Cognition in Major Depressive Disorder: Perceptions of Ability, Depressive Thinking, and Performance in Daily Life

by

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Abstract

Individuals living with major depressive disorder experience functional disability and cognitive difficulties in the mild to moderate range. These impairments are associated with functional disability, worsen with repeated episodes of depression, and persist outside of depressive episodes. While cognitive deficits are important in depression, we have several gaps in our understanding of these deficits. Individuals with depression tend to overestimate the degree of their cognitive impairment and this is associated with difficulties with everyday functioning and lower quality of life. However, we do not currently understand why individuals with depression overestimate impairments and what the consequences of this may be. Traditional assessment methods may not capture the nuance in cognitive performance in depression and novel assessment tools may help us to better understand how these constructs manifest in daily life. The objective of this dissertation was to explore the predictors of the discrepancy between subjective and objective cognitive ability, and to explore cognitive performance and its predictors in daily life in individuals with depression. In Chapter 2, we explored why individuals with depression overestimate their cognitive impairments and found that depressive thinking predicted the tendency to overestimate cognitive impairments. We also found that despite no significant differences in objective performance, individuals with depression underestimated their ability to perform on the easiest level of a cognitive task relative to healthy controls. Further, we found that the tendency to overestimate how cognitively impaired one is mediates the relationship between objective cognitive ability and withdrawal from cognitive challenge in daily life. Chapter 3 presents longitudinal data exploring cognitive performance in the context of daily life using novel cognitive tasks developed to use with Experience Sampling Methods (ESM). Findings were contrary to hypotheses and demonstrated that higher negative affect was

associated with better cognitive performance and participants were accurate in perceiving their performance on cognitive tasks. These results highlight the importance of exploring perceptions of ability in depression, even if they are discrepant from objective assessments, and highlights the potential utility of novel ESM cognitive tasks to explore these constructs in daily life for individuals experiencing depression.

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Chapter 1

General Introduction

1.1 Objectives

Major depressive disorder (MDD) is a leading cause of disability worldwide (World Health Organization, 2023). In addition to disability, a large proportion of individuals with depression experience cognitive deficits in domains such as processing speed, executive functioning, working memory, and memory. These deficits are also associated with disability, tend to worsen with repeated episodes of depression, and are persistent outside of depressive episodes. Despite the importance of cognitive impairment, there remain several gaps in our understanding of these impairments. Individuals with depression tend to report cognitive impairments that are significantly greater than what objective testing shows. More recently, the tendency to overestimate impairments has garnered more attention as these perceptions are associated with lower quality of life and impaired functioning, even when objective testing demonstrates a lack of measurable deficits.

However, little is known about why individuals with depression tend to overestimate impairments, or how this relates to approach or withdrawal from cognitively demanding activities in daily life. Novel methods like Experience Sample Methods (ESM) offer a unique way to investigate these constructs in real time, within real-world contexts, and with reduced recall bias. Nonetheless, ESM has rarely been applied in the study of cognitive functioning in depression.

To address these gaps, this dissertation aimed to investigate the factors that contribute to the tendency to overestimate cognitive impairment, and to explore how these challenges manifest in daily life for individuals with depression. Two studies were conducted using a shared sample:

a cross-sectional investigation of subjective views of cognitive ability and their consequences, and a longitudinal study using ESM to explore how momentary affect and perceptions of cognitive ability are associated with objective cognitive performance in daily life. The first study explored cross-sectional subjective perceptions of cognitive ability in depressed individuals, including factors associated with overestimating cognitive impairments and consequences of this overestimation. The second study used ESM tools to investigate how subjective views of cognitive ability and negative affect are related to cognitive performance longitudinally. In particular, we explored whether there were differences between individuals with MDD and healthy comparison participants in cognitive performance on ESM cognitive tasks, and if higher negative affect was associated with worse cognitive performance. Finally, we examined whether participants with MDD underestimated their performance on ESM cognitive tasks.

This dissertation presents data from two related studies with the following broad research questions:

1. Why do individuals with depression overestimate their cognitive impairments, and is this tendency to overestimate impairments related to withdrawal from cognitive challenge in daily life?
2. How do affect dynamics and perceptions of cognitive ability relate to objective cognitive performance longitudinally and in the context of daily life?

1.2 Major depressive disorder

Over the past 30 years, the global number of incident cases has increased almost 50%, and it is estimated that more than 264 million people are impacted by depression (Liu et al., 2020). In Canada, the prevalence of major depressive disorder increased in prevalence from 4.7% in 2012 to 7.6% in 2022 (Stephenson, 2023). Depression is an episodic condition

characterized by core symptoms of feeling sad and/or experiencing diminished interest or pleasure in activities. The symptoms experienced in depression are heterogenous; individuals with depression experience a range of other symptoms, including sleep difficulties, changes in appetite, loss of energy/fatigue, psychomotor retardation/agitation, concentration difficulties, guilt/worthlessness, and thoughts about death and suicide (American Psychiatric Association, 2013). The way that depression is experienced can look vastly different across different individuals, with heterogeneity in symptom presentation between individuals and variance within individuals over time (van Eeden et al., 2019).

The diagnostic criteria outline that individuals experience at least five symptoms of depression for at least two weeks (American Psychiatric Association, 2013), though many individuals have episodes that persist greatly beyond this timeframe (Kessler et al., 2003; van Eeden et al., 2019). Further demonstrating the heterogeneity of depression presentation, some individuals will experience persistent period of major depressive episodes, others will have frequent recurrences, and some will have years between episodes of depression and experience euthymic mood in between (Kessler et al., 2003; van Eeden et al., 2019). Approximately half of individuals who experience one episode of depression will have a recurrent episode in their lifetime (Monroe & Harkness, 2011; Monroe et al., 2019), with the risk of further recurrences increasing after each subsequent episode (Solomon et al., 2000; Lye et al., 2020).

1.2 Everyday Functioning in Depression

Depression is the leading cause of disability globally (World Health Organization, 2023). Many individuals with depression experience higher unemployment, missed days at work, and difficulty with work performance due to features of depression including somatic symptoms and anhedonia (Rizvi et al., 2015), and difficulty concentrating, reduced motivation, and mental

fatigue have been linked to decreased productivity and absences from work (Lam et al., 2014). Functional deficits in depression encompass occupational, social, and activities of daily living, which are linked to reduced quality of life and delayed recovery from depression (McKnight & Kashdan, 2009; Lam et al., 2014).

Surprisingly, depressive symptom severity accounts for little variance in predicting the persistence of functional impairment and functional disability persists despite improvements in mood (Adler et al., 2006; Kennedy et al., 2007). Indeed, recovery from a depressive episode does not necessarily mean that an individual will return to previous levels of functioning in daily life. Individuals who are classified as in remission from a depressive episode according to diagnostic criteria continue to experience difficulties returning to previous levels of social or occupational functioning (Lam et al., 2014). For example, despite being in remission from a major depressive episode, individuals have sustained difficulty with social functioning and productive functioning (Greer et al., 2012), pointing to functional recovery as separate from the reduction of depressive symptoms. Individuals with depression experience impaired everyday functioning and perceive their functional impairment as significant, rating recovery of life functioning as a more important treatment goal than symptom remission (Zimmerman et al., 2006). To address this, treatment programs have begun moving beyond symptom reduction alone and have emphasized the importance of functional recovery as a treatment goal in depression (Greet et al. 2012; McKnight & Kashdan, 2009). Residual symptoms associated with functional impairment, including neurocognitive functioning (Lam et al., 2014; McIntyre et al., 2013), may help us to understand the sustained disability in depression.

1.3 Neurocognition in Major Depressive Disorder

Diagnostic criteria of MDD reflect core cognitive features of depression: difficulty with concentration and decision making. Cognitive deficits refer to measurable impairments in thinking skills such as attention, memory, processing speed, executive functioning. By the first episode of depression, individuals experience cognitive impairments in verbal and visual memory, processing speed, attention, and executive functioning as compared to healthy comparison participants (Ahern & Semkovska, 2017; Lee et al., 2012). These impairments tend to in the small to moderate effect size range as compared to healthy controls (Baune et al., 2014; McIntyre et al., 2013), though some individuals with depression experience clinically meaningful impairments, with up to 50% experiencing deficits at or below 1 standard deviation below the estimated general population mean (McIntyre et al., 2013).

Importantly, these impairments tend to persist into remission, with a significant proportion of individuals continuing to experience cognitive impairment once depressive symptoms have remitted (Baune et al., 2010; Conradi et al., 2011; Hasselbalch et al., 2011; Semkovska et al., 2019). Cognitive impairment emerges as the most frequently enduring self-reported symptom following remission from a depressive episode (Zimmerman et al., 2012). Cross-sectional and longitudinal findings have implicated cognitive impairment in depression as a robust predictor of everyday functioning (Buist-Bouwman et al., 2008; Jaeger et al., 2006; McIntyre et al., 2013). Depressive symptom severity has been linked to impairments in activities of daily living, satisfaction with role functioning, and interpersonal relationships (McCall & Dunn, 2003). The association between cognitive impairments and psychosocial functioning remains significant even when controlling for residual depressive symptoms (Rock et al., 2014), as well as independent of current depression severity (Saragoussi et al., 2017). Moreover,

McIntyre and colleagues (2015) found that cognitive dysfunction explained greater variance in occupational functioning than depressive symptoms, highlighting the importance of cognitive issues in depression. Cognitive abilities significantly predict functional outcomes six months following an episode of depression (Jaeger et al., 2006). Moreover, 60% of participants with depression continued to experience functional disability in the six months following an episode (Jaeger et al., 2006). Naismith and colleagues (2007) found that self-rated and objectively measured cognitive deficits were associated with increased disability in depression, independent of depressive symptoms (Naismith et al., 2007). Thus, cognitive impairments are prevalent in depression and are an important independent predictor of sustained disability, even in periods of remission from depression.

1.3.1 Medications and Neurocognition

The evidence of how pharmacological treatments impact cognitive functioning in depression is mixed. Vortioxetine, an antidepressant that is classified as a serotonin modulator and stimulator, is associated with improved scores on cognitive tasks in major depression independent of depressive symptoms (McIntyre et al., 2016) and can improve older adults' age-related cognitive decline when paired with cognitive training (Lenze et al., 2020). In a recent systematic review and meta-analysis, Huang and colleagues (2022) found that vortioxetine improved both objective cognitive abilities and subjective views of cognitive abilities. Other antidepressants, including escitalopram, sertraline, and venlafaxine, have not been associated with improvements in cognition, despite symptom improvement following eight weeks of treatment (Shilyansky et al., 2016). However, preliminary results from a more recent meta-analysis suggest that selective serotonin reuptake inhibitors (SSRIs) may be associated with modest improvements cognition in individuals with depression (Prado et al., 2018), indicating

that cognitive benefits may vary by medication type and study design. Taken together, antidepressant medications can improve depression symptoms, however, their efficacy in improving cognitive impairments are variable.

