used for the X axis as this maintains proportional consistency across the range of durations (Corke et al., 2016).

Results

Analyses were performed to investigate the relationship between the measures of affective distress (i.e. BDI, DASS-anxiety & -stress), valence of the stimuli (i.e. neutral or negative), perception of duration (PSE), and the precision of duration estimates (WF). Inspection of the data revealed that eight participants were unable to achieve the minimum acceptable discrimination accuracy levels of 75% (chance=50%), when comparing the durations of the longest (360ms) or shortest (40ms) duration to the reference duration (200ms). The participants were excluded from the analysis. There were no statistical differences between the affective distress measures of the included and excluded participants.

PSE durations and WFs have been summarized in Table 2 and BDI score distributions for included participants have been summarized in Figure 2. DASS21 sample scores ranged from 0-44 (m=16.2), with a possible range of 0-63. BDI-II sample scores ranged from 0-36 (m=13.2), with a possible range of 0-63. Participants with BDI-II scores in excess of 20, suggesting clinical level depression (n=15).Statistical analysis was performed using ANCOVA for each measure of temporal distortion (PSE and WF) x 2 valences (neutral and negative); with BDI, DASS21-anxiety and DASS21-stress scores included as covariates. Due to the high level of correlation between the distress scores, the ANCOVA were performed on each covariate individually (Tabachnick & Fidell, 2007).

The ANCOVA for WF indicated a significant main effect of valence, F (1, 58)=7.934, p=.007, partial η^2=.12. Results indicated that temporal discrimination was slightly better for negatively-valenced images (mean WF=.13) than neutral images (mean WF=.15). There was no evidence of any effect of affective symptoms on participants' perceived duration or temporal discrimination. In particular, the interaction between valence and BDI was non-significant and the effect size was trivial, F (1, 58)=1.278, p=.263, partial η^2=.022.

The ANCOVA for PSE indicated that there was no effect of valence on the perceived duration F (1, 58)=.016, p=.9, partial η^2<.001. Furthermore, the interaction between PSE and BDI was non-significant and the effect size was trivial, F (1, 58)=.173, p=.679, partial η^2= .003. PSE vs. BDI scores are plotted in Figure 2 and WF vs. BDI scores are plotted in Figure 3.

Table 2

Mean scores

	PSE1	PSE2	WF1	WF2	BDI	Anx.	Stress
Mean	192.5	193.7	0.13	0.15	12.5	3.7	6.8
Standard deviation	15.44	9.47	0.06	0.06	10.3	3.6	4.5

Note. PSE1 = low-valence (negative) image, PSE2 = neutral image, WF1 = low-valence (negative) image, WF2 = neutral image.

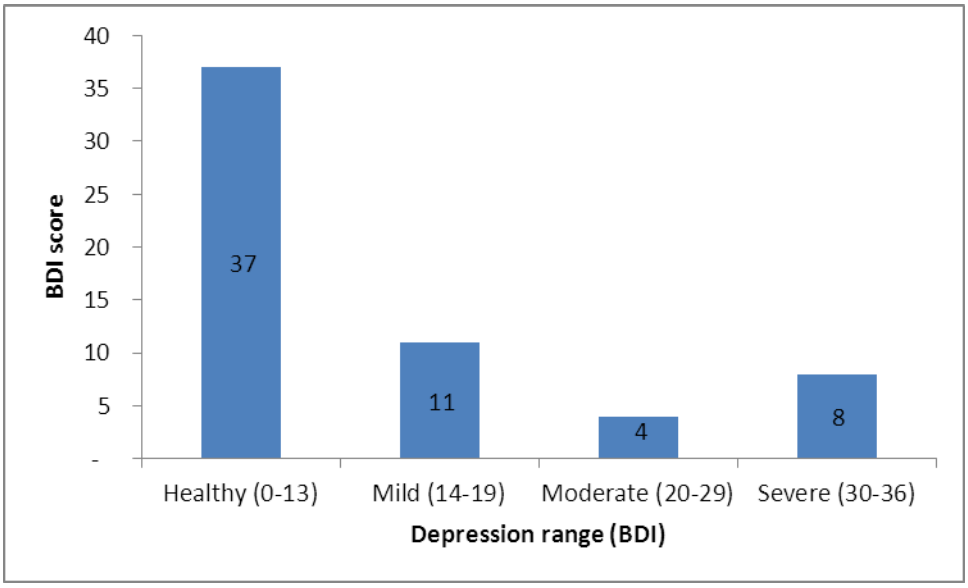

Figure 1. Distribution of depression ranges (BDI scores) for participants.

