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Out-of-the-Blue: Depressive symptoms are associated with deficits in processing
inferential expectancy-violations using a novel cognitive rigidity task

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Abstract

Rigid cognition is frequently cited as a plausible maintenance or risk factor for depression. However, most performance-based measures of cognitive rigidity associated with depression offer poor ecological validity, produce mixed findings, and afford little in the way of therapeutic application. In order to establish a more useful and relevant performance-based measure of cognitive rigidity in depression, we developed a novel task that probes a rigidity process using stimuli highly relevant to the level of construal, the thematic content, and the rhetorical mode of depressotypic thinking. The task consists of a set of narrative vignettes that contain an expectancy-violation that is incompatible with an initially-established interpretation. As hypothesized, depressive symptoms were associated with reduced ability to update interpretations. This finding was independent of the valence of the expectancy-violation (i.e., was not merely a negativity bias), and was significant after controlling for basic set-shifting ability, intelligence measures, working memory, and other potential confounds. The novel Contingent Inference Task is a promising approach that may probe a more ecologically and etiologically relevant form of cognitive rigidity in depression than other related performance-based rigidity tasks. This rigidity process may underlie the persistence of biased beliefs in depression, and represent a new therapeutic target.

Keywords: depression; cognitive rigidity; inference; prediction-error; expectancy-violation.

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As with the psychological distress that accompanies depression, it is difficult to overstate the associated epidemiological and therapeutic challenges. With over 350 million people currently diagnosed with depression (WHO, 2015) and a vast global effort to understand and treat the disorder, we are still far from an adequate etiological model or treatment options. Only 40-60% of depressed individuals respond to current pharmacotherapies and psychotherapies (APA, 2000), with high rates of continued sub-diagnostic symptoms and relapse (Belsher & Costello, 1988; Hollon, Thase, & Markowitz, 2002; Judd, 1997; Mueller et al., 1999).

Within this challenging context, we developed a novel task to probe a plausible psychological process underlying a core feature of depression – rigid cognition. In this paper, we describe the rationale for the development of this task, which employs *expectancy-violations* for inferences using information highly relevant to the features of depressive thinking, and report the findings from two studies. The task employs stimuli in the form of short vignettes that consist of scenario descriptions constrained to the ‘higher-order’ level of construal, thematic contents, and rhetorical form of depressotypic thinking. These vignettes were designed to elicit a particular interpretation, and the dependent variable was the rate of interpretive updating that occurred following exposure to a phrase that was incompatible with this interpretation (the expectancy-violation). Low rates of updating were taken to represent a form of cognitive rigidity that relates to ‘non-contingency’, a processing abnormality that we argue to be central to depressive cognition. Our aim was to probe an ecologically valid form of cognitive rigidity within depression that could potentially inform the development of a new therapeutic target.

‘Non-contingency’ in depression

Depression has been associated with deficits in responding to changing contextual factors on one hand, and judgements of reduced control over contextual factors on the other. In the first instance, this theme of depressive ‘non-contingency’ relates to various forms of rigidity, exemplified by perseverative thinking (Brose, Schmiedek, Koval, & Kuppens, 2014; Snyder, 2013; Watkins, 2008), emotional inertia (Kuppens, Allen, & Sheeber, 2010), emotion context insensitivity (Rottenberg & Hindash, 2015), sustained event-related neural activity (Siegle, Steinhauer, Thase, Stenger, & Carter, 2002), and biased beliefs that are resistant to change (Bridges & Harnish, 2010; Lefebvre, 1981). While inflexible styles of thinking have been associated to varying degrees with other psychopathologies (e.g., Kashdan & Rottenberg, 2010), cognitive rigidity is commonly conceptualized as central to the maintenance of, or vulnerability for, depression (Gross & John, 2003; Young, Weinberger, & Beck, 2001). A

core feature of rigidity in depression is that certain thoughts, feelings, and physiological processes appear less responsive to – or contingent upon – contextual changes.

In the second instance, this theme of depressive ‘non-contingency’ relates to perceived helplessness, exemplified by phenomena ranging from judgements of reduced control in basic button-light tasks (Alloy & Abramson, 1979) to low self-efficacy (Ehrenberg, Cox, & Koopman, 1991; Maciejewski, Prigerson, & Mazure, 2000). Although distinct from rigidity (i.e., changes in cognitive, affective, or physiological representations in response to contextual changes), this reduction in the perceived control of events (i.e., perceived changes in contextual events in response to one’s actions) can also be considered a form of ‘non-contingency’. Thus, depression appears to be linked to a reduction in real or perceived causal interdependence between the person and the world. The notion of ‘non-contingency’ shows that seemingly dissimilar processing abnormalities in depression (e.g., set-shifting deficits, over-generalization, reduced controllability) may, in fact, be closely related.

Relevant to the present study, depression has been linked to deficits in updating expectancies that are contingent on external changes (Glombiewski, 2016; Korn, Sharot, Walter, Heekeren, & Dolan, 2014; Rief et al., 2015) – a basic feature of cognitive rigidity. Indeed, deficits in processing unexpected information appears to be an underlying feature of a wide range of information-processing biases linked to depression. For example, over-general thinking (Williams et al., 2007) can be conceptualized as the over-application of an inference alongside deficits in processing conflicting information. Likewise, biased beliefs in depression (Bridges & Harnish, 2010) may become resistant to change through information processing styles that are both excessively negative and highly selective. As Beck (1976) put it, the depressed person “evidently screens out, or fails to integrate, successful experiences that contradict his negative view of himself”. One of the aims of the second study reported here was to assess whether deficits in updating inferences in depression represent a rigidity process distinct from a negativity bias.

Boundary conditions in depressive ‘non-contingency’

Despite the slew of studies showing that depression is linked to various deficits in responding to contextual changes and in perceiving changes in response to one’s actions, other studies suggest that this ‘non-contingency’ may have boundaries. For example, although depressed individuals sometimes show high rates of perseverative errors on the Wisconsin Card Sorting Test (WCST; Shelley Channon, 1996; Snyder, 2013), many studies also show no link between WCST deficits and depression (for e.g., Degl’Innocenti, Ågren, & Bäckman, 1998; Fossati, Amar, Raoux, Ergis, & Allilaire, 1999; Ravnkilde et al., 2002). In one such study, although depression was not related to WCST perseveration, depression was related to perseveration for negative words in an emotional version of the WCST (the ECST, wherein shapes are replaced by emotional

words that vary in their color, font and number; Deveney & Deldin, 2006). This suggests that set-shifting deficits in depression may be more strongly linked to 'higher-order', depression-related themes. Indeed, the literature shows a more robust link between depression and deficits in processing and integrating information that conflicts with 'higher-order' beliefs (Hollon & Dimidjian, 2008). Here, 'higher-order' implies a more abstract, broad and decontextualized level of construal of information that includes its causes, implications, and meanings (e.g., your friend, who is approaching you, crosses the street to walk on the other side, which implies she does not like you and is avoiding you), as opposed to 'lower-order', which consists in a more concrete, perceptual, specific and contextualized level of construal, and includes its mechanics and feasibility (e.g., you infer that, if your friend is to safely cross the street in front of oncoming traffic, she will need to walk faster).

'Depressive realism' is another example that highlights a possible boundary condition of depressive 'non-contingency'. In tasks that assess perceived control between one's actions (pressing or not pressing a button) and an environmental outcome (onset of a light), depressed individuals perceive a lower (and more accurate) contingency between button-press and light-onset, while non-depressed individuals tend to perceive a higher (and less accurate) button-light contingency (Alloy & Abramson, 1979). Some authors have suggested that the 'Depressive Realism' phenomenon may better reflect an attenuated 'illusion of control' than enhanced 'realism' per se (e.g., Ackermann & DeRubeis, 1991). Importantly, and in line with this argument, this reduction in perceived control is not found when depressed individuals assess the performance of others in a button-light controllability task (Martin, Abramson, & Alloy, 1984; Moore & Fresco, 2012). Additionally, in a variant of this controllability task, depressed individuals *over-estimate* their control over the appearance of depressive self-referent sentences (e.g., 'My problems are unsolvable') but not positive sentences, while non-depressed individuals over-estimate their control over the appearance of positive sentences (Vázquez, 1987). These findings suggest that the reduction in perceived contingency between action and outcome in depression is limited to the depressed individual's own actions (low self-efficacy) and to negative outcomes (negativity bias), both consistent with cognitive themes in depression (A. T. Beck & Dozois, 2011; J. S. Beck, 1995).