1.3.2 Cognitive Remediation and Neurocognition

Cognitive remediation is a behavioural treatment that aims to improve cognitive abilities and everyday functioning in individuals with complex mental illness (Bowie et al., 2020). Drill-and-practice techniques are often used to target cognitive skills including attention, memory, executive functioning, and reasoning. Cognitive remediation also incorporates clinician support to navigate cognitive tasks and to facilitate group discussions of how skills might transfer to real-world situations (Medalia & Bowie, 2016). A meta-analysis found that when cognitive remediation was combined with vocational rehabilitation or social skills training, patients had significantly greater functional improvement (Wykes et al., 2011). Recent meta-analyses provide support for the use of cognitive remediation in individuals with mood disorders, showing improvements in cognitive domains of verbal learning and memory, working memory, and executive functioning (Goldberg et al., 2023; Legemaat et al., 2021). Despite improvements in cognitive functioning, cognitive remediation therapies do not always translate into improvements in functional outcomes (Legemaat et al., 2021; McGurk et al., 2007).

To bridge this gap, emerging cognitive remediation therapies, such as Action Based Cognitive Remediation (ABCR) aim to incorporate strategic learning, individualized goal setting, and transfer of cognitive skills to everyday functioning through role-play and real-world simulation tasks into traditional drill-and-practice cognitive training (Bowie et al., 2017). These emerging treatments result in greater improvements in functioning and generalizing skills to real-world behaviour as compared to traditional drill and practice cognitive training (Bowie et al.,

2017; Kidd et al., 2020; Ott et al., 2021), and demonstrate higher rates of perceived competence to approach cognitively challenging tasks (Bowie et al., 2017).

1.3.4 Course of depression and neurocognition

The literature suggests that the chronic and recurrent course of depression is associated with worsening impairments in cognitive functioning. As applied to depression, the trait marker hypothesis suggests cognitive impairments represent a stable, underlying vulnerability for the onset of the first episode of depression and subsequent recurrent episodes (Gottesman & Gould, 2003). Cognitive impairments persist into periods of remission from depression (Boeker et al., 2012; Conradi et al., 2011; Hammar, Lund, & Hugdahl, 2003; Hammar et al., 2010; Hasselbalch et al., 2011) and at a comparable magnitude to the impairments seen in episode (Bora et al., 2013; Rock et al., 2014). Moreover, cognitive impairments persist and worsen as a scar of the depressive episode (Lewinsohn et al., 1981). Indeed, greater cognitive impairments are associated with a greater number of previous episodes of depression in individuals with remitted recurrent MDD relative to healthy controls (Brown et al., 1999; Kessing, 1998; Semkovska et al., 2019; Sweeney et al., 2000). Further, impairments in verbal memory (Basso & Bornstein, 1999; Gorwood et al., 2008) and executive functioning (Vanderhasselt & De Raedt, 2009) worsen with an increased number of previous episodes of depression. In remitted depression, the cumulative duration of depressive illness has been associated with decreased cognitive abilities (Hasselbalch et al., 2013; Porter, Robinson, Malhi, & Gallagher, 2015).

In contrast, other research has provided evidence for the state-related hypothesis, suggesting cognitive impairments increase or decrease with the severity of depression symptomatology. Current depression severity has been demonstrated to have the strongest association with cognitive task performance (Gorwood et al., 2008) and was related to

impairments in executive function (Snyder, 2013). At the first episode of depression, psychomotor speed, working memory, and general memory functioning were moderated by inpatient and remission status, suggesting these domains may be more state driven impairments in depression (Lee et al., 2012). Moreover, a review of longitudinal studies by Douglas and Porter (2009) found that in individuals with MDD, improvements in verbal memory, verbal fluency, and psychomotor speed were associated with improvements in mood while attention and executive functions were impaired regardless of depression symptom severity. These findings suggest that those with depression may have both domain-specific trait and scar-based impairments (Douglas & Porter, 2009).

The findings exploring neurocognition in depression highlight the considerable heterogeneity of cognitive impairments across phases of depressive illness, and the many factors that may impact the severity of these impairments, including clinical features of depression such as duration of illness (Porter et al., 2015), number of previous episodes of depression (Semkovska et al., 2019), and depression symptom severity (Gorwood et al., 2008; Synder, 2013). Thus, cognitive impairments in depression are pervasive and associated with sustained disability, even outside of an acute episode of depression. However, important gaps remain in our understanding of how cognitive impairments in depression are perceived, assessed, and experienced in daily life.

1.4 Subjective Cognition in Major Depressive Disorder

While findings demonstrated objective and measurable cognitive deficits in depression as highlighted above, researchers have also begun exploring the tendency of depressed individuals to overestimate the degree to which they experience cognitive impairment. Subjective cognitive complaints are an individual's perceptions of their cognitive abilities, often assessing difficulties

with memory, attention, and cognitive slips in daily life. As compared to traditional cognitive assessment tools, individuals with depression tend to overestimate their cognitive impairments (Lahr et al., 2007; Petersen et al., 2019; Schwert et al., 2018; Svendsen et al., 2012). The tendency to overestimate cognitive impairments is related to depressive symptoms (Petersen et al., 2019; Sawada et al., 2019; Serra-Blasco et al., 2019; Srisurapanont et al., 2015), suggesting that biases in depression may impact views of cognition, even when objective cognitive assessment tools do not reflect such deficits. However, in contrast to this, even in periods of remission, up to 44% of individuals with a diagnosis of depression report difficulty with cognition (Conradi et al., 2011). Outside of trait-based assessments of subjective cognition, individuals with depression also underestimate performance on experimental cognitive tasks, despite no objective performance impairments (Dunn et al., 2007; Wood-Ross, 2021).

Overestimation of cognitive impairments has been associated with a range of negative consequences, including poorer quality of life, reduced socio-occupational functioning (Petersen et al., 2019), and lower workplace productivity (Toyoshima et al., 2020). Notably, greater subjective cognitive impairment has also been linked to an increased risk of depressive relapse, as well as poorer psychosocial functioning (Sumiyoshi et al., 2021). Subjective views of cognition partially mediated the relationship between depressive symptom severity and role functioning (Buist-Bouwman et al., 2008). Additionally, older adults with subjective cognitive concerns experienced more difficulties with daily functioning (McAlister et al., 2016).

Taken together, individuals with depression tend to overestimate the degree to which they are impaired, however this may not solely be linked to depressive symptoms. Emerging support shows that there are important consequences of this overestimation, including functional impairments. Rather than considering these impairments as strictly linked to the depressive

process, these subjective views of cognitive abilities may be an important and distinct concept in depression that require attention (Allott et al., 2025).

1.5 Thinking Styles Common in Depression

Beck's cognitive model of depression proposes that individuals with depression have negative core beliefs or schemas about the self, the world, and the future. These schemas are thought to contribute to how information is processed, interpreted, and remembered, and act as vulnerabilities for the onset and maintenance of depression (Beck et al., 1979). Typically, neurocognition is not considered part of the cognitive model, however, research has begun exploring the ways that neurocognitive abilities interact with schemas and how these are associated with functional difficulties in depression (Wood-Ross et al., 2022).

It has been proposed that individuals with both current and remitted MDD exhibit a "catastrophic response to perceived failure" that is demonstrated by a significant decrease in cognitive performance following real or perceived failure on a task (Elliott et al., 1996; Elliott et al., 1997). Beats et al. (1996) demonstrated a similar response in individuals with depression, where once a mistake was made on a cognitive task, subsequent performance deteriorated. Furthermore, the catastrophic response to perceived failure was unique to depression, regardless of episodic status, as compared to controls and other clinical groups (Elliott et al., 1997) pointing to a potential trait feature of depression. Thus, it is possible that individuals with MDD may have the capacity to perform certain cognitive challenges, but in response to real or perceived failure, may doubt their ability to perform well which may consequently limit persistence with effortful cognitive tasks.

Models of cognition in depression propose that neurocognitive difficulties in daily life might interact with existing schemas to reinforce negative self-schemas (e.g., I am not capable)

which might perpetuate the cycle of depression (Ahern et al., 2019). Once activated, schemas and depressive thinking patterns may place demands on cognitive resources, which may impair the use of cognitive abilities such as executive functioning, attention, and memory (Ahern et al., 2019). Indeed, the resource allocation hypothesis proposes that individuals with depression have limited ability to engage neurocognitive abilities as resources needed to do so are engaged in depressive thinking patterns and emotional processing (Ellis & Ashbrook, 1998). I propose that this may extend to difficulties with daily functioning as individuals with depression who have negative beliefs about themselves that extend to their abilities may have more difficulty with approaching challenge in daily life. In a recent study, both neurocognitive functioning and depressive symptoms predicted productive functioning, and each of these relationships was mediated by dysfunctional attitudes, or an individuals' negative underlying beliefs about themselves (Wood-Ross et al., 2022). The tendency to underestimate performance on cognitive tasks and dysfunctional attitudes may interact to limit engagement with cognitive challenge, and together this pattern in depression could be a particularly important barrier to approaching cognitive challenge in daily life.

1.5 Withdrawal from and Avoidance of Cognitive Challenge

In individuals with depression, avoidance of cognitively effortful tasks may contribute to cognitive impairments experienced by individuals with depression (Elliott et al., 1996; Elliott et al., 1997). Individuals with depression may preferentially avoid tasks with higher demands of effort, regardless of the real or perceived benefits of task engagement (Hammar et al., 2011; Kasch et al., 2002). The cognitive effort hypothesis proposes that individuals with MDD are impaired in appropriately allocating effort to tasks that demand greater cognitive abilities (Ellis & Ashbrook, 1988; Hasher & Zacks, 1979). Hammar (2003) provided evidence for this

hypothesis, demonstrating that on a visual search task of high cognitive demand, individuals with MDD required significantly longer search time to achieve the same accuracy as healthy controls. Additionally, when given a choice to approach cognitive challenge, individuals with MDD avoided challenging cognitive tasks significantly more than healthy comparison participants (Wood-Ross et al., 2021). Impairments in effortful processing also persist following clinical remission from depressive symptoms six months following the initial assessment (Hammar & Ardal, 2012). A recent scale developed aims to assess cognitive approach and withdrawal in daily life, and preliminary findings suggest that individuals with higher depressive symptoms have a tendency to withdraw from cognitive challenge in daily life (Tran et al., 2024). Thus, depression is associated with a tendency to perform poorer on and disengage from cognitive tasks that are more effortful, which may contribute to worsening of cognitive impairments. However, few studies have explored what the consequences of this avoidance may be in depression, and how the avoidance manifests in daily life.

Treatments that improve cognition but do not focus on restoration of functioning or address cognitive effort avoidance result in improvements in cognitive abilities, but do not typically produce improvements in everyday functioning in individuals with depression (Gupta et al., 2013; Naismith et al., 2011). Features of depression such as motivation and defeatist beliefs (Bowie et al., 2016) may interact with cognition and restrict the use of cognitive abilities in everyday life. Emerging cognitive remediation treatments as described above aim to bridge this gap (e.g., Bowie et al., 2017). It is possible that an individual's willingness to apply their cognitive skills in real-world challenges may impact cognitive functioning and further impair everyday functioning. On an effortful cognitive task, increased disengagement from low to high cognitive load was associated with more impaired quality of life in individuals with elevated

depression symptoms (Bowie et al., 2017). Further, avoidance of cognitive effort mediates the relationship between cognitive ability and everyday functioning in depression (Tran et al., 2021).