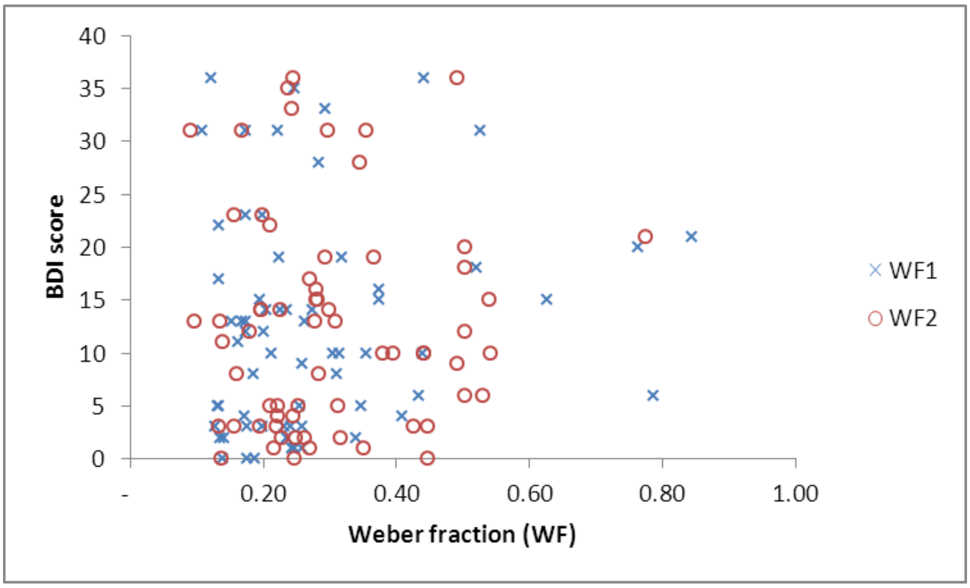

Figure 2. Weber fraction by BDI, WF1 = low valence, WF2 = neutral valence. No visual evidence of any relationship between BDI score and either WF1 or WF2.

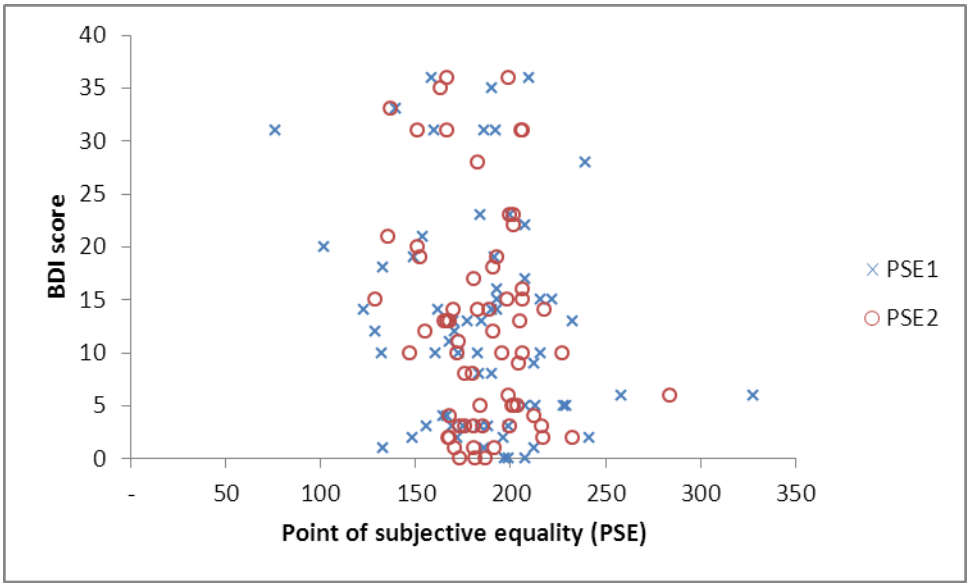

Figure 3. PSE (milliseconds) by BDI, PSE1 = low valence, PSE2 = neutral valence. No visual evidence of any relationship between BDI score and either PSE1 or PSE2.

In addition to the primary measure of depression symptoms, the BDI, analysis was also carried out for the four DASS21 scores: total, depression, anxiety and stress, including using the anxiety and stress scores as covariates. No significant results were found for any of these measures.