The above findings associated with depression suggest that deficits in responding to contextual changes, as well as deficits in perceiving contextual responses to self-generated action, may be largely restricted to particular themes within depressive thinking. It is possible that these 'non-contingency' deficits could extend to 'lower-order' or perceptual forms of rigidity in some cases, such as those probed by the WCST. However, depression does not appear to be linked to *generalized* 'non-contingency'. In addition, the forms of rigid cognition that could plausibly contribute to depressive symptoms, and thereby offer viable therapeutic targets, are likely to be closely related to

the contents of depressive thinking. However, paradigms such as the WCST and button-light controllability tasks probe contingency processing for simple perceptual stimuli that bear little resemblance to the types of cognitive rigidity commonly associated with depressed states. Thus, in order to probe a cognitive rigidity process that could plausibly underlie depressive thinking, it is preferable to employ stimuli relevant to depressive cognition.

Core features of ‘non-contingency’ in depression

In this section we outline some basic features of depressotypic thinking, including the level of construal, the typical content themes, and the rhetorical form. The novel task we present herein was designed to incorporate these features.

Level of construal. So what are the core features of depressive thinking? Referencing a prominent cognition taxonomy (Hollon & Kriss, 1984), depressive cognition involves maladaptive structures or beliefs (implicit, organized and stable associations, such as feeling worthless), processes (cognitive biases, such as over-general thinking) and products (explicit information, such as automatic pessimistic thoughts). At every level of cognition, these structures, processes and products become characteristically depressive through ‘higher-order’ inference, the fundamental sense-making device underlying interpretation, attribution and explanation. ‘Higher-order’ inference involves going beyond perceptual data or propositional statements to extract broad and abstract representations about causes, implication and meaning.

Indeed, in some cognitive-affective models of depression, only ‘implicational’ and not ‘propositional’ thinking can produce emotion (e.g., Teasdale, 1993). Unlike in anxiety disorders, which have been linked to early attentional biases towards negative information (Mathews & MacLeod, 2005), depression is associated with few differences in early processing of negative information (Mathews & MacLeod, 2005), but rather to increased elaboration of, and difficulty disengaging from, negative information (Gotlib & Joormann, 2010). Also, within many diathesis-stress accounts, depression has been conceptualized as arising from a maladaptive and elaborated cognitive response to anxiety (Gotlib & Hammen, 2008). Moreover, rumination, a central cognitive process in depression, involves repetitively and passively thinking about the *meaning* and *implications* of one’s negative symptoms (Koval, Kuppens, Allen, & Sheeber, 2012; Nolen-Hoeksema, 2000). That is, depressive thinking is characterized by elaborated ‘higher-order’ inference. This constitutes a central feature of our dependent variable in the task we present below.

Thematic Contents. As regards the typical contents of depressive structures, products and processes, low self-worth in terms of achievement (e.g., being unsuccessful) and interpersonal expectations (e.g., being unlovable) is pervasive (e.g., A. T. Beck & Alford, 2008; J. S. Beck, 1995; Dozois, 2007; Horowitz & Vitkus, 1986). Indeed, excessive self-focus, self-identity salience, and self-referent reactivity to

negative information are core features of depression (Farb, Anderson, Bloch, & Segal, 2011; Habermas & Bluck, 2000; Mor & Winquist, 2002). In addition, negative interpersonal expectations are common in depressive thinking (A. T. Beck & Alford, 2008; Horowitz & Vitkus, 1986), and depressotypic interpersonal beliefs persist beyond remission, indicative of a trait-like cognitive structure (Dozois, 2007). Indeed, the link between depression and maladaptive social processing is strong. For example, depression is associated with mentalizing difficulties (Bateman & Fonagy, 2012), a core social competence that involves inferring the mental states (e.g., beliefs or intentions) of others based on their behavior (Premack & Woodruff, 1978). Patients in remission from depression who exhibit mentalizing deficits have a greater risk of relapse (Inoue, Yamada, & Kanba, 2006). Depression is also highly correlated with social phobia (Kessler, Chiu, Demler, & Walters, 2005), social role impairments are greater than any other role impairments (e.g., work) in the disorder (Kessler et al., 2003), and Social Anxiety Disorder is the most common comorbid anxiety disorder (Belzer & Schneier, 2004; Zimmerman, Chelminski, & McDermt, 2002). The topics of self-worth and interpersonal consequence feature prominently in depressive thinking, and within our experimental protocol described below.

Rhetorical Form. In making sense of our experience, both communication and thinking typically occur within the narrative form (Bickle, 2003; Bruner, 1990; Fisher, 1984; Graesser, Golding, & Long, 1996; Miller, 1995). That is, thinking and speaking do not generally occur as disconnected cognitive fragments; nor are they represented as logical arguments or lawful formulations; rather, thinking and speaking typically occur as organized stories about what exists, what happens, and what this might mean (Bruner, 1990). Given the prominent role of complex, elaborated, inferential thinking in depression, it is not surprising that numerous narrative-based models of depression have been developed, and that narrative therapeutic approaches can be effective (Howard, 1991; Lopes et al., 2014; Payne, 2006; Pennebaker & Seagal, 1999; Vromans & Schweitzer, 2011; White & Epston, 1990).

Our novel task, presented below, is comprised of narrative vignettes. One rationale for narrative stimuli is that narratological processes may constrain the way in which we interpret events. For example, Fisher (1984, 1985) has argued that the inferential process of abstracting from experience has more to do with telling a 'good story', judged, for example, by internal narrative consistency and verisimilitude, than it does with producing evidence or forming a logical argument. That is, the best 'truth criterion' for extracting meaningful inference from experience may be how well the interpretation resembles a well-structured and recognizable narrative. Also, narratives serve to "structure, simplify, and lay out causal connections among otherwise indefinite and unintelligible events" (Steen, 2005). As with parables, we tend to 'draw lessons' from experiences in story form, and interpret novel experiences by analogy to these 'source stories' (Turner, 1998). If making sense of experience is constrained by criteria

for a 'good story', then responses to experimental narrative vignettes may reflect ways in which people make sense of their experiences.

Of course, another rationale for employing narrative vignettes is that they may simulate experience sufficiently to probe individual differences in experiential sense-making. Indeed, narrative vignettes have been employed extensively in experimental psychology as a form of perceptual simulation (e.g., Alexander & Becker, 1978; Frith & Frith, 2003; Segal & Swallow, 1994). Although processing and responding to narratives may not always be analogous to processing and responding to experience (Parkinson & Manstead, 1993), there is evidence to support the use of narrative simulations as a proxy for real events. For example, emotional responses to both descriptions of arousing images and the images themselves are strongly related (Robinson & Clore, 2001). Whether narratological processes constrain sense-making, or whether narratives are perceptually analogous, narrative vignettes were employed in this task to measure ecologically relevant inferential processes.

The novel Contingent Inference Task (CIT). In designing the CIT, we sought to measure a cognitive rigidity process (bias) that related to the typical features of depressive structures (beliefs) and products (thoughts). In line with the arguments above, we probed the degree to which participants' interpretations were contingent on contextual changes that were delivered in the form of narrative-based expectancy-violations for 'higher-order' inferences that centered on self-worth and interpersonal themes. This task aims to probe a complex and systematic form of cognitive rigidity — referred to here as Inferential Rigidity — using stimuli that are highly relevant to depressive thinking. We measured whether depressive symptoms were related to deficits in processing these expectancy-violations, resulting in poor inferential updating in response to new, conflicting information.

In the CIT, ambiguous vignettes are presented that strongly suggest a particular interpretation while being consistent with another 'concealed interpretation'. An expectancy-violation phrase is delivered towards the end of each vignette that is consistent only with the 'concealed interpretation'. Participants are scored in their ability to generate the 'concealed interpretation', a process that requires detection of the expectancy-violation as well as the facility to replace the initial interpretation with a more supported one. Additionally, in order to probe differences in information processing that are distinct from an individual's specific beliefs, the CIT provides the information for both the expectancy and its violation.

As depression is associated with substantial social impairments, including mentalizing difficulties (Bateman & Fonagy, 2012), a subset of vignettes contained expectancy-violations that exclusively concerned the intentional or mental states of another person, referred to as CIT-mentalizing trials. This subset was included to determine whether Inferential Rigidity in depression was confined to mentalizing processes.

The CIT was designed as a performance-based task, overcoming the well-known limitations of self-report assessments. In addition, the CIT was developed to improve on common performance-based rigidity measures used in depression. These tasks (e.g., the WCST) typically measure the degree to which participants' responses are contingent on unambiguous 'lower-order' perceptual changes, which may not reflect the ability to update an inference in response to ambiguous, 'higher-order' information. In addition to their limited ecological validity, these rigidity measures afford little in the way of plausible therapeutic targets. No study to date has assessed whether depression is related to deficits in processing unexpected information directly relevant to the level of construal, the thematic contents and the rhetorical form of depressive thinking. We argue that, if Inferential Rigidity is associated with depressive symptoms, it may (1) represent an underlying mechanism for the persistence of biased beliefs, (2) contribute to the development or maintenance of depression, and (3) reveal novel therapeutic targets.