One potential consequence of negative self-perceptions of cognitive ability may be withdrawal from cognitively stimulating activities. If individuals with depression believe that they are unable to approach cognitive challenge, they might subsequently avoid tasks that require cognitive engagement. Much of the literature exploring the relationship between decline in cognitive skills and everyday environments has come from the literature in aging individuals. Greater engagement in cognitive activity has been linked to better cognitive functioning in older adults (Hanushek et al., 2025; Wenzel et al., 2024). Similarly, reductions in cognitively active lifestyles are associated with subsequent declines in cognitive domains, which are also associated with less engagement psychosocially (Small et al., 2012).

In summary, the experience of depression may negatively affect an individual's judgment of their performance and ability, which could in turn impair persistence with challenging tasks, ultimately affecting cognitive performance. Individuals with MDD may have the capacity to perform certain cognitive challenges, but in response to real or perceived failure, may doubt their ability to perform well which could consequently limit persistence with effortful cognitive tasks. To date, scarce literature has sought to test how perceptions of ability and the tendency to avoid cognitive challenge manifest in withdrawal from cognitive challenge in daily life.

1.6 Summary of Key Constructs

In summary, the research to date suggests that individuals with depression experience both objectively measured cognitive deficits and a tendency to perceive their cognitive abilities as worse than they are. These negative self-perceptions are associated with real-world consequences, including lower quality of life and reduced everyday functioning, even when

objective cognitive performance is relatively intact. There is also emerging evidence that individuals with depression may withdraw from cognitively demanding activities in daily life, which I propose could be related to negative self-appraisals seen in depression. However, little is known about how these constructs are experienced in the context of everyday life, or how momentary perceptions of ability and affective states interact with cognitive ability over time.

The two studies presented in this dissertation were designed to address these gaps by exploring how subjective views of cognitive ability, objective cognitive performance, and affect interact in individuals with and without depression. Both studies aim to explore how cognitive challenges are experienced and interpreted. The next section describes the relevant assessment tools used to capture these constructs in this dissertation.

1.7 Assessment Methods

1.7.1 Traditional Assessment Methods

1.7.1.1 Neurocognitive Assessment

Traditional neuropsychological assessment tools are widely used in the assessment of cognitive abilities in depression and several other psychiatric conditions (e.g., schizophrenia, obsessive compulsive disorder, learning disabilities). In traditional assessment methods, we use comparison of demographically matched individuals on variables such as education, sex, and age, from the general population (Lezak, 2004) to characterize individuals on a normal distribution of scores, to explore how an individual deviates from the population mean (i.e., *z*-score of 0, standard deviation of 1).

Using traditional assessment tools, substantial variability has been demonstrated in the prevalence of cognitive impairments in individuals with mood disorders (Douglas et al., 2018). Tran and colleagues (2021) found that when measuring cognitive functioning with traditional

tools relative to premorbid estimates of cognitive functioning, 62.2% of the sample was classified as impaired, as compared to only 25% when using traditional assessment tools alone. Thus, the reliance on assessment of cognition using traditional tools alone may not accurately capture the number of individuals that are affected by changes in cognition related to the onset or persistence of depressive symptoms. Further, traditional assessment tools capture cognitive ability at an individual's performance at a given time point in a highly controlled environment that may limit ecological validity and the ability to capture changes in cognition that may occur within or across days (Spooner & Pachana, 2006). Cross-sectional studies assessing cognition collect data with the goal of assessing peak performance in constrained and contrived environments.

1.7.1.2 Symptom Assessment

Assessment of depression symptoms tends to rely on standardized symptom interviews and self-report scales that aim to track symptoms over the course of the last several days or two weeks. In symptom interviews, patients are typically asked to report on their various symptoms and to indicate the frequency of these symptoms (e.g., how many times in the last week have you had decreased appetite), the intensity (e.g., how sad did you feel on a scale of 0-10), and the duration (e.g., how long have you been having sleep difficulty). Scales like the Montgomery-Asberg Depression Rating Scale (MADRS; Montgomery & Åsberg, 1979), Hamilton Depression Rating Scale (HAM-D; Hamilton, 1960), Beck Depression Inventory (BDI; Beck et al., 1961), and Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001) are widely used measures in research and clinical settings to capture and understand experiences with depression. These symptom assessments of depression allow us to capture more episodic periods of depression

symptoms over several days or weeks. However, they may not capture the fluctuations seen in mood throughout the day.

Our traditional tools are limited by our reliance on retrospective recall in patients. Individuals with depression tend to have a bias to negatively recall past events (Ben-Zeev et al., 2009; Solhan et al., 2009) and tend to recall the most negative and recent periods of mood more strongly than the average of daily reports, suggesting a peak-end recall bias (Horwitz et al., 2023). As such, retrospective assessments of mood may at times overestimate depression severity. Further, symptom interviews often provide clinicians and researchers a cumulative score of depressive severity and do not always allow us to explore the trajectory of symptoms that may unfold across a period of time. As such, traditional assessments allow us to capture broad patterns of symptoms that may at times overestimate severity. Implementing brief, intermittent assessments may allow us to explore how symptom trajectories manifest in daily life.

1.7.2 Mobile Assessments

1.7.2.1 Neurocognition

Experience sampling methods (ESM) are techniques where participants are prompted to a mobile device multiple times per day, randomly or predetermined times, within their naturalistic context of daily life (Shiffman et al., 2008). ESM provides repeated assessment within an individual's everyday life which allows for an examination of variables across varying contexts (e.g., environment, mood). Typically, these assessments are completed on participants' smartphones. ESM based cognitive assessments may allow us to explore how an individual's cognitive performance may change as depression symptom severity fluctuates and with changes to situational factors in daily life. An individual's cognitive performance can fluctuate in their

daily life as a function of stress, fatigue, lack of sleep, distracting environment, and circadian rhythms (Metternich et al., 2009; Schmidt et al., 2007). It has been proposed that these state-dependent factors can impact compensatory cognitive resources, which would be more available under ideal conditions (i.e., laboratory settings) but to a lesser degree in real-world contexts (Small et al., 2019).

An emerging literature base provides evidence for the utility of ESM to capture cognitive ability. Environmental demands may cause variability in neurocognitive performance (Costa & Fardell, 2019) and ESM provides an opportunity to explore cognitive performance within the context of everyday life. ESM based cognitive assessments have been demonstrated to have excellent between person reliability and reliable within-person variability across measurement occasions (Sliwinski et al., 2018). Further, using ESM based cognitive assessment may allow for the exploration of how cognitive performance fluctuates across time points and what factors might be related to these fluctuations (e.g., mood, fatigue). In one of the first studies exploring cognitive performance using ESM was conducted in a sample of breast cancer survivors where Small and colleagues (2019) explored the relationships between fatigue, depressed mood and cognitive performance and found that higher fatigue was associated with poorer performance on a processing speed task. The authors also had excellent compliance in their sample, with an average 88% response rate (62 prompts out of a possible 70) to the daily ESM prompts (Small et al., 2019). Other researchers have used ESM to study cognitive performance in aging populations and have found cognitive tasks delivered in an ESM format, such as the n-back, to be a reliable assessment of cognition that captures fluctuations in performance over time and with context, something that traditional performance-based measures cannot capture as easily (Schmitter-Edgecombe et al., 2020). ESM approaches to measuring cognition are accessible, convenient,

and may also be more sensitive to subtle fluctuations in cognition that we may not be able to capture using traditional cognitive assessment tools (Öhman et al., 2021; Harris et al., 2024). However, few researchers have explored the use of ESM to assess cognitive ability in individuals currently experiencing depression.

1.7.2.2 Mobile Assessments

ESM methods may allow us to capture how people feel, think, and act in the moment, rather than across several days. Indeed, research has highlighted the utility of ESM to assess self-report symptoms (Harvey et al., 2021; Moore et al., 2022; Sliwinski et al., 2018). Additionally, ESM symptom assessments reduce reliance on retrospective assessments (Colombo et al., 2019) and can allow us to assess affective states in real-time to explore fluctuations throughout the course of the day (Myin-Germeys et al., 2018; Peeters et al., 2003; Schoevers et al., 2020). Daily affect dynamics predict symptom trajectories in depression (Panaite et al., 2020) and negative and positive affect are both considered fundamental in the onset and maintenance of depression (Bown, 2007; Clark & Watson, 1991). ESM studies show that MDD participants have significantly increased variability and instability in negative affect (Crowe et al., 2019; Koval et al., 2013; Schoevers et al., 2020). While ESM may provide us with unique insight into affect fluctuations in individuals with depression within and across days, how these fluctuations relate to cognitive performance in major depressive disorder remains underexplored.

1.8 Summary

In sum, major depressive disorder is associated with persistent cognitive deficits, both objectively measured and subjectively perceived, which are associated with functional impairment and reduced quality of life. While subjective cognitive impairments are common and often overestimated relative to objective performance, the mechanisms underlying this

overestimation and the consequences, including withdrawal from cognitive challenge, remain poorly understood. Traditional assessment methods have provided valuable insight into these challenges but are limited in ecological validity and may not allow us to capture within-person fluctuations. ESM tools offer a promising approach to assess objective cognitive ability, affect, and subjective views of cognitive performance in real time, but have yet to be explored in individuals with depression. This dissertation aims to address these gaps through two related studies: a cross-sectional examination of subjective cognitive ability in depression, including factors associated with overestimation and its relationship to withdrawal from cognitive challenge, and a longitudinal ESM examination of affect, perceived cognitive ability, and objective cognitive performance in daily life.

Chapter 2

Mind the Gap: Exploring the discrepancy between subjective and objective cognitive impairments in depression and implications for cognitive withdrawal

2.1 Introduction

Beyond the hallmark symptoms of low mood and anhedonia, cognitive impairment, such as difficulties with concentration, decision-making, memory, and attention, are also included in the diagnostic criteria for major depressive disorder (MDD; American Psychiatric Association, 2013). Cognitive impairments are evident as early as the first episode of depression and span multiple domains including verbal and visual memory, processing speed, attention, memory, and executive functioning (Ahern & Semkovska, 2017; Bora et al., 2013; Lee et al., 2012; Rock et al., 2014). These impairments have been shown to persist into remission from a major depressive episode and to worsen over time with repeated episodes (Semkovska et al., 2019) and are a strong predictor of functional impairment in both cross-sectional and longitudinal studies (Buist-Bouwman et al., 2008; Jaeger et al., 2006; Matcham et al., 2022; Morey-Nase et al., 2019; McIntyre et al., 2013). However, the degree of impairment and domain affected tends to be quite heterogenous (Parkinson et al., 2020). While some individuals with depression demonstrate clinically significant cognitive deficits, others perform within the normative range (Moritz et al., 2017).

Self-reported cognitive difficulties are frequently endorsed by individuals with depression, even in the absence of measurable impairment. Individuals with MDD tend to overestimate their cognitive impairments relative to their objective level of impairment as measured by neuropsychological testing (Lahr et al., 2007; Petersen et al., 2019; Schwert et al., 2018; Svendsen et al., 2012). Petersen et al. (2019) found that individuals with a diagnosis of

MDD, both in episode and remission, were more likely to overestimate impairments in attention and concentration as compared to memory and planning problems. Even in periods of remission, self-reported cognitive complaints remain common, with up to 44% of individuals reporting cognitive impairments when in remission from a major depressive episode (Conradi et al., 2011). Similarly, studies using experimental tasks have shown that individuals with current or subsyndromal depression tend to underestimate their performance on cognitive tasks, even in the absence of any objective deficit when compared to healthy participants (Dunn et al., 2007; Wood-Ross et al., 2021).