Discussion

This study investigated the hypothesis that distortions in temporal processing in people with depression symptoms are related to the attentional deficits associated with depression; and not a change in the underlying temporal mechanism. If this hypothesis is correct, then a distortion should only occur at longer durations when people with depression symptoms experience impaired sustained attention; whereas, if the perceptual distortion is caused by a change in the underlying temporal mechanism, then the change should be detectable at the earliest stages of attention and cognition. Prior studies that have used longer stimulus durations (>1,000ms) have consistently identified that the perception of time slows in depressed individuals, providing support for the attentional hypothesis. However, studies that have examined shorter durations have either showed inconsistent results or they had significant methodological issues.

In this study, we used an improved methodology to compare the effects of neutral and emotional stimuli. We predicted that if the attentional hypothesis was correct, then the following three measures will be unrelated to symptoms of depression: a) PSE shift for neutral stimuli (as measured by TOE); b) PSE shift related to emotion stimuli; and, c) the precision of temporal estimates (WFs).

Overall, the study findings provided support for the attentional hypothesis. No evidence of any change in the underlying temporal mechanism was detected in relation to depression score, based on the measures of temporal distortion and the precision of temporal discrimination. We also investigated the effects of negative emotion stimuli on temporal distortion and temporal discrimination, finding that temporal discrimination was better for negatively-valenced images than neutral images, confirming that the paradigm was sensitive enough to detect non-trivial effects. Our findings are consistent with those of Sévigny et al. (2003) and Msetfi et al. (2012) but not with Gil and Droit-Volet (2009).

Unlike our study, Gil and Droit-Volet (2009) found a shortening of time perception related to depression symptoms at 1,000ms, and they suggested that this was likely due to a sadness-induced slowing of the temporal mechanism. While a sadness-induced slowing of the internal clock mechanism is one possible explanation, the findings may have been influenced by the nature of the task they used. The researchers used a temporal bisection task in which the participants were required to learn the duration of two visual stimuli, one short and one long (400ms and 1,600ms). Intermediate duration probe stimuli were then presented and the participants had to indicate if the probes were closer to the short or long duration. Results showed that the point of subjective equality (PSE) was higher in depressed participants (929ms), compared to non-depressed participants (833ms), indicating a shortening effect of duration estimates in the depressed participants.

A temporal bisection point task with learned durations requires participant to memorize the reference durations prior to presenting the test probes. However, if the internal temporal mechanism did indeed slow down in depressed people, then the effect on the learned durations should have been proportional to the effect on the test probe duration, with the net effect being zero (Msetfi et al., 2012). In addition, the requirement to memorise a duration involves relatively long-term memory resources (typically several minutes). Thus, it is possible that only relatively long-term memory resources are affected by depression, unlike the shorter-term memory processes involved in 2AFC comparisons (milliseconds in this study). Another possible issue with the Gil and Droit-Volet (2009) study was their use of a reference interval of 1,000ms which coincides with the hypothesised transition point between sub- and supra-second human timing mechanisms.

Our study addressed these potential methodological issues and given that our findings support those of Sévigny et al. (2003) and Msetfi et al. (2012), we conclude that depression symptoms were unlikely to be related to a change in the measures of temporal distortion (PSE shift) or measures of the precision of temporal discrimination (WF) at short durations (< 1,000ms).

Although our findings are consistent with two of the three studies, the finding of no significant effect may be considered problematic. Thus, we have considered alternative reasons for these findings:

a) *Sample size may have been too small to detect an effect.* However, we found a significant effect of valence on WF, confirming that our paradigm was sensitive enough to detect a non-trivial effect. (*Note for thesis purposes only: ideally for publication, the sample size would be increased to at least 128, to give power of 0.8 to detect a medium effect size in a between subjects comparison. However the difficulty in obtaining participants with high depression scores made this impractical and given that the effect size found was so small and the p values were >.5 with the current sample, it was decided not to increase the sample size)*

b) *Methodological or experimental issues may have created noise, masking an effect.* The small size of the WFs (mean=.14) suggests that the resolution of the temporal discrimination procedure was high and therefore the methodology was suitable. In comparison, a study using similar methodology which detected an effect of valence on temporal processing had a mean WF of .17 (Corke et al., 2016).

c) *The heterogeneity of depression symptoms may have masked correlational findings.* People with depression are extremely heterogeneous in terms of their current symptoms (type and severity); previous symptoms; neurological changes; number of previous episodes; exposure to antidepressant treatments; exposure to psychological treatments; comorbidity; genetics; current life-stressors; past life-stressors; and demographics (Dunn et al., 2015). This level of heterogeneity has the potential to mask correlational findings that might small in size and related to one particular combination of the factors (e.g. effect only seen in people with comorbid anxiety and depression.