Study 1

Inferential Rigidity in depression. We hypothesized that depressive symptoms would be associated with Inferential Rigidity, that is, deficits in processing expectancy-violations and updating interpretations accordingly in the CIT (H1). Also, as depression has been linked to mentalizing deficits, we hypothesized that depressive symptoms would correlate more strongly with low scores for the CIT-mentalizing trials (H2).

Attention and Mood. In controlling for task motivation and attention issues linked to depression (e.g., S Channon & Green, 1999), we hypothesized that the relation between depression and Inferential Rigidity would not be accounted for by Task Attention (H3). Moreover, given our argument that Inferential Rigidity may contribute to the development or maintenance of depression, we hypothesized that the link between depression and Inferential Rigidity would not be fully accounted for by differences in current mood (H4).

Set-shifting. Additionally, in line with our argument that cognitive rigidity in depression is more related to the 'higher-order' features of depressotypic thinking than to 'lower-order' perceptual processing, we hypothesized that the association between depressive symptoms and Inferential Rigidity would be significantly greater than the association between depressive symptoms and WCST perseveration (H5). Given that both the CIT and the WCST measure updating processes, albeit very different in kind, we hypothesized that Inferential Rigidity would correlate with WCST perseverative errors (H6).

Control measures. We also sought to determine the degree to which Inferential Rigidity could be accounted for by basic set-shifting deficits on the WCST, and controlled for two aspects of intelligence – working memory and social cognition –

considered important potential confounds. We hypothesized that the link between depression scores and Inferential Rigidity would not be significantly accounted for by perseverative errors on the WCST, or by intelligence subscales or working memory (H7).

Method

Participants

After exclusions, participants were 107 undergraduate psychology students (86% female) aged 18 to 47 years ($M=20.10$ years, $SD=4.75$) at the University of Melbourne, Australia, who participated in exchange for course credit. Participants were mostly (79%) native English speakers, and all others indicated English fluency. Five participants had been diagnosed in the past with either anxiety or depression disorders; no participants had been diagnosed with bipolar, psychotic or substance use disorders. CES-D scores ranged from 0 to 37 ($M=12.98$, $SD=8.56$). One participant was removed due to missing data. Three participants were removed who provided incorrect responses for over 50% of the expectancy-consistent trials' target question, suggesting poor vignette comprehension. We also used four repeat questions embedded within the questionnaires described below as a measure of conscientious participation; however, all participants were consistent in their responses to the repeat questions.

Materials

Contingent Inference Task. Twenty-two expectancy-violation vignettes (EV trials; 30-60 seconds in duration) were developed, along with an expectancy-consistent version of each (EC trials). All vignettes incorporated features highly relevant to depressive cognition, as outlined above: they probed 'higher-order' inferential updating for unexpected information relating to interpersonal and self-worth themes, and delivered within the narrative form.

The general format of the EV trials begins with an ambiguous narrative that strongly suggests a particular 'initial interpretation', while also being consistent with an alternative 'concealed interpretation'. In the second half of the vignette, a subtle phrase (the *expectancy-violation*) is delivered that is inconsistent with the 'initial interpretation' and suggests an alternative 'concealed interpretation'. For a participant to update an inference, they would need to attend to and process the expectancy-violation, abandon their previous interpretation, and generate an alternative interpretation that is supported by the entire vignette, referred to as an *updated inference*. The remainder of the narrative is consistent with both inferences, thereby restricting the updating cue only to the expectancy-violation. The two plausible interpretations are logically mutually exclusive.

In the CIT-mentalizing trials, inferential updating following the expectancy-violations does not necessitate updating of the 'visual' simulations of things or events.

That is, only the *meaning* of, or *intentions* behind, the behavior require updating. There were 10 trials within the CIT-mentalizing subset.

The EC trials are identical to their EV trial counterparts, with the expectancy-violation replaced by a control phrase that is congruent with the 'initial interpretation'. The EC trials had three functions: they served as fillers to reduce insight into the format of the EV trials; they allowed us to determine whether the EV trials actually elicited the intended 'initial interpretation' prior to delivering the expectancy-violation; and they afforded a means to assess vignette comprehension for each participant, distinct from updating ability. Participants received 22 trials made up of 10 EV trials and 12 EC trials.

All vignettes were presented aurally through headphones, preventing participants from reparsing the vignette, particularly the expectancy-violation. Each vignette was followed by a set of four questions concerning the content of the vignette just delivered. These were presented on a computer screen with open-ended answer fields. One of the four questions ('target') probed whether inferential updating had occurred, while the other three questions served as attention checks. An example vignette follows:

A tall man in a dark blue trench coat runs down a quiet alley. Two police officers are giving chase not far behind him. The tall man leaps onto a garbage bin, swings himself over a high fence and rapidly climbs a stairwell on the outside of an apartment block. The officers, who are both overweight, are struggling to climb the high fence. The tall man hears someone shout 'thief!' and another shouts 'cut!' and he sees the first officer has made it over the fence. The tall man is out of breath and sits down at the top of the stairwell, panting. He remembers how fit he once was, and wonders whether he is still cut out for this line of work."

The four questions presented on screen following this vignette were:

1. Where does the tall man sit down?
2. Why are the officers struggling to climb the fence?
3. Why are they chasing the tall man? (*target*)
4. The tall man wonders whether he is still cut out for _____ ?"

The 'initial interpretation' for this example is that the tall man is a thief. However, the expectancy-violation, 'cut', is only compatible with an alternative 'concealed interpretation'; the tall man is an actor being filmed. The EC version of this vignette replaces the expectancy-violation with the word 'stop', which is consistent with the 'initial interpretation' and therefore should not create an expectancy-violation. The vignette shown above is an example not within the CIT-mentalizing subset (i.e., the inference updating here necessitates alterations to the 'visual' simulation of events, and not only to the intentions of the characters or the meaning of their behavior). An example of a CIT-mentalizing vignette describes a woman who appears to not be enjoying the company of the man she's on a first date with; however, she is actually struggling with the hot curry at the restaurant. The full set of vignettes is available from the authors.

A total score for the CIT ('CIT-total') was calculated for each participant using responses from the target question of the EV trials as follows: a score of +1 for each correctly updated inference, and a score of -1 for failing to update the inference, summated and divided by the number of valid responses (excluding ambiguous responses that were not scorable, or indicative of misunderstanding the vignette content or question; for e.g., an ambiguous response to the above target question was "It is not apparent that the man is actually in trouble."). Thus, the CIT-total score is a proportion of correct inferential updating, and ranged from -1 to +1 where 0 is equivalent to an equal number of trials wherein participants demonstrated successful updating and failure to update on EV trials. High CIT-total scores reflected Inferential Flexibility, while low scores reflected Inferential Rigidity.

In addition, because depression is associated with deficits in attention (Lemelin, Baruch, Vincent, Everett, & Vincent, 1997) and task motivation (S Channon & Green, 1999; Elliott, Sahakian, Herrod, Robbins, & Paykel, 1997), which might plausibly account for any link between depression scores and Inferential Rigidity, we derived a Task Attention score, calculated as the proportion of correct answers for the 3 non-target questions following each vignette.

Affective measures. The Center for Epidemiologic Studies Depression Scale (CESD; Radloff, 1977) is a 20-item scale designed to assess depressive symptoms in the general population. Respondents are asked to rate the frequency of symptoms using a 4-point rating scale (ranging from 'rarely or none of the time' to 'most or all of the time'). The CES-D has been found to have high criterion validity (Haringsma, Engels, Beekman, & Spinhoven, 2004; Radloff, 1977), reliability across diverse population subgroups (Orme, Reis, & Herz, 1986; Radloff, 1991; Roberts, 1980), good test-retest reliability (Devins et al., 1988; Radloff, 1977) and high internal consistency (Radloff, 1977).

Pre-task mood was assessed using the 10-item short form of the Positive and Negative Affect Schedule (Short PANAS; Mackinnon et al., 1999). This asked participants to '...indicate to what extent you feel this way right now, that is, in the present moment', followed by emotion words (e.g., 'upset', 'excited') with 5-point rating scales (ranging from 'very slightly or not at all' to 'extremely'). The PANAS is scored on two separate factors – positive affect (PA) and negative affect (NA) - the two main affect dimensions in Watson & Tellegen's (1985) factor model of affect (see also Tellegen, Watson, & Clark, 1999; Watson & Clark, 1992).