Despite a growing body of research demonstrating that individuals with depression tend to subjectively overestimate cognitive impairments as compared to their objective cognitive profile, relatively little is known about what contributes to the overestimation of cognitive impairments. Several studies have found that the degree of overestimation increases with depressive symptom severity (Petersen et al., 2019; Sawada et al., 2019; Serra-Blasco et al., 2019; Srisurapanont et al., 2015), and is also linked to younger age and longer illness duration, particularly among individuals in remission (Petersen et al., 2019). Self-perceived impairments in cognition are associated with lower quality of life, reduced socio-occupational functioning, (Petersen et al., 2019; Toyoshima et al., 2020), and increased risk of depressive relapse (Sumiyoshi et al., 2021). When features of depression were controlled for including motivational deficits and concerns about performance, the majority of group differences in the depression group to healthy controls on cognitive tests were no longer significant (Moritz et al., 2017).

Dysfunctional attitudes, an individual's negative underlying beliefs about themselves, the world, and the future, are a core feature of depression and often conceptualized as trait-like

cognitive vulnerability that can confer risk for depression that become more salient during episodes of low mood **(**Brown & Beck, 2002; Dykman & Johll, 1998**)**. Dysfunctional attitudes have been shown to mediate the relationships between cognition, depressive symptoms, and real-world functioning (Wood-Ross et al., 2022). Findings in other severe mental illness such as schizophrenia have found that higher scores on dysfunctional attitudes scales are related to more severe cognitive impairment (Grant & Beck, 2009). Although the literature related to cognition and dysfunctional attitudes is limited, Beck's cognitive theory (Beck et al., 1979) suggests that these attitudes shape how individuals with depression interpret their abilities and their future. This paper will be novel in examining the degree to which dysfunctional attitudes extend to appraisals of one's cognitive impairments.

We hypothesize that regardless of objective cognitive impairment, individuals who overestimate their cognitive impairments will have greater behavioural avoidance of cognitive challenge. Indeed, individuals with higher depression symptom severity have demonstrated greater disengagement from tasks as they became more challenging, even when objective performance was intact (Bowie et al., 2017), and individuals with depression chose to avoid cognitively challenging tasks as compared to healthy controls, despite no significant differences in objective performance accuracy on the task (Wood-Ross et al., 2021). In a qualitative study of young people with depression, participants described a relationship between experiencing reduced motivation and worsening cognitive abilities that they observed occurring through their withdrawal from cognitively-demanding activities (Morey-Nase et al., 2019). Indeed, researchers have demonstrated that withdrawal from leisure activities is associated with lower cognitive function in older individuals with depression (Hao & Kim, 2024). In a sample of non-clinical participants, individuals with higher depression symptoms demonstrated significantly greater

cognitive withdrawal than those with low depressive symptoms, and self-reported cognitive difficulties were associated with cognitive withdrawal from activities in daily life (Tran et al., 2024). Taken together, we propose that individuals with depression may have reduced confidence to approach tasks perceived as cognitively challenging and as a result, may exhibit greater withdrawal from such tasks in daily life.

Avoidance of cognitive effort may be a phenomenon in depression that is objectively measurable and related to disability. However, to date, no studies have directly tested how overestimation of cognitive impairments may relate to the withdrawal from cognitive demanding tasks in everyday life in depression. Additionally, the literature base testing how features of depression, including symptom severity and dysfunctional attitudes are related to the overestimation of subjective cognitive impairments relative to objective cognitive performance is limited. The purpose of the present study was to investigate how features of depression relate to the overestimation of objective cognitive impairments, and to explore whether the overestimation of cognitive impairments mediates the relationship between objective cognitive ability and withdrawal from cognitively demanding activities in daily life. The current study included community-dwelling participants with a diagnosis of MDD as well as age and gender matched healthy comparison participants.

The following hypotheses were tested:

1a. Individuals with depression were hypothesized to overestimate their cognitive impairments on subjective measures relative to their objective performance.

1b. It was further hypothesized that greater depression symptom severity and higher levels of dysfunctional attitudes would predict greater overestimation of cognitive impairments.

2a. Using a working memory task with two difficulty levels (easy and moderate), it was hypothesized that individuals with depression would rate their performance as significantly worse than healthy controls on both levels of the task.

2b. It was further hypothesized that participants with depression would perform significantly worse only on the moderate difficulty level of the working memory task.

3. It was hypothesized that the relationship between objective cognitive ability and withdrawal from cognitive challenge in daily life would be significantly mediated by the degree to which participants with depression overestimate their cognitive impairments.

2.2 Method

2.2.1 Participants

Seventy-seven patients with a diagnosis of major depressive disorder and 75 healthy controls participated in the study. Participants all lived in Ontario, Canada and were recruited from the community through online advertisements, posters, and the Queen's University Psychology Participant Pool. MDD participants were also recruited from an outpatient mood disorders clinic. Healthy comparison participants were matched for age and sex to the MDD group comparison participants and were recruited as a reference sample for the calculation of standardized scores in this study.

All participants completed a phone screening conducted by a trained bachelor's level research assistant or doctoral level graduate student in clinical psychology. Inclusion criteria for both groups were English-speaking, aged 18-65 years of age, normal or corrected vision and hearing, and had access to a computer with a webcam and mobile device with internet connection. Inclusion criteria for the MDD sample included experiencing a current episode of depression, with at least two previous episodes, as individuals who experience two or more

episodes of depression are thought to be phenotypically different from those who experience a single lifetime episode of depression (Roca et al., 2011). Current depression status was determined based on a phone screening interview at the time of recruitment developed in the Mood Laboratory at Queen's University (see Appendix B for screening module used). All healthy comparison participants were screened using the Mini International Neuropsychiatric Interview (Sheehan et al., 1998) to assess whether criteria were met for any current or previous psychiatric illness. Participants were excluded if they had the presence of a medical diagnosis that is associated with known cognitive impairments, diagnosis of a bipolar disorder, psychotic disorder, and/or substance or alcohol use disorder. We obtained written informed consent from all participants.

2.2.2 Procedure

Data were collected virtually on a Zoom call through the Cognition in Psychological Disorders lab at Queen's over the course of one session, or over multiple sessions if requested by participants. For the duration of the study visit, either a trained research assistant or doctoral level student in clinical psychology was present on the Zoom call to administer cognitive tasks and remained on the call to observe participants completion of Inquisit cognitive tasks and Qualtrics questionnaires. Participants were asked to leave their webcam and audio on for the entirety of the study Zoom call. Participants were also asked to complete the study visit in a room alone with reduced background noise and distractions. A trained research assistant blinded to study hypotheses completed the neurocognitive assessment and sent participants a link to complete the Inquisit cognitive tasks (Symbol Search and n-back). Following each level of the n-back, participants were asked to report what they believed their performance accuracy was on each of the tasks to obtain a measure of subjective performance accuracy. Following completion

of the cognitive tasks, a research assistant sent participants a link to study questionnaires administered through Qualtrics. At the end of the study visit, a trained research assistant or doctoral level student administered the MADRS and LIFE-RIFT to participants with MDD. All procedure were completed during a 2-hour session. Participants were compensated $15 per hour.

2.2.3 Measures

2.2.3.1 Demographic Information

Participants completed an online questionnaire to ascertain demographic information: age, gender identity, ethnicity, education, employment, self-reported diagnoses, marital status, living circumstances, source of income.

2.2.3.2 Neurocognitive Battery

Participants completed a battery of cognitive tests in processing speed, executive functioning, working memory, verbal fluency, verbal learning. Although manualized norms are available for many of these measures, they are derived from in-person administration. Given that our testing was conducted remotely, manualized norms may not be directly comparable. Due to the remote nature of our tests, each raw test score was converted to a *z* score ($M = 0$, $SD = 1$) based on the healthy control group, who completed the same tasks under the same remote conditions. Each MDD participant's raw score was subtracted from the healthy control group's mean and divided by the healthy control group's standard deviation. Finally, a neurocognitive composite score was computed by averaging across each domain *z* scores.

2.2.3.2.1 Processing speed. Oral Trail Making Test – Form A (oTMT-A; Ricker & Axelrod, 1994) and Symbol Search (Wechsler, 2008) were used to measure processing speed. The oral TMT-A is a verbally administered adaptation of the traditional trail making test designed for remote assessment when in-person paper-and-pencil administration is not feasible. In oral TMT-

A, participants were instructed to orally count as fast as possible from 1 to 25. The total time elapsed to completion was the outcome variable, with higher scores indicating slower performance. Scores were reversed in the *z*-score calculation to ensure that higher scores consistently indicated better neurocognitive performance. Symbol search was administered virtually through Inquisit Web and was modelled after the Symbol Search task developed by Wechsler (2008). On each trial, participants were presented with two target symbols and asked to indicate whether either target symbol matched one of several symbols in an adjacent search array. The outcome variable was the total number of correct responses, with higher scores reflecting faster processing speed.

2.2.3.2.2 Executive functioning. Oral Trail Making Test – Form B (TMT-B; Ricker & Axelrod, 1994), the Delis-Kaplan Executive Function System (DKEFS) Category Switching subtest (Delis et al., 2001) were used to assess set-shifting. The oral TMT-B instructs participants to switch between stating numbers in ascending order and letters in alphabetical order (i.e., 1-A-2-B-3-C, etc.) up to a pre-determined endpoint. Participants responded orally, and the examiner recorded the time to completion and number of errors. Errors were immediately corrected by the examiner and the total time included corrections. The outcome variable was total time to completion (in seconds), with longer times indicating poorer set-shifting. Scores were reverse scored in computing the *z*-score to indicate that a higher score is indicative of better cognitive performance. On the DKEFS category switching task, participants were asked to orally generate as many words as possible, alternating between two categories, fruits and furniture (e.g., banana, chair, apple, couch) within 60 seconds. The outcome variable was the total number of correct switches.

2.2.3.2.3 Verbal fluency. DKEFS Verbal Fluency (Delis et al., 2001) was used to measure verbal fluency. Participants were asked to name as many words relevant to the provided category and letters as quickly as possible. The outcome variable was the total number of words produced across all trials.

2.2.3.2.4 Working memory. Letter Number Sequencing test (Gold et al., 1997) was used to assess working memory. Participants heard a mixed sequence of letters and numbers and were asked to repeat the numbers in ascending order followed by the letters in alphabetical order. Sequence length increased across trials. The outcome variable was the total number of correctly recalled sequences.

2.2.3.2.5 Verbal learning. The California Verbal Learning Test – Second Edition (CVLT-II; Delis et al., 2000) measured verbal learning and memory. Participants heard a list of words over five trials and were asked to recall as many words from the list as possible after each trial. Participants then heard a new list of words and were asked to recall as many words as they could from the new list. Finally, participants were asked to recall as many words as they could from the initial list. The outcome variables were the total number of words correctly recalled as well as the total words recalled from the short delay trial.