d) *Distribution of depression severity across participants may not have been large enough to reveal a statistical difference*. The generally accepted cut-off for clinically- relevant depression is a BDI score >19 and a score of 13 to 19 suggests moderate depression or dysphoria (Dozois et al., 1998). Scores reported by our participants ranged from 0 to 36, 14 of them had scores in the clinical range and a further 12 had scores in the range of 13 to 19. Although the distribution of scores in our sample included a range of symptoms, with more than a third of participants showing symptoms of depression, it is possible that a larger number of participants with extreme scores would increase statistical power and reveal a small effect.

On the basis of the above, we suggest that the null findings may be valid and that if any effects did exist, they may be trivial. However further studies with larger clinical sample sizes would be needed to fully support this conclusion.

Our study results are consistent with the hypothesis that distortions in temporal processing in depressed individuals are related to attentional deficits associated with depression. Such attentional deficits are only present at longer durations (>1000ms) (Gotlib & Joormann, 2010; Msetfi et al., 2012; Sévigny et al., 2003), whereas a change in the underlying temporal mechanism should be evident at all stimulus durations. Therefore, the finding of no distortions in temporal processing at a duration of 200ms supports the hypothesis that a distortion in temporal processing in depressed people were likely related to attentional deficits and not a change in the underlying temporal mechanism.

Chapter 7. Summary and discussion

7.1 Summary of findings

Despite many decades of research, neither the biological nor cognitive models of depression can fully explain the disorder nor do they result in effective treatment for all affected individuals. That is, the most widely used treatments, psychotherapy and antidepressants, have relatively low success rates (+-50%). Thus, it is important to advance research and the clinical understanding of depressed mood and depression symptoms.

This thesis focused on better understanding two of the cognitive symptoms of depression. Although depression symptoms are heterogeneous, two of the cognitive symptoms appear to be relatively ubiquitous: (a) an impaired ability to disengage from negative material (Armstrong & Olatunji, 2012; Donaldson et al., 2007; Gotlib & Joormann, 2010; Koster et al., 2011; Koster et al., 2005); and, (b) a distortion in the processing of temporal intervals, leading to the sensation that time is dragging (Bschor et al., 2004; Kitamura & Kumar, 1982; A. Lewis, 1932; Sévigny et al., 2003; Wyrick & Wyrick, 1977). The specific aim of the thesis was therefore to investigate whether the two symptoms occur at short durations. If they did occur at short durations, it might have suggested that the cognitive impairments and distortions are related to changes in the underlying mechanisms associated with attention, cognition, and temporal processing.

There would be other benefits to identifying these distortions. First, any advance in our understanding of depression would further our progress of developing a comprehensive model of the illness, facilitating better treatments and prevention. Second, identifying biological or physiological changes in depression would potentially help some patients to accept that the depression is “not their fault” and help to explain why they cannot just “snap out of it”, “think positively”, or other responses that they are often told or feel (Griffiths, Christensen, & Jorm, 2008).

Study 2 investigated the relationship between depression symptoms and impaired disengagement from negative and positive emotional material using an EIB paradigm, which tested stimulus durations of 200ms and 800ms. No evidence was found of any relationship between depressive symptoms and impaired disengagement from negative or positive emotion stimuli.

Study 4 investigated the relationship between depression symptoms and impairments and distortions in temporal processing. The study used a 2AFC paradigm to compare the duration of two images, neutral-neutral and neutral-negative. The reference duration was 200ms and the measures of impairment and distortion were PSE shift and WF. Once again, no evidence was found of any relationship between depressive symptoms and the impairments or distortions.

Together, the findings suggest that depression is unrelated to an impaired temporal processing mechanism or impaired mechanisms responsible for the disengagement from emotion stimuli. Instead, the findings are consistent with the cognitive models of depression. Specifically: (a) the impaired disengagement from negative material in depression was more likely to be related to rumination and its effects on attentional control rather than earlier cognitive processes (Donaldson et al., 2007; Koster et al., 2011); and, (b) the perception of time slowing in depressed individuals was likely to be related to the cognitive impairments in sustained attention – especially that people with depression tend to focus on the passage of time (Gallagher, 2012; Msetfi et al., 2012).