Set-shifting. The Wisconsin Card Sorting Test (WCST; Heaton, 1981) measures a form of cognitive flexibility - the ability to alter responses in accordance with changing feedback (sorting rule) for 'lower-order' perceptual features (color, shape, and number). The WCST was employed for two reasons. Firstly, we argue that depressive rigidity has more to do with deficits in updating inferences based on conflicting 'higher-order' information than for conflicting perceptual information, as probed by the WCST. In

addition, we sought to determine whether any variance in Inferential Rigidity as assessed by the CIT could be accounted for by 'lower-order' set-shifting impairments using the WCST. The WCST was presented via computer and required participants to match a series of 128 cards to reference cards according to the color, shape, or number of symbols on the cards. Feedback was given ('right' or 'wrong') following each attempt. Once participants achieved 10 consecutive successful sorts based on a given set, the sorting rule was changed without forewarning. The task was complete once participants correctly shifted sets 6 times, or all 128 cards were used. Perseverative errors (sorts based on the previous set), non-perseverative errors, number of cards used, and number of completed sets were recorded. A general set-shifting perseveration score was calculated as the average number of perseverative errors per set-shift in the WCST (Heaton, 1981).

Control measures. To control for working memory as a potential confounding variable, we employed the Digit-span subtest (WAIS-dig) from the fourth edition of the Wechsler Adult Intelligence Scale (WAIS-IV, Wechsler, 2008). Working memory span has been linked with the ability to resolve ambiguities in narrative comprehension (Just & Carpenter, 1992) and increased elaborative inference production (George, Mannes, & Hoffman, 1997), either of which could impact CIT scores in this study. Moreover, depression and rumination have been linked to working memory deficits in some studies (Meiran, Diamond, Toder, & Nemets, 2011; Pelosi, Slade, Blumhardt, & Sharma, 2000; Rose & Ebmeier, 2006), while not in others (Grant, Thase, & Sweeney, 2001; Sweeney, Kmiec, & Kupfer, 2000; Zakzanis, Leach, & Kaplan, 1998).

The ability to generate inferences about behavior in the context of social norms was also relevant to this protocol. To control for this, we administered two WAIS-IV subtests: The Comprehension subtest (WAIS-com), which assesses the ability to deal with abstract social conventions, and the Similarities subtest (WAIS-sim), which measures basic concept formation.

Procedure

All participants completed the study in quiet laboratory conditions. Participants were told that the study assessed individual differences in story comprehension, without any reference to expectancy-violations. After providing consent, participants were seated at a computer on which questionnaires and tasks were presented using Inquisit software (Draine, 2009). Participants firstly completed a brief demographic survey, the CES-D, and the Short PANAS. Next, a practice EC trial was presented through headphones and participants were given an opportunity to ask clarifying questions before proceeding. Another EX trial was then presented to reduce the probability of participants detecting the EV format, followed by 20 vignettes (10 EV trials and 10 EV trials), randomized. Participants were randomized into two groups, each receiving alternative versions (EV or EC) of each vignette. Each vignette was followed by four

subsequent questions. After the final vignette, participants were asked a question regarding the story format: *Did you notice any particular structure(s) to the stories you heard?* This question probed whether participants became aware of the EV trial format, which may have subsequently increased vigilance for the expectancy-violation. The WCST was then delivered on screen. Finally, the three WAIS-IV subtests were administered manually by the experimenter and participants were fully debriefed.

Data analysis

We first conducted bivariate correlations, and then examined partial correlations for all relevant covariates. Finally, we conducted a hierarchical multiple regression to assess whether depression scores predicted CIT performance while controlling for the influence of a range of relevant covariates.

Results

Table 1 shows relevant correlations and scale statistics. Eight participants (7.5%) had CES-D scores indicative of moderate to severe depression (using a typical cut-point for this sample of 27; Stansbury, Ried, & Velozo, 2006), which is in line with depression rates (6-7%) of 16 to 24 year olds in the Australian population (Slade, Johnston, Oakley Browne, Andrews, & Whiteford, 2009). For the EC trials, participants generated the correct 'initial interpretation' an average of 93% of the time prior to participant exclusions, indicating that, without the expectancy-violation, the EV trials were predominantly unambiguous and easily comprehended, and that generating the correct updated inference following the expectancy-violation likely involved replacing the intended previously formed inference. For valid EV trial responses, participants generated the updated inference an average of 45.5% of the time (i.e., they failed to update their inference 55.5% of the time). Only 11% of participants detected the general EV trial format at the end of the task, indicating task-naivety for the majority of participants.

Table 1: Zero-order correlations, means, standard deviations and internal consistencies.

Variable	1	2	3	4	5	6	7	8	9	10
1. CES-D										
2. NA	.533**									
3. PA	-.294**	.003								
4. CIT-total	-.099	-.150	.061							
5. CIT-mentalizing	-.311***	-.258**	.160	.735***						
6. Task Attention	-.078	-.278**	-.053	.418***	.328***					
7. WCST	.048	-.025	-.069	-.149	-.088	-.083				
8. WAIS-sim	.040	-.059	.041	.164	.073	.250**	.108			
9. WAIS-com	.008	-.135	-.036	.161	.147	.268**	.007	.264**		
10. WAIS-dig	.023	-.100	-.004	-.049	-.087	.092	.061	.110	.027	
M	12.98	6.55	14.98	-.11	-.09	.89	1.47	24.31	25.55	31.19
SD	8.56	2.26	3.83	.37	.61	.07	.70	3.97	4.39	5.26
α	.896	.712	.786	-	-	-	-	-	-	-

Note. * $p < .05$; ** $p < .01$; *** $p < .001$. CES-D, The Center for Epidemiologic Studies Depression Scale, NA, negative affect, PA, positive affect, CIT-total, Contingent Inference Task total score, CIT-mentalizing, Contingent Inference Task mentalizing subset score, WCST, Wisconsin Card Sorting Test perseveration, WAIS-sim, Wechsler Adult Intelligence Scale Similarities subtest, WAIS-com, Wechsler Adult Intelligence Scale Comprehension subtest, WAIS-dig, Wechsler Adult Intelligence Scale Digit Span subtest.

Inferential Rigidity in depression. To test our first hypothesis, we examined correlations between individual differences in depression scores and Inferential Rigidity scores. Contrary to our first prediction (H1), CES-D scores did not correlate significantly with the CIT-total score (mean CIT score for all vignettes), $r = -.10$, $p = .311$. However, in line with our second hypothesis (H2), CES-D scores were negatively correlated with CIT-mentalizing scores, $r = -.31$, $p = .001$, with a 95% confidence interval from $r = -.13$ to $r = -.47$. Thus, the subsequent analysis focusses on the CIT-mentalizing score.

Attention and Mood. In support of our third prediction (H3), the partial correlation between CES-D and CIT-mentalizing scores remained significant and similar to the zero-order correlation after controlling for Task Attention, $pr = -.30$, $p = .002$.

Positive affect (PA) did not correlate with any of the CIT scores. In contrast, Negative affect (NA) correlated significantly with CIT-mentalizing scores, $r = -.26$, $p = .007$. Although NA and CES-D share considerable variance, the partial correlation between CES-D and CIT-mentalizing scores while controlling for NA remained significant, $pr = -.21$, $p = .030$, while the partial correlation between NA and CIT-mentalizing scores while controlling for CES-D did not, $pr = -.12$, $p = .243$. That is, as predicted (H4), depressive

symptoms accounted for variance in CIT-mentalizing scores over and above current mood.

In an exploratory analysis, the partial correlation between NA and CIT-mentalizing scores while controlling for Task Attention was $pr = -.18$, $p = .060$, suggesting a role for attention in this link. That is, the relationship between NA and CIT-mentalizing was in part accounted for by Task Attention. In contrast and as noted above, the relationship between CES-D and CIT-mentalizing was not accounted for by Task Attention.

Set-shifting. In support of our fifth hypothesis (H5), CES-D did not correlate with WCST perseveration, $r = .05$, $p = .626$. While WCST perseveration (rigidity) did not correlate with CIT-mentalizing (flexibility), $r = -.09$, $p = .37$, failing to support hypothesis six (H6), WCST perseveration (failing to respond to feedback) correlated positively with the mean number of EV trials wherein participants perseverated with the 'initial interpretation' (failing to respond to the expectancy-violation), $r = .20$, $p = .041$. Also, as predicted (H7), the link between CES-D and CIT-mentalizing scores could not be accounted for by WCST perseveration: The partial correlation between CES-D and CIT-mentalizing scores while controlling for WCST perseveration was unchanged from the zero-order correlation, $pr = -.31$, $p = .001$.

Control measures. None of the WAIS-IV measures correlated with either CES-D or CIT-mentalizing, and partial correlation confirmed that none of the WAIS measures accounted for any of the relationship between CES-D and CIT-mentalizing (H7).