2.2.3.3 n-back

We used the *n*-back task on Inquisit Web to examine working memory performance and perceived performance ratings. Participants were asked to indicate whether a number presented is the same as or different from a stimulus presented *n* trails before by pressing the 'A' key when the number matched the one presented *n* trials before and the 'L' key if the number did not match the one presented *n* trials before. For example, in a 1-back task in which the trials consist of numbers, participants were asked to decide whether the current number is the same as the letter

in trial *n* – 1. The *n*-back had three difficulty levels: *N* varies among 1, 2, and 3, allowing the assessment of performance across increasing working memory span. The primary outcome measure was d prime (i.e., *d'*), or the signal detection index, which was calculated as the ratio between the number of correct Target trials (i.e., "hits") and number of Non-Target trials (i.e., "false alarms"). *d'* provides a measure of the discrimination of target from nontarget when performing a task and was calculated for each condition of the *n*-back, with higher scores representing better working memory performance.

Participants completed 10 practice trials followed by a total of 98 experimental trials. In our version of the *n*-back, numbers were presented as stimuli for 500 ms followed by a delay period of 2500 ms, totaling 3000 ms per trial. Experimental trials had 33 targets, and 65 non-targets. If participants did not respond prior to the next stimulus presented, then no response was recorded. We used the 1- and 2-back levels of the n-back only as a recent meta-analysis found that the 1- and 2-back tasks are the most discriminatory between groups with depression and healthy controls and the 3-back appears to have a floor effect where individuals, regardless of group, have difficulty engaging with the cognitive load of this level (Nikolin et al., 2021).

Following each difficulty level of the *n*-back, participants were asked to self-report their subjective performance immediately following each level of the n-back, indicating what they believed their performance to be on a scale of 0-100%.

2.2.3.4 Interviews

2.2.3.4.1 Montgomery Åsberg Depression Rating Scale (MADRS; Montgomery & Åsberg, 1979).

The MADRS is a 10-item clinician administered symptom interview to assess depression symptom severity in the last week (apparent sadness, reported sadness, inner tension, reduced sleep, reduced appetite, concentration difficulties, lassitude, inability to feel, pessimistic

thoughts, and suicidal thoughts). Items are scored on a severity scale ranging from 0-6, resulting in a range of total score from 0 to 60, with total scores ranging from 0 to 60. Higher total scores indicate greater depressive symptom severity. Both the internal consistency (Cronbach's $\alpha = .85$; Kjaergaard et al., 2014) and interrater reliability ($r = .89$ - .97; Montgomery & Åsberg, 1979) are high.

2.2.3.4.2 The Longitudinal Interval Follow-up Evaluation – Range of Impaired Functioning Tool (LIFE-RIFT; Leon et al., 1999). The LIFE-RIFT is a brief, interviewer-rated measure to assess psychosocial functioning across four domains: work, interpersonal relationships, overall satisfaction, and recreational activities. The interview was administered by trained doctoral students in clinical psychology, or a trained research assistant and ratings were provided with anchors 0 (not applicable) to 6 (no information), with scores in the range 1-5 indicating severity. In order to generate a total score, the highest scores from each domain are summed together. Scores range from 4-20, and higher scores indicate greater functional impairment.

2.2.3.4.3 Mini-International Neuropsychiatric Interview (MINI; Sheehan et al., 1998). The MINI is a structured diagnostic psychiatric interview that assesses diagnoses according to the DSM-5 criteria. Trained doctoral students in clinical psychology and trained research assistants administered this interview to assess whether participants in the depression group currently met criteria for major depressive disorder and any other psychiatric disorders (dysthymia, bipolar disorder, panic disorder, agoraphobia, social phobia, generalized anxiety disorder, obsessive-compulsive disorder, posttraumatic stress disorder, alcohol and substance dependence and abuse, and psychotic disorders). Each module follows the diagnostic criteria for each disorder and begins with screening questions that are followed by a series of yes/no

questions in the module if the participant endorses the screening items. Inter-rater reliabilities for the MINI exceed .75, indicating strong reliability in MINI diagnoses across interviewers (Sheehan et al., 1997).

2.2.3.5 Self-Report Measures

2.2.3.5.1 Cognitive Complaints in Bipolar Disorder Rating Assessment (COBRA; Rosa at al., 2013). The COBRA is a 16-item self-report measure assessing perceived cognitive difficulties in everyday life across domains of attention, memory, and executive functioning. Participants indicate how often they experience an item on a 4-point Likert scale ranging from 0 (*Never*) to 3 (*Always*), scores were summed and higher total scores indicating greater subjective cognitive impairment. Although created for bipolar disorder, the scale has been validated for use in individuals with unipolar depression (Ott et al., 2015). The COBRA demonstrated excellent internal consistency in the present study (Cronbach's $\alpha = .92$).

2.2.3.5.2 Dysfunctional Attitudes Scale – Form A (DAS-A; Weissman & Beck, 1978). Participants completed the 40-item DAS indicating the degree to which they agree with negative and maladaptive beliefs (e.g., if I fail at my work, then I am a failure as a person). Items were rated on a 7-point scale from 1 (*Totally Disagree*) to 7 (*Totally Agree*); responses to positively worded items were reverse-coded and summed to generate a total score, with higher total scores indicate greater dysfunctional attitudes. Total scores range from 40 to 280. The DAS had good internal consistency in the present study (Cronbach's $\alpha = .87$).

2.2.3.5.3 Cognitive Motivation Scale (Tran et al., 2024). Participants completed a 20-item questionnaire with two subscales: cognitive approach (e.g., enjoyment and engagement with cognitive effort) and cognitive withdrawal (e.g., avoidance or distress related to cognitive tasks). Items were rated from 1 (*Strongly Disagree*) to 7 (*Strongly Agree*), and subscale scores were

calculated by averaging items from each corresponding subscale. Higher scores indicate a stronger tendency to either approach or withdraw from cognitively effort activities. The internal consistency was excellent for both the cognitive approach subscale (Cronbach's α = .92) and cognitive withdrawal subscale (Cronbach's α = .87).

2.2.3.5.4 Patient Health Questionnaire-9 (PHQ-9; Kroenke et al., 2001). Participants completed a nine item self-report measure based on the DSM diagnostic criteria for major depressive disorder. Participants were asked to rate how often they experienced each symptom over the past two weeks on a 4-point Likert scale ranging from 0 (*Not at All*) to 3 (*Nearly Everyday*). Scores were summed and total scores ranged from 0 to 27, with higher scores indicating greater depression symptom severity. The internal consistency for the PHQ-9 in the present study was excellent (Cronbach's α = .95).

2.3 Results

2.3.1 Statistical Analysis

All statistical analyses were performed using Statistical Package for the Social Sciences (SPSS Version 25). Data were inspected for normality (skew +/- 1.5, kurtosis +/- 3.0) and outliers prior to any statistical analysis. Data points falling 4 *SD*s or more above or below the mean on variables were Winsorized (Tukey, 1962). Specifically, each outlier above or below the mean was replaced with the next highest or lowest value plus or minus one data point. The Winsorized variables were inspected a second time for normality.

Raw scores for each of the cognitive measures for the MDD participants were converted into *z*-scores based on data derived from our healthy comparison participants. Each MDD participant's raw cognitive score was standardized by subtracting the healthy comparison group's mean and divided by the standard deviation of the healthy comparison group, resulting in a *z*-

score relative to the healthy comparison group. Composite cognitive scores were computed for working memory, verbal fluency, learning memory, executive functioning, and processing speed by averaging *z*-scores for the corresponding cognitive tests. A cognitive composite score was computed by averaging domain *z*-scores. Group differences in demographic data, self-reports, and objective and subjective cognition were explored using *t*-tests.

To examine the discrepancy between objective and subjective cognitive functions, discrepancy scores were computed following the approach described by Miskowiak et al. (2016). First, a global composite *z*-score was computed for each participant's objective cognitive performance based on the mean and standard deviation of the healthy control group. subjective cognitive impairment was assessed using the total score on the COBRA scale. Next, both the objective composite *z*-scores and COBRA scores were standardized to the same scale (*z*-scores), and the discrepancy score was calculated by subtracting the standardized objective cognitive score from the standardized subjective score. The discrepancy score represents the degree to which individuals' subjective reports of cognitive impairment align with their objectively measured cognitive performance. Scores were calculated across a global cognitive composite. Discrepancy scores ranged from -10 to +10, with positive values indicating greater subjective complaints relative to objective impairments (i.e., overestimation), negative values indicating better subjective reports than objective performance (i.e., underestimation), and scores near zero reflecting alignment between subjective and objective cognition. The discrepancy score was used as a continuous variable in regression and mediation analyses conducted within the MDD group only. The HC group was used to generate standardized objective cognitive scores; including them in analyses using the discrepancy score would violate statistical independence as their data were used to compute the metric.

Hypothesis 1a and 1b were tested using a hierarchical multiple regression. Hypothesis 2a and 2b were tested using a 2 (n-back level: 1-back, 2-back) x 2 (measure type: objective, subjective) x 2 (group: MDD, HC) mixed-model repeated-measures Multivariate Analysis of Variance (MANOVA), followed by one-way ANOVAs for follow-up comparisons. Hypothesis 3 was tested using mediation analysis with bootstrapping (10,000 samples) via Haye's (2013) PROCESS macro (Model 4).

2.3.2 Demographics

Demographic variables of the sample are presented in Table 2.1. The average age across both groups was 29 years old. Groups did not significantly differ on age, sex, gender, ethnicity, or neurocognitive composite score. Groups did differ significantly in educational attainment, occupational status, depressive symptoms, and perceived cognitive impairments. Clinical variables of the sample are presented in Table 2.2. Participants with depression reported significantly higher depressive symptoms and subjective complaints of cognitive ability than the healthy comparison group.