7.2 Context of findings

Two studies in the literature (Onie & Most, 2017; Rokke et al., 2002) provided an indication that the impaired disengagement from negative stimuli related to depression symptoms may also occur at shorter intervals. Rokke et al. (2002) found an increased level of attentional blink (AB) in subjects with dysphoria, using an RSVP task with a neutral distractor. However, they only found that the effect occurred in the more demanding dual task condition. They interpreted the findings to indicate that the increase in AB was related to a more general impairment in cognitive capacity; consistent with the results of this thesis, as the EIB paradigm is cognitively similar to their less demanding single task condition, in which there was found to be no effect.

Similarly, Onie and Most (2017) found a significant relationship between EIB and ‘negative affect’ at a lag of 100ms. ‘Negative affect’ was based on the combined measures of depression, anxiety, and stress from the DASS21, thus, it indexed global affective distress which is highly correlated to depressive symptoms. One explanation of their findings is that a relationship exists between EIB scores and affective disorders other than depression (e.g. anxiety, including autonomic arousal sensations or threat-related cognitions), and as stress and anxiety often coexist with depression symptoms, this may result in some studies showing an effect for depression whereas others do not. Thus, as a significant relationship was not demonstrated between the effects and depression symptoms in this and other studies, it is more likely that impaired disengagement from negative material in depressed individuals is caused by rumination and its effects on attentional control.

Results of the studies in this thesis also provide no evidence of a relationship between depression symptoms and impairments and distortions in temporal processing at short durations. The results are consistent with two of the three relevant studies in the psychological literature, by Sevigny et al. (2003) and Msetfi et al. (2012), but they are inconsistent with those of Gil and Droit-Volet (2009) who found a shortening of the perception of duration at 1000ms in depressed individuals. The findings of Gil and Droit-Volet were unexpected in two regards: first, they are inconsistent with the results of Sevigny et al. (2003), Msetfi et al. (2012), and this thesis; and second, the distortion was in the opposite direction to that which was expected. A large number of longer duration studies have shown that a lengthening of the perception of duration was related to depression, not a shortening of it (Bschor et al., 2004; Kitamura & Kumar, 1982; A. Lewis, 1932; Sévigny et al., 2003; Wyrick & Wyrick, 1977). Therefore, it is suggested that the findings were influenced by the temporal bisection paradigm that was used. In this task, participants were required to memorize short and long reference durations and then test probes, between the two durations, were presented, and participants had to indicate if the test probes were long or short. Long-term memory is a critical component of this task due to the requirement to memorize short and long durations in advance; and there is no way to differentiate between the effect of depression on the: (a) memory of the reference durations; and, (b) perception of the duration of the test probe in the paradigm. Thus, it is possible that the findings were related to memory effects rather than the perception of duration.

7.3 Implications of findings

The primary research questions underpinning this thesis were partly inspired by the developing literature which shows links between depressive symptoms and physiological changes in the brain. Neuroimaging studies have provided evidence of changes in biological mechanisms that are consistent with Beck's cognitive model of depression (Disner et al., 2011). For example, during eye-tracking tasks, individuals with depression show reduced functional activity in the anterior cingulate cortex, dorsolateral prefrontal cortex, ventrolateral prefrontal cortex, and superior parietal cortex; which are brain areas involved in engagement and disengagement from positive and negative stimuli (Disner et al., 2011). In addition, Disner (2011) has provided a detailed model linking changes in areas of the limbic system and frontal cortex to each of the main elements of the cognitive model of depression (i.e. biases in attention, processing and memory, and increases in rumination and activation of negative schemas). Another promising area of biological research on depression is related to the various brain inflammatory hypotheses (Maes et al., 2016). According to the hypotheses, stress (e.g. major life events or social adversity) can activate the immune system, in particular pro-inflammatory cytokines (e.g. interleukin-6) (Slavich & Irwin, 2014). The biological response system is thought to have evolved to deal with injuries from physical threats, but in modern society the system is more likely to be activated by real or perceived social threats or adversity. Short-term activation of the inflammatory response system is posited to lead to hypervigilance, anxiety, disrupted sleep and depressed mood, whereas chronic activation can lead to inflammatory diseases and susceptibility to infection. In the models, mood symptoms and the social withdrawal of depression are regarded as ‘sickness behaviour’ which are regarded as adaptive behaviour that can promote time for healing and potentially limit the spread of disease (Maes et al., 2016; Slavich & Irwin, 2014). Collectively, the theories may indicate that typical physiological changes in the brains of depressed people may result in changes in attention, cognition, and temporal processing. However, the studies in this thesis did not provide evidence of any changes in the physiological mechanisms we examined; instead the findings suggested that changes are only likely to occur at longer durations.