A final hierarchical regression was conducted to assess whether depression scores predicted Inferential Rigidity for the mentalizing vignettes while controlling for a range of covariates (see Table 2). The following covariates described below were controlled for in this final regression model. A minority (11%) of participants reported that they were explicitly aware of the structure of the expectancy-violation vignettes, termed 'Vignette Grammar Insight'¹. Surprisingly, some participants generated the updated inference following EC trials (no expectancy-violation) in a small percentage (4.93%) of responses, termed 'Uncued Updating'¹. As the aim of the CIT was to measure cued inferential flexibility, or sensitivity to an expectancy-violation, we controlled for Uncued Updating. Also, as some non-native English speakers were clearly not fluent, English fluency¹ was also considered a potential confound. Finally, as there were significant differences between the two randomly allocated groups in performance on the CIT and other instruments, but not in depressive scores, Participant Group¹ was also controlled for.

Preliminary tests were performed to ensure that the assumptions of linearity, non-multicollinearity, independence and normality of residuals, and homoscedasticity were not violated. The predictor variables other than CES-D explained 29.1% of the variance in CIT-mentalizing scores. After the CES-D score was entered in the second block, the total variance explained by the model was 36.4%, $F(10, 95) = 5.44$, $p < .001$,

with R^2 change=.073, and F change(1, 95)=10.92, p =.001. In the final model (see Table 2) only the Participant Group, Native English, Task Attention, and Depression were statistically significant predictors. The beta value for depression, β =-.27, in the final model was highly significant and comparable to the zero-order correlation between depression and CIT-mentalizing scores (r =-.31), suggesting that this range of covariates accounted for little of the association between depression scores and CIT-mentalizing scores.

Table 2: Linear regression predicting CIT-mentalizing score

Predictor	β	t	p
WCST	.019	.223	.824
WAIS-sim	-.047	-.521	.604
WAIS-com	.067	.763	.447
WAIS-dig	-.079	-.942	.349
Vignette Grammar Insight	.089	1.034	.304
Uncued Updating	.171	1.828	.071
Participant Group	.250	2.747	.007
Native English	.203	2.352	.021
Task Attention	.191	2.089	.039
CES-D	-.273	-3.304	.001

Note. CIT-mentalizing, Contingent Inference Task mentalizing subset score, WCST, Wisconsin Card Sorting Test perseveration, WAIS-sim, Wechsler Adult Intelligence Scale Similarities subtest, WAIS-com, Wechsler Adult Intelligence Scale Comprehension subtest, WAIS-dig, Wechsler Adult Intelligence Scale Digit Span subtest, CES-D, The Center for Epidemiologic Studies Depression Scale.

Discussion

This initial study employing the novel CIT generated promising findings, albeit with some limitations. Although depression scores were not associated with decreased performance across the entire CIT battery, they correlated significantly with the ‘mentalizing’ subset. As the target interpretation for all CIT-mentalizing trials likely required mentalizing processes, and depression was not associated with difficulties in interpreting the EC trials (equivalent to the ‘initial interpretation’ in the EV trials), this relation between depression and Inferential Rigidity appeared to indicate deficits in processing information relating to the unexpected mental states of others. One explanation for this finding is that it might occur through an additive effect between cognitive rigidity (Rogers et al., 2004) and mentalizing deficits (Bateman & Fonagy, 2012) - both known to be associated with depression. However, as we did not assess

mentalizing specifically, we could not determine whether mentalizing deficits accounted for this finding. Consequently, mentalizing ability was explicitly assessed in Study 2.

In line with our prediction, although current mood strongly correlated with depression, it did not account for the link between depression and deficits in the CIT. Given the strong test-retest reliability of the CES-D (ranging from .4 to .7 over intervals from 2 weeks to 1 year; Devins et al., 1988), this suggests that Inferential Rigidity may be a trait-like variable that could contribute to either the vulnerability or maintenance of depression, and likely relates to other features of depression beyond low mood. Also noteworthy was that, in contrast to the depression finding, the relation between NA and CIT deficits was largely accounted for by poor Task Attention.

Our finding that depressive symptoms, while being associated with Inferential Rigidity for this subset, were not associated with basic set-shifting perseveration on the WCST, supports the notion that depressive rigidity has boundary conditions (i.e., it is not generalizable to all forms or levels of information processing), and may not extend to expectancy-violations about perceptual features. While CIT-mentalizing did not correlate with WCST perseveration, the latter score correlated with the updating fail-rate across the entire CIT battery, suggesting that updating deficits in the CIT may be related to WCST set-shifting deficits. However, this 'lower-order' rigidity did not account for our main finding. In sum, this suggests that the CIT probes a potentially related, albeit distinct, form of rigidity to that of the WCST. In addition, our main finding was not accounted for by measures of intelligence, working memory, or Task Attention, adding further support to the notion that this task assesses a rigidity mechanism.

A limitation of this study was low statistical power, due to the low number of participants with high CES-D scores, which may have reduced the range of depressive phenomena we could observe. In addition, our more demographically homogenous undergraduate sample limits the generalizability of these findings. Regarding the stimulus-set, there were only a few vignettes that contained a negatively-valenced expectancy-violation (switching from a more positive to a more negative interpretation). If most vignettes contain a positive expectancy-violation (shifting to a more positive interpretation), any depression link could be attributed to a negativity bias, rather than to a rigidity mechanism. Additionally, some vignettes showed high ambiguous responding, suggesting that these vignettes were too difficult to comprehend, or did not adequately invoke the intended initial and updated interpretations exclusively. Finally, many of these vignettes contained unrealistic or 'magical' expectancy-violations, which may have contributed to comprehension or interpretation difficulties. The CIT was improved in Study 2 to address the limitations that emerged from Study 1.

Study 2

In light of both the promising results and limitations of our initial CIT study, we attempted to improve the vignette stimulus-set along various criteria and conduct a replication and extension using participants from a different population. Firstly, we replaced ten vignettes (see details under materials below). Also, as depression is strongly associated with a negativity bias for information processing (e.g., A. T. Beck, 1976; Rude, Wenzlaff, Gibbs, Vane, & Whitney, 2002), we developed both a CIT-negative trial subset (containing vignettes that switch from a more positive to a more negative interpretation) and a CIT-positive trial subset (containing vignettes that switch from a more negative to a more positive interpretation) to determine whether deficits in updating interpretations were confounded by a bias towards more negative interpretations in depression. In replacing vignettes, we ensured that both the CIT-negative trials and the CIT-positive trials contained both mentalizing and non-mentalizing vignettes. Finally, various instruments were added and others replaced to test new predictions or make the procedure amenable to online presentation.

Study 2 employed the online crowdsourcing platform 'Mechanical Turk', using a sample of participants from the United States of America. This provides a cost-effective way to obtain high quality data from participant samples that are typically more demographically diverse than student samples (Buhrmester, Kwang, & Gosling, 2011).

Inferential Rigidity in depression. As in Study 1, the main prediction in Study 2 was that depressive symptoms would be associated with deficits in processing expectancy-violations, or Inferential Rigidity, using the CIT (H1). Following on from the findings in Study 1, we also hypothesized that depression would be more strongly associated with deficits in the CIT-mentalizing trials (H2), and part of this association would be significantly accounted for by mentalizing ability (H3). In line with our intention to measure a cognitive rigidity process distinct from a negativity bias, we hypothesized that depression would be related to deficits on both the CIT-positive trials and the CIT-negative trials (H4).

Attention and Mood. Also following on from Study 1, we hypothesized that Task Attention would not account for the association between CES-D and Inferential Rigidity (H5), but would significantly account for the association between NA and Inferential Rigidity (H6). Again, we hypothesized that the link between CES-D and Inferential Rigidity would not be accounted for by NA (H7).

Set-shifting. As before, we hypothesized that depression would correlate more strongly with CIT-total than with WCST perseveration (H8), and that CIT-total would negatively correlate with WCST perseveration (H9).

Explanatory measures. Following on from the results of Study 1 that showed a link between depressive symptoms and the CIT-mentalizing trials types, we included a mentalizing survey measure (AQ-mentalizing; Palmer, Paton, Enticott, & Hohwy, 2015)

in order to test whether mentalizing ability predicted flexibility on the CIT-mentalizing vignettes. We added the Rumination Response Scale (RRS) questionnaire (Treynor, Gonzalez, & Nolen-Hoeksema, 2003) as a measure of convergent validity for the relation between depressive symptoms and CIT performance, and hypothesized that brooding, and not reflective, rumination would correlate with Inferential Rigidity, and would significantly account for part of the association between depression and Inferential Rigidity (H10). Brooding, but not reflective, rumination is a cognitive hallmark of depression, characterized by perseverative, passive and abstract processing of negative information. Brooding has been shown to correlate with current ($r=.44$) and future ($r=.37$) depression (Treynor et al., 2003), and has been linked to a range of rigidity processes for both negatively valenced tasks (for review, Gotlib & Joormann, 2010) and neutrally valenced task (Davis & Nolen-Hoeksema, 2000; Owens & Derakshan, 2013; Whitmer & Banich, 2007; Whitmer & Gotlib, 2012).