Table 2.1

Descriptive Characteristics of the Sample by Group

	MDD (n = 77)	HC (n = 75)	Statistic
Age M (SD)	29.58 (9.55)	29.59 (8.50)	$t(1, 150) = -.002$, $p = .999$
Sex n (%)			χ^2 (2, N = 152) = 1.16, $p = .56$
Male	19 (24.7%)	21 (28%)	
Female	57 (74%)	54 (72%)	
Prefer not to answer	1 (1.3%)	0 (0%)	
Gender n (%)			χ^2 (3, N = 152) = 6.97, $p = .073$
Man	17 (22.1%)	20 (26.7%)	
Woman	51 (66.2%)	54 (72%)	
Trans	2 (2.59%)	0 (0%)	
Non-binary	3 (3.89%)	1 (1.3%)	
Ethnicity n (%)			χ^2 (7, N = 152) = 9.47, $p = .22$
White	41 (53.2%)	35 (46.7%)	
Hispanic/Latino	1 (1.3%)	1 (1.3%)	
African	2 (2.6%)	0 (0%)	
Asian	17 (22.1%)	26 (22.1%)	
Middle Eastern	1 (1.3%)	1 (1.3%)	
Multiple identities selected	14 (18.2%)	7 (9.3%)	
Other	1 (1.3%)	4 (5.3%	
No answer	0 (0%)	1(1.3%)	
Education n (%)			χ^2 (4, N = 152) = 16.15, $p < .05$
High school	10 (13%)	1 (1.3%)	
College	15 (19.5%)	9 (12%)	
University	42 (54.5%)	40 (53.3%)	
Post-Graduate	8 (10.4%)	23 (30.7%)	
Other	2 (2.6%)	2 (2.7%)	
Occupation n (%)			χ^2 (6, N = 152) = 16.27, $p < .05$
Employed	32 (41.6%)	44 (58.7%)	
Unemployed	11 (14.3%)	2 (2.7%)	
Retired	0	2 (2.7%)	
Student	11 (14.3%)	14 (18.7%)	
Other	8 (10.4%)	1 (1.3%)	
Multiple selected	14 (18.2%)	11 (14.7%)	
No answer	1 (1.3%)	1 (1.3%)	

Table 2.2

Clinical Variables by Group

	MDD (n = 77)	HC (n = 75)	Statistic
Neurocognitive Composite Score *M* (SD)	-.12 (.60)	-.001 (.55)	$t(1, 150) = -1.25$, $p = .22$
Self-Reported Depressive Symptoms (PHQ-9) *M* (SD)	19.17 (4.25)	2.79 (3.59)	$t(1, 147.02) = 25.69$, $p < .001$
Self-Rated Cognitive Difficulties COBRA *M* (SD)	26.38 (7.66)	13.37 (7.85)	$t(1, 150) = 10.34$, $p < .001$
Dysfunctional Attitudes Scale *M* (SD)	109.90 (24.60)	84.01 (30.57)	$t(1, 150) = 5.76$, $p < .001$
Discrepancy Score *M* (SD)	0.15 (2.61)		
Clinician Assessed Depression Symptoms (MADRS) *M* (SD)	27.96 (6.14)		
Functioning (LIFE-RIFT) *M* (SD)	12.96 (2.58)		

2.3.4 Hypothesis 1a and 1b: Predictors of the Discrepancy Score

A hierarchical multiple regression analysis was conducted in the MDD group only to test hypothesis 1a and 1b in evaluating how dysfunctional attitudes and self-reported depression symptoms predict the discrepancy between objective and subjective cognitive ability. As shown in Table 2.3, Model 1 is significant and accounts for 5% of the variance in the discrepancy score. Depressive symptoms significantly predicted the discrepancy score, such that more severe depression symptoms were associated with greater overestimation of cognitive impairments.

In Model 2, scores from the Dysfunctional Attitudes Scale were added to the regression. As shown in Table 2.3, Model 2 was also significant and explained an additional 6% of the variance in discrepancy scores. In this model, only dysfunctional attitudes significantly predicted the discrepancy score, with higher scores on the Dysfunctional Attitudes Scale associated with greater overestimation of cognitive impairments.

Table 2.3

Regression Coefficients for Predictors of Overestimation of Cognitive Impairments in MDD Group

	b	SE	β	*t*	F(df)	R^2	Adjusted R^2	R^2 change
Model 1					4.37*	.05	.04	
Depression symptoms	.14	.07	.24	2.09*				
Model 2					4.67*	.11	.09	.06
Depression symptoms	.08	.07	.13	1.08				
Dysfunctional Attitudes	.03	.013	.26	2.81*				

*$p < .05$

2.3.5 Hypothesis 2a and 2b: Objective and Subjective Performance on the n-back

To test hypothesis 2a and 2b, a 2 (n-back level: 1-back, 2-back) x 2 (measure type: objective performance, subjective performance) x 2 (group: MDD, HC) mixed-model repeated-measures MANOVA was conducted to examine group differences in both objective performance accuracy (*d*') and subjective ratings of performance accuracy on the n-back. Measure type and n-back level were within-subjects factors, and group was a between-subjects factor. We explored whether patterns of change in performance and perceived performance across task difficulty differed between groups.

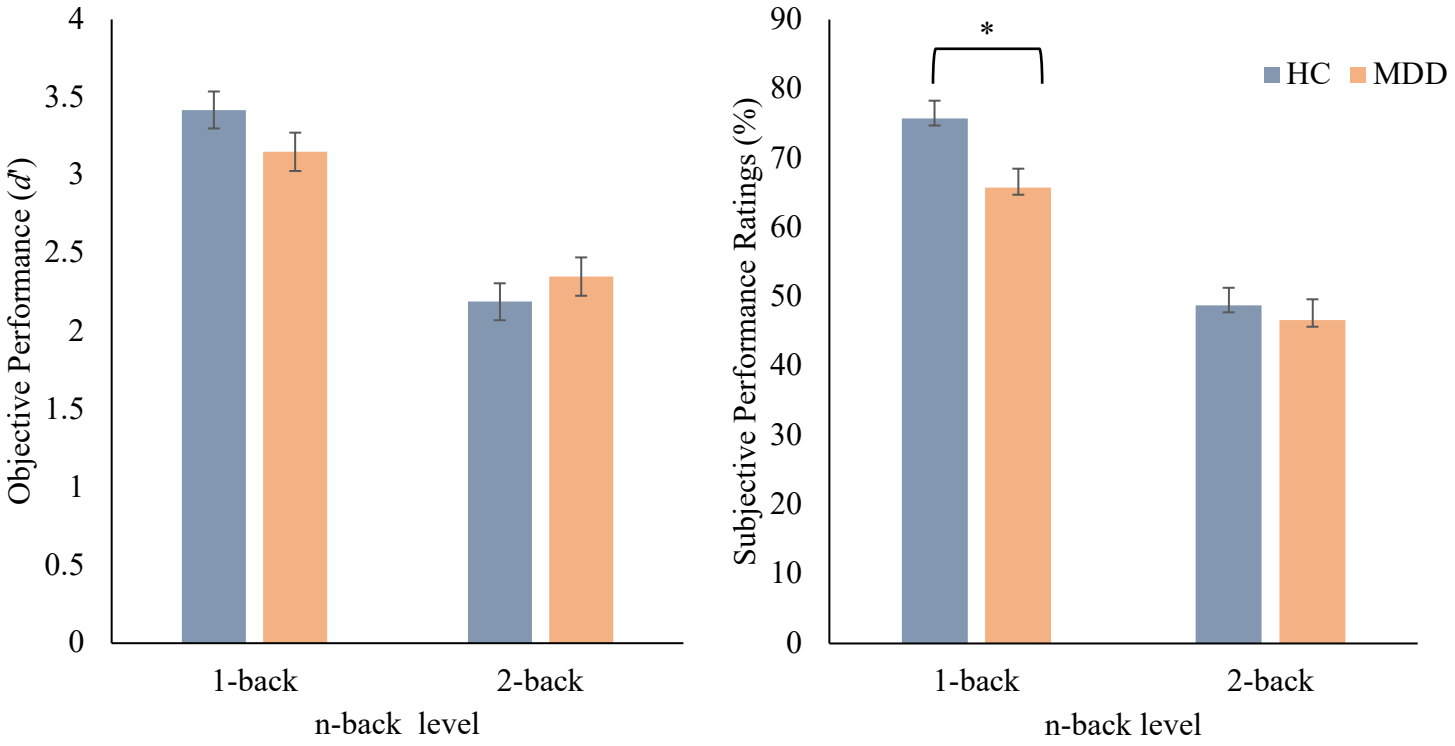
There was a significant main effect of n-back level on objective performance accuracy, $F(1, 148) = 164.42$, $p < .001$, partial $\eta^2 = .53$, indicating that all participants performed better on the 1-back ($M = 3.29$, $SD = 1.06$) than on the 2-back ($M = 2.27$, $SD = 1.05$). There was also a significant main effect of n-back level on subjective ratings of performance, $F(1, 148) = 1146.00$, $p < .001$, partial $\eta^2 = .89$, indicating that all participants perceived their performance as higher on the 1-back ($M = 70.60$, $SD = 23.82$) than on the 2-back ($M = 47.89$, $SD = 23.99$).

There was a significant interaction between objective performance and group, $F(1, 148) = 4.85$, $p = .029$, partial $\eta^2 = .032$. There was a significant interaction between objective performance accuracy and subjective views of performance, $F(1, 148) = 150.13$, $p < .001$, partial $\eta^2 = .50$. There was not a significant interaction between subjective views of performance and group interaction, $F(1, 148) = 3.60$, $p = .060$, partial $\eta^2 = .024$.

The three-way interaction exploring objective performance accuracy, subjective views of performance, and group performance was significant, $F(1, 148) = 4.24$, $p = .041$, partial $\eta^2 = .028$ (see Figure 2.1). To test hypothesis 2a and 2b exploring group differences on subjective views of performance (hypothesis 2a) and objective performance (hypothesis 2b), the significant interaction was followed up by four one-way ANOVAs to compare groups on objective and subjective performance accuracy. On the 1-back, the MDD group ($M = 3.15$, $SD = 1.08$) did not perform significantly differently from HC group ($M = 3.42$, $SD = 1.02$) on objective performance accuracy, $F(1, 148) = 2.45$, $p = .12$, partial $\eta^2 = .02$. Similarly on the 2-back, the MDD group ($M = 2.35$, $SD = 1.06$) did not perform significantly differently from HC group ($M = 2.19$, $SD = 1.03$) on objective performance accuracy, $F(1, 148) = .88$, $p = .35$, partial $\eta^2 = .006$. In terms of subjective performance accuracy on the 1-back, the MDD group ($M = 65.73$, $SD = 24.06$) estimated their performance to be significantly lower than the HC group ($M = 75.72$, $SD = 22.32$), $F(1, 148) = 7.04$, $p = .009$, partial $\eta^2 = .045$. On subjective performance accuracy on the 2-back, the MDD group ($M = 46.69$, $SD = 25.77$) subjective performance estimates were not different from the HC group ($M = 48.77$, $SD = 22.04$), $F(1, 148) = .29$, $p = .59$, partial $\eta^2 = .002$.

Figure 2.1

Group Comparisons of Objective Performance and Perceived Performance on the 1- and 2-back



Note. Objective (left) and perceived performance (right) on the 1- and 2-back tasks by group (HC = healthy control, MDD = major depressive disorder). Error bars represent standard error.

*$p < .05$.