The study findings have implications for Cognitive Bias Modification (CBM), an experimental treatment for depressed mood. In particular, the findings of Studies 2 and 4 are consistent with one type of CBM – interpretive bias modification (CBM-I). CBM-I involves working with conscious negative thoughts and training participants to make more positive interpretations of their thoughts, consistent with Beck’s cognitive model of depression and the rumination hypothesis. However, the other version of CBM, attentional bias modification (CBM-A), involves targeting specific attentional and early stage cognitive biases related to depression, including impaired disengagement from negative material (MacLeod, 2012). In CBM-A, participants are trained to orient preferentially towards positive material or disengage faster from negative material. Early evaluations of the therapy were promising and the therapy has since proliferated, possibly due to the fact that the treatment is easy to carry out in a laboratory environment. However, a recent meta-analysis concluded that there were "no significant clinically-relevant effects" (Cristea et al., 2015), and the effect sizes became non-significant after adjusting for publication bias and excluding outliers. Consistent with this latter assertion, our findings suggest that impaired disengagement from negative material at short durations is likely to be trivial if it exists at all. Thus, the results call into question the relevance of CBM-A as it directs attention towards the disengagement from negative material at short durations, which were shown to be unrelated to depression symptoms in our studies.

Studies 1 and 3 in this thesis do not directly address the main thesis questions, instead they cover technical issues related to the paradigms used to explore the questions. Study 1 "The Influence of Prior images on Emotion-induced Blindness", investigated the influence of prior distractor images on the EIB effect. We found that mixing positive and negative distractors in the same block of trials reduced the EIB effect size in later trials, suggesting a habituation to the stimulus effect. This did not occur where blocks only contained distractors of a single valence. Further studies are required to more fully evaluate and confirm this effect; however, our findings suggest that future studies should not use both positive and negative distractors in the same blocks, until the effects have been clarified.

Study 3 "Perceived Time Slows During Fleeting Fun or Fear", investigated the distortions in temporal processing at intervals of 50-1,000ms. Some studies have suggested that the perception of duration of emotive images is inconsistent across this temporal range, suggesting a transition point between temporal processing mechanisms; however, the results have been inconsistent. Given that the main thesis question focused on durations within this range, it was appropriate to test this consistency prior to selecting a temporal range for Study 4 (Time Slows in Depression). We used improved methodology and found a consistent increase in the perceived duration of positively- and negatively-valenced stimuli across the temporal range of 5-1,000ms. Our findings will allow future studies of temporal processing to use a duration within this range that best suits the researchers' question, without being concerned about the potential effects of inconsistency within the range.

7.4 Limitations of studies

An important limitation of Studies 2 and 4 in this thesis relates to the construct of depression and the measurement of its symptoms. Depression refers to both the people with a clinically-diagnosed major depressive episode or major depressive disorder (American Psychiatric Association, 2013) and the people who meet criterion for clinically-relevant depression, as indicated by a Beck Depression Inventory-II (BDI-II) score of >19 ** (A.T. Beck, Steer, & Brown, 1996). The use of this dual definition is commonly employed in the psychological literature, such that a large number of studies have used different criteria to differentiate between depressed individuals and healthy controls (Gotlib & Joormann, 2010; Peckham, McHugh, & Otto, 2010). Additionally, the diagnostic criteria for depressed mood have changed over the decades (American Psychiatric Association, 2016).

In our thesis, the BDI-II measure was used to index participants' depression symptoms. This instrument was chosen as it has good validity and reliability and it is one of the most commonly used research measures of depression (A.T. Beck et al., 1996; Dozois et al., 1998). However, the BDI-II has reported limitations. First, it is not a diagnostic instrument, but it can be used as a screening instrument for depression and it has clinical cut-off scores that correspond to a possible or probable diagnosis of clinical depression (Dozois et al., 1998), although it does not provide the same certainty as a diagnostic interview. Nonetheless, the tool has often been used in large-scale RCTs to evaluate depression treatments in terms of the proportion of participants who no longer meet criteria for major depression. However, in the case of this thesis, we examined the correlations between depression symptoms and the degree of cognitive impairments and distortions. Using two continuous measures is thought to represent better statistical practice rather than splitting participants into depressed versus healthy individuals, then using an ANCOVA to measure any statistical relationship (DeCoster, Iselin, & Gallucci, 2009).