In addition, depression has been robustly linked to low self-efficacy, a measure of one's perceived influence over internal or external phenomena (Bandura, Pastorelli, Barbaranelli, & Caprara, 1999; Ehrenberg et al., 1991; Maciejewski et al., 2000). As we argue that Inferential Rigidity and low self-efficacy may represent two forms of 'non-contingency', and as low self efficacy has been linked to poor cognitive task performance (Bouffard-Bouchard, 1990), we hypothesized that low self-efficacy would correlate with Inferential Rigidity, and would significantly account for part of the relation between depression and CIT scores (H11). To this end, we employed the General Self-Efficacy Scale (GSE; Schwarzer & Jerusalem, 1995).

Control measures. Also similar to Study 1, we hypothesized that our relation between depression and Inferential Rigidity would not be fully accounted for by any of the following variables: WCST perseveration, intelligence, working memory, and two new items probing Task Memory and Task Comprehension (H12). However, we used different measures of intelligence and working memory, which were more suitable for online administration.

As this study was part of a broader program of research, a few additional survey measures that did not relate to the stated hypotheses were included, but are not reported here.

Method

Participants

After exclusions, participants were 148 adults (69% female) recruited through Mechanical Turk (MTurk). Eligibility criteria was for MTurk 'Workers' to have more than 50 but less than 100 completed MTurk jobs², to be between 18 and 55 years old, and to be residing in the United States. The actual age range was 18 to 55 years ($M=31.59$ years, $SD=9.49$), and almost all participants (96%) were native English speakers, with

the remainder fluent. Previous depression diagnosis was 24.3%, and 13.5% were currently on antidepressants. CES-D scores ranged from 0 to 44 ($M=16.54$, $SD=11.01$). Participants were paid US\$6 as compensation for their time, with an offer of a US\$2 bonus for 'conscientious and effortful completion of the task', which was determined by a maximum of one rating-point difference for each of the four repeat questions embedded within the questionnaires, as in Study 1. Four participants failed to complete the study and were removed. Eight participants were excluded for failing to provide consistent responses to repeat questions. And 16 participants were removed for failing to achieve more than 50% of the correct responses for the EC trials, as per Study 1.

Materials

Revised CIT. The same CIT trial protocol was employed as in Study 1, with 10 of the 22 vignettes replaced by new vignettes. There were two justifications for removing vignettes: six vignettes contained unrealistic or 'magical' expectancy-violations (for example, a person becoming a dog), while four additional vignettes generated relatively high (5-13%) ambiguous responding. The replacement vignettes further improved on the stimulus set by ensuring clear boundaries between different stimuli subcategories, and by increasing the number of CIT-negative trials (that switch from a more positive to a more negative interpretation). In addition, there were a few British English words that were replaced by their American English equivalent (e.g., "kilometers" was changed to "miles"), given the participant source. Two other EC trials, used in Study 1 as the practice and the initial vignette, were also removed to reduce the duration of the study (the initial vignette presented was always an EC vignette, to reduce detection of the CIT format, with the remainder randomized). The final stimulus set contained ten CIT-positive, six CIT-negative and four CIT-neutral trials. Of these, ten were CIT-mentalizing vignettes, split between the positive and negative valence subgroups. The full set of vignettes is available from the authors.

In order to check the reliability of the classification of vignettes, four independent expert raters also assigned each vignette to a positive, neutral or negative category. Intra-Class Correlations between these ratings and those used in the study ranged from .777 to .913 across the four raters, with 95% confidence intervals ranging from .436 to .966, and $p<.001$ for all F-tests. The same four raters also assigned each vignette to either mentalizing or non-mentalizing categories. Intra-Class Correlations between these ratings and the assignments used in the study ranged from .759 to .846 across the four raters, with 95% confidence intervals ranging from .392 to .939, and $p<.002$ for all F-tests. This demonstrates an acceptable to excellent degree of inter-rater agreement regarding the assignment of vignettes to the valence and mentalizing subcategories.

Affective measures. Once again the CES-D was employed. For a more robust measurement of state affect, the 10-item Short-PANAS was replaced by the full 20-item PANAS (Watson, Clark, & Tellegen, 1988).

Set shifting. The version of the WCST described in study 1 was again employed to test basic set-shifting ability.

Explanatory measures. Participants completed six items from the Autism Quotient that constitute a mentalizing factor (AQ-mentalizing; Palmer et al., 2015). An example item is, 'I find it difficult to work out people's intentions'. We included the 10-item Rumination Response Scale (RRS) questionnaire (Treyner et al., 2003), an instrument that assesses brooding and reflective response styles. In addition, we employed the General Self-Efficacy Scale (GSE), a measure of optimistic self-belief and perceived influence over internal and external phenomena (Schwarzer & Jerusalem, 1995).

Control measures. Due to time-constraints, we replaced the WAIS-IV Comprehension and the Similarities subtests with the International Cognitive Ability Resource Verbal Reasoning subtest (ICAR-VR; Condon & Revelle, 2014), a public-domain measure that includes a variety of logic, vocabulary, and general knowledge questions. The ICAR, which has been tested and normed on five groups of a total of 97,000 participants, correlates highly with the Shipley-2, a commercial intelligence measure ($r=.81$), and with combined SAT scores ($r=.59$), and shows good internal consistency ($\alpha=.81$).

Given the online presentation of Study 2, conscientious participation on the Digit Span WAIS-IV subtest could not be monitored (participants might simply write down the aurally-presented numbers). Accordingly, this measure was replaced with a single task N-Back following the protocols described in Jaeggi et al (2010), but using letters instead of shapes (as in Ragland et al., 2002). Briefly, participants were presented with a sequence of uppercase consonants, each for 500ms with a 2500ms interstimulus interval, and were required to press a button only on the appearance of a target letter (the response window was inclusive of the interstimulus interval). Target letters were defined as being identical to the letter presented n trials back, with n being equal to 1, 2, or 3 depending on the block. A block consisted of 6 targets and $14+n$ non-targets each. Two blocks for each level n were presented, making a total of six blocks. The dependent measure was the proportion of *hits* (correct presses) minus *false alarms* (incorrect presses) averaged over the entire task.

Procedure

The procedural order was as follows: Demographics, CES-D, PANAS, CIT, WCST, ICAR-VR, RRS, AQ-mentalizing, GSE and N-Back. The study was listed on the MTurk worker website, and participants were directed to the Inquisit launch page after reading the plain language statement and clicking to consent.

MTurk has been argued to provide a reliable participant source for experimental psychology (Buhrmester et al., 2011). We employed repeat questions to detect inattentive participation, and limited the total allowable task time to 1.5 hours to ensure completion in a single sitting.

Data analysis

The same analysis strategy was used as Study 1.

Results

Preliminary statistics

Table 3 shows relevant correlations and scale statistics. Twenty-six participants (17.6%) had CES-D scores indicative of moderate to severe depression (using a typical cut-point of 27; Stansbury et al., 2006). This is higher than typical rates in the United States (~7%; Kessler et al., 2005), and previously found within MTurk Workers (e.g., ~5% using the BDI; Shapiro, Chandler, & Mueller, 2013). Prior to exclusions, participants generated the correct 'initial interpretation' (using the EC trials) 89% of the time, indicating a high level of task comprehension. The general EV trial format was detected by 16.2% of participants, representing task-naivety in the majority of participants.

Table 3: Zero-order correlations, means, standard deviations and internal consistencies.

Variable	1	2	3	4	5	6	7	8	9	10	11
1. CES-D											
2. NA	.616***										
3. PA	-.407***	-.323***									
4. CIT-total	-.316***	-.195*	.082								
5. Task Attention	-.206*	-.180*	-.035	.375***							
6. WCST	.043	-.037	.063	-.142	-.040						
7. ICAR-VR	-.270***	-.134	-.058	.198*	.159	-.085					
8. N-Back	-.148	-.208*	.004	.190*	.232**	-.238**	.368***				
9. RRS-Brood	.642***	.449***	-.292***	-.221**	-.138	.027	-.178*	-.105			
10. RRS-Reflect	.284***	.300***	-.141	-.054	.050	-.002	.025	-.054	.376***		
11. GSE	-.402***	-.243**	.433***	.213**	.061	.009	.055	.043	-.327***	-.145	
M	16.54	13.58	29.10	-0.14	0.77	2.09	4.69	3.30	11.63	11.04	31.01
SD	11.01	5.03	8.21	0.36	0.17	1.14	2.19	1.17	3.12	3.09	5.01
α	.925	.829	.791	-	-	-	-	-	.807	.759	.892

Note. * $p < .05$; ** $p < .01$; *** $p < .001$. CES-D, The Center for Epidemiologic Studies Depression Scale, NA, negative affect, PA, positive affect, CIT-total, Contingent Inference Task total score, WCST, Wisconsin Card Sorting Test perseveration, ICAR-VR, International Cognitive Ability Resource Verbal Reasoning subtest, N-Back, working memory task, RRS-Brood, Rumination Response Scale Brooding subscale, RRS-Reflect, Rumination Response Scale Reflection subscale, GSE, General Self-Efficacy.