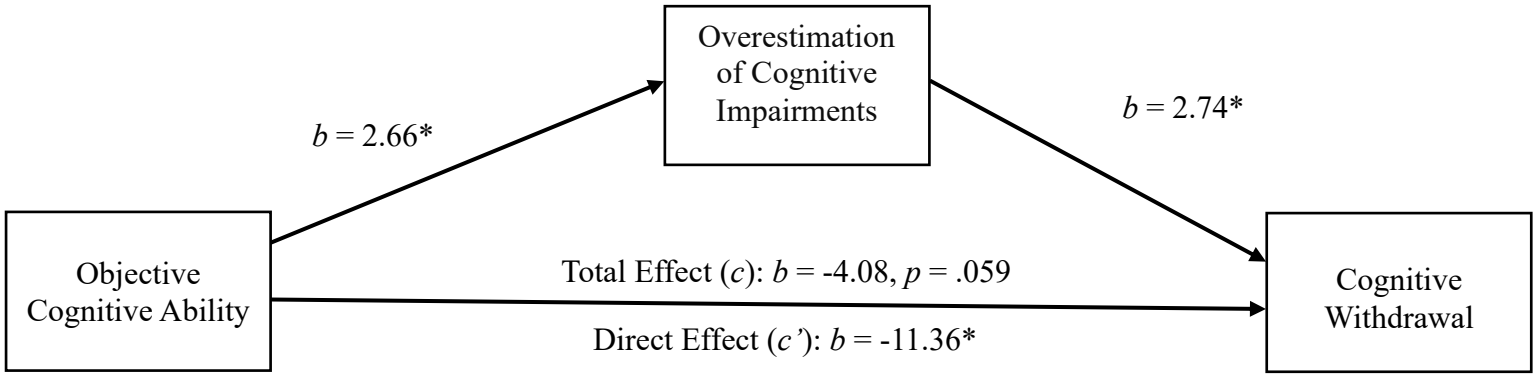
2.3.6 Hypothesis 3: Mediation Model of Objective Cognition, Discrepancy Score, and Withdrawal

We conducted a simple mediation analysis using Model 4 from Hayes's (2013) PROCESS macro for SPSS to test hypothesis 3. Lower objective cognitive ability predicted greater cognitive withdrawal independent of discrepancy scores, $b = -4.08$, $t(75) = -1.92$, $p = .059$, indicating a trend-level effect. When controlling for this objective and subjective discrepancy score, participants with lower objective cognitive ability had significantly greater

withdrawal from cognitive activities in daily life, b = -11.36, $t(75)$ = -4.89, p <.001. Participants with higher objective cognitive ability had a significantly higher overestimation of their cognitive impairments, b = 2.66, $t(75)$ = 6.66, p < .001. We also found that a higher overestimation of cognitive impairments was significantly associated with greater withdrawal from cognitive activities in daily life when controlling for objective cognitive ability, b = 2.74, $t(75)$ = 5.14, p <.001. A bias-corrected bootstrap confidence interval for the indirect effect (b = 7.28) based on 10,000 bootstrap samples was entirely above zero (4.00 to 11.28) indicating a significant indirect effect.

Figure 2.2

Mediation Model of the relationship between Objective Cognitive Ability and Cognitive Withdrawal as mediated by Overestimation of Cognitive Impairments in MDD



Note. Unstandardized betas (b) shown in image. **p < .001

2.4 Discussion

An emerging literature base has explored various aspects of cognition in depression, including objective cognitive abilities as assessed using traditional cognitive assessment tools, as well as subjective views of cognitive abilities. It is widely accepted that individuals with depression experience challenges with cognition and tend to overestimate cognitive impairments. Our understanding of objective and subjective cognitive functioning has begun shifting to

understand that while these concepts are not typically related to one another, they both represent important domains to explore in depression due to their implications for functioning and recurrence of depressive illness. The current study is one of the first to explore predictors of the overestimation of cognitive impairment using two different approaches, and possible implications of the discrepancy between objective and subjective cognition in a currently depressed sample. We found that our participants with depression tended to overestimate their cognitive impairments subjectively relative to objective measures of cognition. This overestimation of cognitive impairment was predicted by depression symptom severity and dysfunctional attitudes. Further, despite no significant differences in objective performance on the n-back, our MDD group significantly underestimated their performance on the easiest difficulty level of this task as compared to healthy controls. Finally, we found that the discrepancy score assessing the difference between subjective and objective cognitive ability significantly mediated the relationship between objective cognitive ability and withdrawal from cognitive challenge in daily life.

The tendency to overestimate cognitive impairment may be a distinct feature of depression and our results suggest that it is related to depression symptom severity and dysfunctional attitudes, or negative self-evaluation. Typically, dysfunctional attitudes are beliefs about the self, world, and future (e.g., “I often think I’m not good at anything”). Beck’s (1976) cognitive theory proposes that individuals with depression have a bias to negatively view themselves and the world around them, and our results are in line with this where we may see individuals hold more negative attitudes towards themselves, and thus underestimate their cognitive abilities. Our findings are in line with past research that has demonstrated that depressive thought content is related to worse performance on cognitive tasks (Yapici-Eser et al.,

2023), and relationships between dysfunctional attitudes, depressive symptoms, cognition, and real-world functioning (Wood-Ross et al., 2022). We add to this limited literature base as our findings suggest that individuals with depression tend to overestimate the degree to which they are cognitively impaired, and this overestimation is related to both depression symptom severity and beliefs about oneself. As dysfunctional attitudes are thoughts to be a trait feature of depression, clinicians and researchers may consider how these may confer a risk for overestimating impairments in depression.

Consistent with previous research (Dunn et al., 2007; Wood-Ross et al., 2020) we found that the depression group significantly underestimated performance compared to healthy controls at the easiest level of the n-back, despite no significant differences in performance between groups. It is possible that the initial perceived challenge of the n-back task in our depression group resulted in an activation of the dysfunctional attitudes as described above and resulted in an underestimation of ability to complete the task. Previous research has explored perceived challenge on the n-back and found that individuals with current depression perceived the 1- and 2-back to be more difficult than healthy controls, however, the groups did not differ in ratings of task difficulty significantly at the 3- and 4-back (Seidman et al., 2023). Additionally, individuals with current depression rated the 1-back as requiring more effort than controls, but the groups did not differ significantly in ratings of cognitive effort required to complete the n-back at the 2-, 3-, and 4-back (Seidman et al., 2023). Thus, it is possible the moderate and high cognitive load levels of the n-back are perceived as effortful and challenging for all individuals, regardless of diagnostic group, and that the initial perception of challenge on the task is more salient for individuals with current depression.

Contrary to hypotheses, at a more challenging level of the n-back, the MDD group did not perform significantly worse than healthy controls. A recent meta-analysis found that individuals with depression tend to perform significantly worse than controls at all levels of cognitive load of the n-back (1-, 2-, and 3-back; Nikolin et al., 2021a). However, Nikolin and colleagues (2021a) also found that there was a high level of heterogeneity between studies, in particular for the 2-back. Indeed, some studies have not found a significant difference in performance on the n-back between individuals with depression and healthy controls (Gärtner et al., 2018; Matsuo et al., 2007; Nikolin et al., 2021b). Interestingly, these studies utilized neuroimaging techniques and found that the depression groups demonstrated engagement of additional neural resources to maintain performance accuracy similar to controls. Taken together, it is possible that individuals with depression might have to engage additional effort and neural resources to perform at levels comparable to healthy controls on the n-back. Future research may consider utilizing neuroimaging tools alongside complex tasks to continue exploring how intact performance accuracy on tasks like the n-back is achievable in MDD groups.

Our study is among the first to explore the relationships between objective cognition, the overestimation of subjective cognitive impairments relative to objective cognition, and withdrawal from cognitive challenge in a sample of individuals with major depression. Consistent with previous research that has highlighted the importance of underestimating ability and subsequent withdrawal from cognitive challenge in daily life (Morey-Nase et al., 2019), our findings suggest that the tendency to overestimate cognitive impairments may have an impact on how individuals with depression engage with cognitive challenge in the world and what tasks they choose to engage in or withdraw from. Importantly, our results demonstrate that this finding

is not only relevant for those with objective impairments, but broadly for those with depression who overestimate their cognitive impairments.

It is possible that the tendency to overestimate cognitive impairments may perpetuate disengagement from cognitively stimulating activates, which could lead to broader cognitive decline and relatedly, functional impairments. Indeed, researchers have demonstrated that engaging in a less stimulating cognitive environment is related to worsening cognition (Hanushek et al., 2025). Emerging psychological therapies, such as Action Based Cognitive Remediation (ABCR), have begun to target the avoidance of cognitive effort through therapist guided exploration of metacognitive processes combined with cognitive training principles in severe mental illness including major depressive disorder (Bowie et al., 2017). Importantly, individuals who received ABCR as compared to traditional cognitive remediation techniques had higher perceived competence to complete cognitively challenging tasks and improved functioning following treatment (Bowie et al., 2017). Interventions targeting engagement in cognitively stimulating daily activities have shown improvements in measures of age-related cognitive decline as well as improved subjective ratings of cognitive performance for older individuals (Raji et al., 2025; Tesky et al., 2011). Thus, future research should seek to apply therapeutic techniques to increase engagement in cognitively stimulating activities to explore whether the same positive effects from these treatments in older adults translates to individuals experiencing depression. Additionally, researchers may seek to explore how subjectively overestimating cognitive impairments relates to cognitive decline longitudinally in younger individuals with depression.

2.4.1 Implications

Traditionally, researchers have shown that there is a low concordance between subjective and objective cognition in individuals with major depressive disorder (Lahr et al., 2007; Petersen et al., 2019; Schwert et al., 2018; Svendsen et al., 2012). Our study results highlight subjective ratings of cognition as a distinct and important component of depression that should not be disregarded as part of the depressive process. When engaging in an easy version of a cognitive task, individuals with depression rated that they performed worse than healthy controls, despite no objective impairments in performance. In considering how this may translate daily life, it is possible that depressed individuals perceive tasks as more challenging than their actual demands, and this could result in higher likelihood or more rapid disengagement from tasks that are perceived as difficult. In line with this hypothesized cycle, we found a relationship between overestimating cognitive impairment and withdrawal from everyday activities that are cognitively challenging. Clinicians and researchers may seek to identify individuals most likely to misjudge their abilities in order to guide interventions that target not just cognitive impairments, but also self-perceptions of ability. Emerging cognitive remediation treatments (e.g., ABCR; Bowie et al., 2017) incorporate therapeutic techniques to target these types of metacognitive processes. Clinicians and researchers may also consider applying treatment techniques from cognitive behavioural therapy, like behavioural experiments, to help individuals with depression challenge maladaptive beliefs about their ability to engage in cognitive challenge and test these beliefs in their daily lives. Future research may consider using novel assessment tools, such as ecological momentary assessment, to explore how cognition and perceptions of cognitive ability manifest in a more ecologically valid context to help uncover the implications of these phenomenon in the daily lives of individuals experiencing depression.

2.4.2 Limitations

Study results should be interpreted in the context of limitations. Participants tended to be well-educated which may limit generalizability of findings across other samples. Depressive symptoms were in the moderate range for the depressed group, however cognitive ability in the depression group was in the average range overall, indicating that the majority of our depression group on average was not cognitively impaired relative to our healthy comparison group. Future research should explore these research questions across a more symptomatic and functionally and cognitively impaired sample. Finally, our study was cross-sectional, limiting our ability to understand causality. Future research should aim to pursue ideas related to cognition and subjective functioning in a longitudinal and more ecologically valid study, exploring how subjective views of cognitive ability fluctuate as depressive symptoms fluctuate, including using tools like ecological momentary assessment.

2.4.3 Conclusion

The present study was one of the first to explore the relationships between features of depression with the discrepancy between subjective and objective cognition, and to explore implications for withdrawal from cognitive challenge. Our findings provide evidence for consideration of subjective perceptions of cognition as a distinct feature of depression that are important to consider, even in the absence of objective deficits. Additionally, we found dysfunctional attitudes were related to the tendency to overestimate cognitive impairments, suggesting a relationship between depressive thinking patterns and perceptions of ability. Furthermore, we found that the tendency to overestimate cognitive impairments was related to withdrawal from cognitive challenge in the daily life. Overall, our results add to the limited literature base in depression expanding on what the implications of overestimating cognitive

impairments are and provide preliminary evidence that the tendency to overestimate cognitive impairments subjectively relative to objective measures of cognition may be an important mechanism to explore in understanding disability in depression, and a target for future research and treatment of major depressive disorder.