Second, the BDI-II, arguably, is not a continuous variable. Measures of pathology such as the BDI-II do not meet criteria for a continuous measure on two counts: the zero point does not necessarily equate to zero depression symptoms and the score is not necessarily linear, in that a person with a score of 20 is not necessarily twice as depressed as someone with a score of 10. These statistical limitations are inherent in most of the prior research using psychological instruments to assess depression, and as such, the approach is accepted in the literature as there is no practical alternative.

Additionally, the studies in this thesis may have limitations regarding the paradigms used. The EIB paradigm has two main potential limitations. First, the measure itself can be statistically analysed in two different ways. Either the raw accuracy scores can be used for each lag x valence combination or EIB scores can be used; that is, the difference between the accuracy of valenced distractors and neutral distractors. The EIB scores provide a clear measure of the effect being examined and it is an attractive option to use as the scores are simple to represent graphically. However, using difference scores instead of raw scores has the potential to distort results, principally because of the low reliability of difference scores compared to the raw scores; see (Gardner & Neufeld, 1987) for a detailed early review of the statistical issues and opinions. More recently Hedge et al. (2018) explain that when using difference scores, the subtraction process reduces the variance (error) between participants scores and therefore increases the proportion of measurement error, compared to between-participant variance. This clearly has the potential to distort the results. Therefore, we chose to initially run ANCOVAs using the raw accuracy scores to identify any statistical relationships, and then split the participants into high- and low-depression-score groups, using the published BDI clinical cut-off score, and their EIB scores were used to clearly represent the results graphically.

A second issue with the EIB paradigm is the treatment of outliers. Univariate outliers are typically identified by applying a cut-off point based on the number of standard deviations outside the sample mean (Tabachnick & Fidell, 2007). However, this approach is less clear in the case of the EIB paradigm. For example, in our study, several participants' accuracy scores at L2 for positive distractors were around 50% (chance level), whereas their accuracy for neutral distractors was around 90%. At L8, scores for the positive distractors had recovered to around 90%. Using a simple univariate outlier approach would have excluded them from analysis, based on their extreme L2 positive distractor scores. However, given that they were able to perform normally at the other data points, their scores were retained as they could represent genuine 'blindness' and, as such, it can be argued that they should not be excluded. Thus, we chose to include the participants' scores in the final analysis and only excluded them in participants who were unable to perform the task at all, as measured by failing to achieve an acceptable accuracy using neutral distractors.

It should be noted that decisions made regarding the EIB paradigm can have implications for the statistical conclusions. A preliminary analysis performed after half of the data had been collected showed that a significant relationship existed between BDI-II scores and EIB scores at L8 for positive distractors (i.e. positive distractor accuracy – neutral distractor accuracy). However, this relationship was not significant when the outliers were excluded or when the raw accuracy scores were used instead of EIB scores. Once the full data set had been collected the relationship was no longer significant, even with the outliers included or using EIB scores, which illustrates the importance of using a large enough sample size when using the EIB paradigm.

Study 4 used a 2AFC temporal discrimination paradigm, comparing the duration of two stimuli. This paradigm has a similar limitation to most other paradigms that have been used to examine the effects of depression (or other conditions) on the perception of short durations; where the effects of the condition are applied to both the reference and test duration, then typically, no measurable difference in the perception of duration are found. Some studies at longer durations have used a subjective self-report measure such as “I felt that time was passing slowly” to index the perception of duration. To date, no studies have found an ideal method of objectively measuring a change in the perception of durations at short intervals. In this thesis, we used two methods to identify the changes, examining both the time-order-error (TOE) between the first and second durations and the precision of the duration estimates (WFs). Neither of these measures are direct metrics for duration perception, but we hypothesized that any change in the underlying temporal mechanisms could affect one or both of the measures.

Another concern with the findings of Study 4 was the absence of an effect of valence on PSE shift. In Study 3, negatively-valenced images created a larger PSE shift (TOE) than neutral images, at all durations, suggesting that the duration of negatively-valenced images was perceived as longer than that of neutral images. Although the study was investigating differences in PSE shift between healthy individuals and those with symptoms of depression, the absence of an effect of valence raises questions as to the effectiveness of the paradigm. The paradigm used in both studies was similar in terms of the equipment, the images and the experimenter running the studies. The main differences were in the durations tested and the samples used. In Study 3, there were five participants, the experimenter and four other students, all of whom were trained observers. Adequate statistical power was achieved by running a large number of trials for each participant (810 each). By contrast, in Study 4, there were 68 participants, recruited from first- and second-year psychology courses, with fewer trials (370 each). In Study 3, six durations were tested (50ms, 100ms, 200ms, 400ms, 800ms and 1,600ms), whereas in Study 4, only one duration was tested (200ms).