Inferential Rigidity in depression. To test our main predictions, we examined zero-order correlations between depression scores and CIT-total. In support of our main hypothesis, we found a significant negative correlation between CES-D and CIT-total (representing the entire vignette stimulus set), $r = -.32$, $p < .001$, with a 95% confidence interval from $r = -.17$ to $r = -.46$ (H1). In addition, CES-D correlated significantly with all vignette subcategories: CIT-mentalizing, $r = -.20$, $p = .015$; CIT-non-mentalizing, $r = -.27$, $p = .001$; CIT-positive, $r = -.18$, $p = .031$; CIT-neutral, $r = -.27$, $p = .001$; CIT-negative, $r = -.17$, $p = .039$. The fact that CES-D scores showed similar correlations across the positive, negative, and neutral vignettes suggests that the CIT measures a rigidity process and not merely a negativity bias (in line with H4).

Additionally, these results failed to confirm the hypothesis that depression would be related to greater difficulties for the mentalizing subset (H2). The partial correlation between CES-D and CIT-mentalizing while controlling for mentalizing deficits on the AQ-mentalizing survey was comparable to the zero-order correlation, $r = -.21$, $p = .011$, suggesting that performance on the CIT did not depend upon mentalizing ability (failing to support H3). Mentalizing deficits did not correlate with CIT-total, CIT-mentalizing

scores or CES-D scores, but showed a negative non-significant correlation with Task Comprehension, $r = -.16$, $p = .055$.

Attention and mood. The attention and mood findings in Study 1 were mostly replicated in Study 2. Although CES-D correlated with Task Attention in this study, $r = .21$, $p = .012$, the partial correlation between CES-D and CIT-total while controlling for Task Attention was $r = -.26$, $p = .001$. This suggests that Task Attention accounted for very little of the relationship between CES-D and CIT-total (H5).

Again, PA did not correlate with CIT scores, but NA correlated significantly with CIT-total, $r = -.20$, $p = .018$. Similar to Study 1, Task Attention accounted for a substantial amount of the relation between NA and CIT-total, $pr = -.14$, $p = .092$, but only accounted for a minimal amount of the relation between CES-D and CIT-total, $pr = -.26$, $p = .001$ (H6).

Once again, the partial correlation between CES-D and CIT-total while controlling for NA was still significant, $pr = -.25$, $p = .002$, while the partial correlation between NA and CIT-total while controlling for CES-D was not, $pr = .00$, $p = .998$, suggesting that depressive symptoms predicted Inferential Rigidity beyond the effects of current mood (H7).

Set-shifting. Our WCST hypotheses were all supported, replicating the findings from Study 1. No link was found between CES-D scores and WCST perseveration (H8), $r = .04$, $p = .610$; WCST perseveration showed a trend association with the CIT-total score (H9), $r = -.14$, $p = .088$; and the partial correlation between CES-D and CIT-total while controlling for WCST perseveration was comparable to the zero-order correlation (H10), $pr = -.30$, $p < .001$. This adds further support to our suggestion that the CIT probes a form of rigidity not accounted for by basic set-shifting deficits, and more strongly related to depression.

Trial-difficulty. Interestingly, depression was somewhat more strongly correlated with Inferential Rigidity within the easiest quarter of the vignettes (highest average updating rates), $r = -.29$, $p < .001$, than within the hardest quarter, $r = -.17$, $p = .040$. However, a test of the difference between the correlation coefficients was non-significant. Also, on average participants failed to update the target inference for the EV trials 57% of the time. These findings may either indicate a 'floor effect', or that trial-difficulty had an impact on the relation between depression and Inferential Rigidity.

Explanatory measures. Brooding, but not reflective rumination correlated with CIT-total, $r = -.22$, $p = .007$, and both RSS factors were strongly associated with CES-D. A partial correlation between CES-D and CIT-total while controlling for brooding rumination was $pr = -.22$, $p = .008$. While demonstrating a reduction from the zero-order correlation, this analysis failed to support our prediction (H10).

The self-efficacy findings were similar. GSE¹ correlated positively with CIT-total, $r = .21$, $p = .010$ (H12). A partial correlation of the association between depression and CIT scores while controlling for GSE exhibited a reduction from the zero-order

correlation, $pr=-.25$, $p=.003$, but did not significantly account for the relation between depression and Inferential Rigidity, failing to support our prediction (H11).

We conducted a partial correlation between CES-D and CIT-total while controlling for each of the variables that showed a significant zero-order correlation with both CES-D and CIT-total: Task Attention, brooding rumination, self-efficacy, and verbal reasoning. This partial correlation using multiple control variables was $pr=-.14$, $p=.105$, suggesting that these variables together accounted for most of the link between depressive symptoms and Inferential Rigidity.

Control measures. Partial correlations confirmed that the relationship between CES-D and CIT-total was not accounted for by verbal reasoning¹, working memory¹, Task Memory¹ or Task Comprehension¹ (H12). Partial correlations also confirmed that the relation between depression and Inferential Rigidity was not accounted for by Vignette Grammar Insight or Uncued Updating. Similar to Study 1, significant CIT differences, but not CES-D differences, were found between the two randomly allocated groups. As in Study 1, along with WCST perseveration and Task Attention, all the above covariates were controlled for in the final regression analysis.

We conducted a final regression analysis to assess whether depressive symptoms predicted Inferential Rigidity on the CIT while controlling for a range of covariates. Assumptions of linearity, non-multicollinearity, independence and normality of residuals, and homoscedasticity were not violated. The predictor variables without CES-D explained 27.1% of the variance in CIT-total scores. With the CES-D score entered in the second block, the total variance explained by the model was 31.6%, $F(10, 131)=6.05$, $p<.001$, with the R^2 change=.045, and F change (1, 131)=8.56, $p=.004$. In the final model (see Table 4) only the Vignette Grammar Insight, Participant Group, Task Attention and Depression variables were statistically significant.

Table 4: Linear regression predicting CIT-total score

Predictor	β	t	p
WCST	-.100	-1.342	.182
ICAR-VR	-.002	-.027	.979
N-BACK	.039	.473	.637
Task Memory	-.118	-1.270	.206
Task Comprehension	.063	.751	.454
Vignette Grammar Insight	.265	3.342	.001
Uncued Updating	-.106	-1.380	.170
Participant Group	-.167	-2.266	.025
Task Attention	.345	3.746	.000
CES-D	-.230	-2.926	.004

Note. CIT-total, Contingent Inference Task total score, WCST, Wisconsin Card Sorting Test perseveration, ICAR-VR, International Cognitive Ability Resource Verbal Reasoning subtest, N-Back, working memory task, CES-D, The Center for Epidemiologic Studies Depression Scale.

Discussion

The results from Study 2 built on those of Study 1, providing further and clearer support for our main hypothesis: Depressive symptoms were related to Inferential Rigidity on the CIT while controlling for a range of potential confounds, with an effect size that was in line with average effects sizes within individual differences research and psychology more generally (Mar, Spreng, & DeYoung, 2013). Improvements made to the CIT potentially increased its ability to validly assess this form of cognitive rigidity. In addition, the subcategory results show that depression-related deficits on the CIT reflect a rigidity process rather than a negativity bias, as depression was associated with inference updating deficits regardless of whether the ‘concealed interpretation’ was more positive or more negative than the ‘initial interpretation’. Furthermore, numerous findings from Study 1 were replicated in Study 2.

Based on the findings of Study 1, we hypothesized that depression may be especially related to deficits in processing mentalizing expectancy-violations. However, this hypothesis was not supported by the results of Study 2. Firstly, depression did not relate more strongly to the mentalizing subcategory than to the complete stimulus set or the other subcategories. Secondly, AQ-mentalizing scores did not correlate with either CIT-mentalizing or depression scores. Given this, it is possible that depression negatively correlated only with the mentalizing subset in Study 1 because this subset contained fewer vignettes with ambiguous and ‘magical’ expectancy-violations (three of these vignettes were replaced) than the non-mentalizing subset (seven of these vignettes were replaced), and was somewhat ‘easier’ than the remainder of the task

battery. Trial-difficulty appeared to affect the association between depression and Inferential Rigidity in Study 2 also, with a somewhat greater correlation between depression and the 'easier' vignettes than with the 'harder' vignettes. Since a very subtle expectancy-violation would be difficult for anyone to detect, such a vignette would be less able to distinguish differences across the continuum of depression severity. The stimulus set was improved following Study 1 by removing vignettes that received many ambiguous responses, and those with 'magical' expectancy-violations, which likely reduced trial-difficulty.

Other differences between Study 1 and Study 2 may have also contributed to the different results between these two studies. For example, Study 1 was conducted in-person in the laboratory, while Study 2 was conducted completely online. Also, Study 1 used an Australian sample, while Study 2 used an American sample. Finally, participants in Study 2 had substantially higher rates of depressive symptoms than in Study 1, which may have contributed to increased power to detect differences in the CIT as a function of depressive symptoms.

In Study 1 we found that Task Attention accounted for substantially more of the relationship between negative affect and CIT scores than between depression and CIT scores. This was also evident in the findings of Study 2. Indeed, previous research has shown a link between negative affect and attention deficits (Brose, Schmiedek, Lövdén, & Lindenberger, 2012; Smith, 2013). Depression has been linked to attention deficits too, though predominantly when tasks require substantial cognitive effort (Cohen, Lohr, Paul, & Boland, 2001; Egeland et al., 2003), and the CIT was not considerably demanding. This finding further highlights the ability of the CIT to probe a rigidity process not confounded by other factors such as poor attention.

Replicating Study 1, although Inferential Rigidity was somewhat related to WCST perseveration, depression was not, nor was the relation between depression and Inferential Rigidity accounted for by WCST perseveration. This adds support to the argument that depressive rigidity has boundary conditions that may not extend to basic perceptual-feature tasks such as the WCST. Taken together, these findings suggest that the CIT may probe a form of rigid cognition more pertinent to depression than 'perceptual' set-shifting deficits probed by the WCST.

Partial correlations showed that the relation between depression and Inferential Rigidity was not accounted for by Task Memory, Task Comprehension, working memory, verbal reasoning, Vignette Grammar Insight or Uncued Updating. A final regression model confirmed that the association between depression and CIT scores was not accounted for by a range of potential confounds.

A partial correlation with multiple control variables was conducted, using variables that correlated with both CIT-total and CES-D: brooding rumination, self-efficacy, Task Attention, and verbal reasoning. Together, these four variables accounted for most of the relation between depression and Inferential Rigidity. This finding was

interesting as, of all the variables measured, three of these (excluding verbal reasoning) may best represent the notion of 'non-contingency' in depression. As outlined in the introduction, the first form of 'non-contingency' involves deficits in responding to changing contextual factors. Both brooding rumination (which is characteristically decontextualized and abstract) and poor Task Attention relate closely to decreased contextual processing. The second form of 'non-contingency' involves judgements of reduced control over contextual factors, which relates to low self-efficacy, a construct that is closely linked to deficits in perceived controllability.

The link between brooding rumination and poor CIT performance provides convergent validity to the novel Inferential Rigidity construct. As brooding rumination is considered to represent depressotypic cognition (Joormann, Dkane, & Gotlib, 2006), this finding further supports our argument that the CIT assays a form of cognitive rigidity relevant to depressive thinking. Also, working memory and verbal reasoning negatively correlated with CIT-total. While these two variables did not account for much of the relation between CIT-total and depressive symptoms, these correlations likely reflect the roles of both working memory and verbal intelligence in the ability to comprehend and draw inferences from ambiguous narrative stimuli presented over the course of about a minute (George et al., 1997; Just & Carpenter, 1992; Trabasso, 2005).

Finally, the MTurk sample afforded a few advantages compared with the student sample. For example, the former provided better statistical power owing to a wider range of depression scores, and greater demographic heterogeneity (wider age range, less sex imbalance, and educational and occupational variability), thereby increasing the generalizability of this finding. As noted, the rates of depressive symptoms in this sample were considerably higher than typical rates found within the community and within MTurk samples in previous studies. No reference was made to depression in the MTurk advert, nor in the Plain Language Statement, and no other factor specific to this study can be identified that might explain these high rates. The sample were, on the whole, highly conscientious in their participation, as reflected in high completion rates, low rates of ambiguous responding, good reliability for repeat questions, elaborated responses in the CIT, and many participants provided extensive and articulate comments and suggestions in a final *optional* question regarding their experience of the study. One disadvantage was that more participants than in Study 1 gave high numbers of incorrect answers to the EC trial target questions, reflecting either poor attention or lack of comprehension of the vignettes in this minority of participants. However, given our exclusion of participants with poor scores for the EC trials, this disadvantage did not impact our analysis.

General discussion

Here we have reported two studies in which we developed and trialed a novel task to probe a psychological rigidity process highly relevant to depressive thinking. Although various cognitive rigidity measures have been associated with depression, no performance-based tasks we are aware of offer a systematic rigidity measure that relates directly to the level of construal, thematic contents, and rhetorical form of depressive thinking. Therefore, few cognitive rigidity tasks appear ecologically or therapeutically relevant. This paper reports a more promising, novel approach. The central finding was that depressive symptoms were related to deficits in updating interpretations about the meaning of a described event following exposure to information that conflicted with a current interpretation, or Inferential Rigidity. This finding reflected a rigidity process and not merely a negativity bias.

Although no measured variable appeared to fully account for the association between depression scores and Inferential Rigidity, Task Attention, brooding rumination, self-efficacy, and verbal reasoning each accounted for a modest amount of this association. When they were controlled for together, the relation between depression and Inferential Rigidity was reduced to non-significance. Taken together, three of these variables (excluding verbal reasoning) may best represent both forms of depressive ‘non-contingency’ as outlined in the introduction (see Study 2 Discussion for more detail).

The results from both studies support the argument that depressive rigidity has boundary conditions, as CES-D scores were related to CIT deficits but not to WCST deficits. This supports our argument that Inferential Rigidity has greater ecological validity for cognitive rigidity in depression as compared to WCST perseveration.

Our findings may be affected by various methodological and interpretative limitations. Although the second study exhibited many improvements from the first, the task may have still been too difficult on the whole, and given trial-difficulty appeared to affect the association between depression and Inferential Rigidity, an easier stimulus set may have increased the effect size. In addition, Study 2 was more a conceptual replication than a methodological replication, due to the extent of changes made. An exact methodological replication is warranted to bolster these findings. Another limitation is that we did not use a clinical sample. Although the results from this study should generalize to people affected by sub-diagnostic depressive symptoms, they may also generalize to Major Depressive Disorder (MDD), as a high number of participants in Study 2 had a previous or current MDD diagnosis. Finally, although we argue that the vignette method likely probes individual differences relevant to cognition *in the wild*, deficits in processing expectancy-violations within narrative vignettes may not predict deficits in processing unexpected experiential information.

In order to determine the clinical relevance of Inferential Rigidity, future studies comparing CIT performance of MDD patients to healthy controls, or comparing changes in Inferential Rigidity to changes in depressive symptoms over time would be needed. Also, it would be interesting to determine whether depressive symptoms predict deficits in processing unexpected information in daily life. To determine whether Inferential Rigidity plays a causal role in the disorder, future studies could develop a training protocol to increase *inferential flexibility* for depressed individuals who score low on the CIT. This could be achieved by training participants to generate multiple and varied inferences from ambiguous information that relates to the contents of depressive cognition, improve expectancy-violation processing ability, and increase ambiguity tolerance through the continued maintenance of multiple possible interpretations. Such interventions should ultimately seek to increase inferential flexibility *in the wild*, and ascertain whether depressive symptoms are subsequently reduced.

In conclusion, although cognitive rigidity is a key feature of depression, few systematic rigidity processes have been identified as important in the vulnerability or maintenance of depression. In an attempt to uncover an ecologically relevant form of cognitive rigidity using a performance-based task, we focused on the central theme and boundary conditions of ‘non-contingency’ in depressive thinking. We employed expectancy-violations within common scenario descriptions to simulate the conditions in daily life that afford inferential updating, a process that appears to be impaired within depression. Our finding of a link between depressive symptoms and Inferential Rigidity on the CIT may represent a measure of rigidity more pertinent to depressive cognition than those assessed using other performance-based cognitive rigidity tasks. In addition to deficits in affectively responding to environmental changes (represented by constructs such as emotional inertia and emotion context insensitivity), depression appears to be linked to deficits in cognitively responding to environmental changes too. Such a rigidity process may underlie certain typical cognitive features of the disorder such as biased beliefs that resist change, and may therefore contribute to the maintenance or risk for depression. Our hope is that this finding may reveal a new therapeutic target.

Footnotes

¹ See Supplementary Materials for further detail on these covariates.

² To increase the likelihood of including participants who were experienced in participating in online research, while maximizing task naivety.

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