One explanation for the absence of the PSE shift in Study 4 is that the data required to obtain precise psychophysical measurements such as a PSE shift, need to be relatively clean. A Gaussian curve, plotted by software, can easily be distorted by the noise of a single data point that was affected by inattention. This suggests that the use of precise psychophysical paradigms when testing for clinical outcomes in student populations needs to be carefully considered. One option for Study 4 could have been to screen data for each participant and reject participants or trials where specific criteria were not met. However, in clinical studies, this raises the conundrum that trials outside the set criteria could have been related to the clinical condition and not just inattention. Rejecting trials could therefore reduce the experimental effect. Future studies could consider modifying the paradigm to reject trials outside an extreme limit and automatically present additional trials to compensate. This could provide a level of data cleansing without eliminating participants' results.

All four studies in this thesis have the same limitation in relation to the sample population. The use of Australian undergraduate students in the studies means that the sample was likely to consist of young adults who were relatively healthy with above-average intelligence and education, and a medium to upper socio-economic status (SES) background, which may affect the external validity of the findings for older individuals with lower SES and depressed mood. However, the features of attention, perception, and cognition that were tested in this thesis are at a relatively basic level and they are therefore more likely to extrapolate beyond the sample population. However, the ANU student population is ethnically diverse with a high proportion of international students (ANU, 2017). Furthermore, a broad range of psychopathology symptoms was obtained by recruiting participants who attended the ANU Psychology Clinic, which supplemented the responses of undergraduate psychology university students, who themselves have reported high levels of stress, anxiety and depression symptoms.

7.5 Future directions

The depression results in this thesis prompt some interesting future directions. The EIB and depression study found a small number of outliers who showed a strong relationship between EIB and depression scores. One possible explanation of the outliers is the apparent heterogeneity of depression. That is, people with depression are extremely heterogeneous in terms of their current symptoms (type and severity); previous symptoms; neurological changes; number of previous episodes; exposure to antidepressant treatments; exposure to psychological treatments; comorbidity; genetics; current-life stressors; past-life stressors; and demographics (Dunn et al., 2015). This level of heterogeneity has the potential to mask correlational findings that might be related to one particular combination of the factors (e.g. effect only seen in people with comorbid anxiety and depression). Future studies should, therefore, more carefully examine different combinations of symptoms to identify which, if any, are associated with an increase in EIB. The challenge, however, is that the sample size could rapidly become impractical as each of the above factors may further be broken down into multiple levels (e.g. cognitive versus somatic symptoms of depression). Thus, another solution might be to develop an extension to the paradigm that examined within-subject changes instead of between-subject correlations, in order to increase statistical power.

Finally, the depression and temporal processing study detected no effects of a change in temporal processing at short durations. Future research could use a similar paradigm and extend the durations of stimuli above the 200ms reference point that was used in this thesis. If, for example, the distortions in temporal processing were found at the one-minute duration point, where rumination can clearly happen, this would provide some evidence that the paradigm was relevant, and if so, the findings at 200ms (in this thesis) would then carry more weight. Notwithstanding, using a 2AFC temporal discrimination paradigm at longer intervals is extremely time-consuming and it introduces additional variability such as memory effects. One solution could be to determine a minimum duration where rumination can occur in the majority of participants, and if this was in the range of seconds rather than minutes, it could be practically used as a reference duration.

7.6 Conclusions

The studies in this thesis did not detect any evidence of an impaired ability to disengage from negative material or distorted temporal processing at short intervals which was related to depression symptoms. Evidence for the cognitive impairments occurring at short durations in people with depression symptoms might have suggested that they were related to changes in the underlying mechanisms associated with attention, cognition, and temporal processing. Instead our findings supported the hypotheses that the: (a) impaired disengagement from negative material in people with depression symptoms was related to rumination and its effects on attentional control; and, (b) perception of time slowing was related to the cognitive impairments in sustained attention – especially that people with depression tend to focus on the passage of time instead of the task at hand. Thus, the results of this thesis suggest that the depression symptoms experienced by study participants did not occur ‘before you know it’. Rather, the results were consistent with cognitive models of depression (e.g. Beck’s CBT model), suggesting that systematic distortions of a person’s construction of his or her experiences contributed to the sense that time was passing slowly (A. T. Beck, 1967).

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