Chapter 3

Negative Affect and Subjective Cognition as Predictors of Momentary Cognitive Performance in MDD

3.1 Introduction

Traditional measures of cognition demonstrate that individuals with depression experience deficits in domains such as attention, memory, processing speed, and executive functioning (Ahern & Semkovska, 2017; Bora et al., 2013; Lee et al., 2012; Rock et al., 2014). These cognitive impairments are a predictor of functional disability (Buist-Bouwman et al., 2008; Jaeger et al., 2006; Matcham et al., 2022; Morey-Nase et al., 2019; McIntyre et al., 2013). However, the experience of those with depression suggests their perception of their cognitive impairments is greater in severity than what is measured using traditional cognitive assessment tools (Lahr et al., 2007; Petersen et al., 2019; Schwert et al., 2018; Svendsen et al., 2012). Recent literature proposes that subjective cognitive impairments are a distinct and clinically meaningful dimension of depression (Allott et al., 2025). In depression, limited research to date has explored whether cognitive performance, symptom severity, and perceived impairments in cognitive abilities fluctuate across contexts and time. Our most commonly used assessment tools at present do not allow us to readily capture these changes and fluctuations to explore how these constructs relate to one another. This paper aims to explore how cognitive performance may fluctuate in individuals experiencing major depressive disorder as compared to healthy comparison participants with symptoms and perceived performance using novel tools, including experience sampling methods (ESM).

3.1.1 Traditional Assessment Tools

Traditional standardized neuropsychological tests provide an estimate of cognitive ability in a controlled laboratory setting. Paper and pencil cognitive tests are the most common assessment tools used by clinical neuropsychologists in North America (Rabin et al., 2016) and allow us to assess and characterize an individual's cognitive profile at a given time point. However, they also have limitations, including infrequent collection of cognitive testing data, limiting our ability to detect changes in cognition that may occur within or across days, limited ecological and predictive validity (Spooner & Pachana, 2006), and high cost for use (Harris et al., 2024). Additionally, traditional assessment tools allow us to obtain a snapshot of an individual's cognitive functioning under ideal conditions, in a highly controlled environment without auditory, visual, or other disruptions, raising questions about the ecologically validity of traditional cognitive assessment procedures and tools.

3.1.2 Experience Sampling Methods

An emerging literature base demonstrates the utility of ESM to assess cognition. In ESM designs, participants are prompted with surveys to their mobile devices, typically multiple times per day, within a naturalistic context (Shiffman et al., 2008), allowing researchers to examine variables across a variety of contexts. Cognitive performance may fluctuate in daily life in relation to stress, fatigue, environmental distractions, and circadian rhythms (Metternich et al., 2008; Schmidt et al., 2007). Using ESM methods to capture cognition allows us to explore how these state-dependent factors are associated with cognitive performance in real-world contexts and allow for the exploration of how cognitive performance fluctuates across time points and what factors might be related to these fluctuations (e.g., mood, fatigue; Small et al., 2019). Preliminary research demonstrates that ESM cognitive tasks are reliable assessments of

cognition (Sliwinski et al., 2018) and can capture subtle fluctuations in performance on cognitive tasks over time and with context (Öhman et al., 2021; Harris et al., 2024; Schmitter-Edgecombe et al., 2020; Small et al., 2019). However, to date, fluctuations in cognitive performance have not been explored using ESM with individuals experiencing major depressive disorder.

3.1.3 Cognition and Depression

Cross-sectionally in laboratory settings, depressive symptom severity is associated with greater cognitive impairments (Douglas & Porter, 2009; Gorwood et al., 2008). While measures of depression symptom severity can capture trait-like symptom patterns over the course of a week or two, measuring momentary affect may allow us to assess emotional states in real-time that fluctuate throughout the course of the day (Myin-Germeys et al., 2018; Peeters et al., 2003; Schoevers et al., 2020). Compared to healthy comparison participants, participants with depression have significant instability in negative affect (Crowe et al., 2019; Koval et al., 2013; Schoevers et al., 2020). In a non-clinical sample of younger adults, higher negative affect was associated with lower working memory performance over the course of 100 days (Brose et al., 2012). Taken together, ESM may offer a unique opportunity to eliminate the retrospective assessments that are not able to account for current affect levels (Vanags & Raščevska, 2021). However, there is currently a gap in the literature exploring how affect fluctuations relate to cognitive performance in major depressive disorder.

Individuals with depression tend to subjectively overestimate the degree to which they experience cognitive impairment (Lahr et al., 2007; Petersen et al., 2019; Schwert et al., 2018; Svendsen et al., 2012), and underestimate their performance on cognitive tasks as compared to their objective performance accuracy (Wood-Ross et al., 2020), which both occur as a function of depression symptom severity (Petersen et al., 2019; Sawada et al., 2019; Serra-Blasco et al.,

2019; Srisurapanont et al., 2015). Much of the research gathered in perceived cognitive performance and subjective cognition is collected cross-sectionally and limited research to date has explored how perceived performance estimates relate to objective performance accuracy on cognitive tasks using ESM. Furthermore, little is known about the interaction between perceived performance accuracy and negative affect on objective performance accuracy in individuals currently experiencing an episode of depression.

3.1.4 The Current Study

This study aimed to explore the relationships among negative affect, perceived performance on cognitive tasks, and objective cognitive performance both in the context of everyday life using ESM. We recruited community-dwelling participants with a diagnosis of major depressive disorder who were currently in an episode of depression at the time of a baseline assessment, along with age and gender matched healthy comparison participants from the community. Participants completed 15 days of ESM surveys four times per day during which they were asked to self-report current affect, complete two cognitive tasks, and to report their perceived performance immediately following each cognitive task. We hypothesized that concurrent ratings of affect would be related to cognitive performance, such that higher ratings of negative affect would be associated with lower performance on ESM cognitive tasks in participants experiencing depression only. We also hypothesized that lower perceptions of performance accuracy on the cognitive tasks would be associated with higher ratings of negative affect in individuals experiencing depression only.

3.2 Methods

3.2.1 Participants

Seventy-seven participants with a diagnosis of MDD in a current episode and 75 healthy comparison participants completed the study. Participants all lived in Ontario, Canada and were recruited from the community through online advertisements, posters, and the Queen's University Psychology Participant Pool. MDD participants were also recruited from an outpatient mood disorders clinic. All healthy comparison participants were matched for age and sex to the MDD group. All participants completed a phone screening conducted by a trained bachelor's level research assistant or graduate student. Inclusion criteria for both groups were English-speaking, aged 18-65 years of age, normal or corrected vision and hearing, and had access to a computer with a webcam and mobile device with internet connection. Inclusion criteria for the MDD sample included experiencing a current episode of depression, with at least two previous episodes, as individuals who experience two or more episodes of depression are thought to be phenotypically different from those who experience a single lifetime episode of depression (Roca et al., 2011). Current depression status was determined based on a phone screening interview at the time of recruitment developed in the Mood Laboratory at Queen's University (see Appendix C for screening module used). All healthy comparison participants were screened using the Mini International Neuropsychiatric Interview (Sheehan et al., 1998) to assess whether criteria were met for any current or previous psychiatric illness. Participants were excluded if they had the presence of a medical diagnosis that is associated with known cognitive impairments, diagnosis of a bipolar disorder, psychotic disorder, and/or substance or alcohol use disorder. We obtained written informed consent from all participants.

3.2.2 Procedures

Participants completed a baseline study appointment where they were trained on the use of the ESM application, mEMA created by ilumivu (ilumivu, 2024), and guided through the download and installation process on their smartphone. Participants were given a chance to practice and informed of barriers to participation (e.g., to not respond when driving). During instruction, participants were asked to indicate times that they would not be able to answer. Participants were instructed to begin the next day and provided with contact information for questions. Compliance was monitored daily, and a prewritten email prompt was sent to participants who missed two consecutive days of prompts reminding them to complete the ESM prompts.

Participants were prompted four times throughout the day for 15 days. At each survey prompt, participants were first asked to report their current context, second to complete self-reports of current depressive symptoms and affective states, third to complete the spatial span task followed by self-reported perceived performance of spatial span, and then finally to complete the n-back followed by self-reported perceived performance of n-back. Prompts were adjusted to the sleep window of participants: approximately 1 hour after usual wake time, 3 hours after, 7 hours after, and 12 hours after usual wake time (e.g., around the hours of 9am, 12pm, 4pm, and 9pm). The timing appeared quasi-random to participants to reduce the anticipation of prompts. The ESM procedures were estimated to take approximately 5 minutes to respond. Following a prompt, participants had one hour to respond to the survey before it was closed. During the one-hour survey window, participants were sent three reminders to complete the survey. There was up to 60 responses per participant on ESM procedures. Participants were

compensated $1 per prompt completed at the end of the 15-day period, for a possible total of $60.

3.2.3 Measures

3.2.3.1 Experience Sampling Methods

3.2.3.1.1 Daily activities. At each prompted survey, participants were asked to respond to a series of questions about the current context they were in and recent experiences. They were first asked where they were located (i.e., at home or out of the house) and how many people they were with. Based on their response of if they were at home or not at home, participants were provided with different options on what they were currently doing. Responses about what participants were doing was categorized into cognitively stimulating activities, passive leisure activities, physical activity, social activity, and other activity (Campbell et al., 2020).

3.2.3.1.2 Depression symptoms. At each prompted survey, participants were asked to respond on a Likert scale for five questions about depressed mood. Participants were asked four questions about the two core symptoms of depression, sadness and anhedonia, by reporting what their mood was (i.e., "I feel sad right now", "I feel hope for the future right now"), to rate their anhedonia (i.e., "I feel interested in things or am able to experience pleasure right now", "I feel unmotivated right now"), and also to rate their current cognitive complaints (i.e., "I am experiencing difficulty with concentration right now") on five separate scales ranging from "not at all" to "very much", rated from 1 to 7.

3.2.3.1.3 Affect. At each prompted survey, participants were asked to rate their current affect on eight items in total: four assessing positive affect (*happy, relaxed, interested, enjoying myself;* e.g., *"Please indicate how happy you are right now"*) and six assessing negative affect (*irritated, down, anxious, tense, ashamed, guilty;* e.g., *"Please indicate how down you are right*

now"). Participants were asked to respond on a Likert scale for questions about affect in the present moment on a 7-point Likert scale ranging from 1 (*not at all*) to 7 (*very much*). These items were selected based on prior ESM studies of affect in MDD (Crowe et al., 2019; Peeters et al., 2006). For each survey response, positive and negative affect scores were calculated by summing the four respective items, resulting in two separate scores per prompt: one for positive affect and one for negative affect.

3.2.3.1.4 Cognitive tasks. Experience sampling methods (ESM) cognitive tasks similar to those used here have exhibit excellent reliability and convergent validity with traditional neuropsychological instruments (Sliwinski et al., 2018). We chose to use working memory tasks as it is a domain shown to be among the most frequently impaired in MDD (Semkovska et al., 2019).

3.2.3.1.4.1 n-back. This continuous working memory task (Gevins & Cutillo, 1993) requires participants to indicate whether a stimulus presented is the same as or different from a stimulus presented *n* trials before. For the ESM portion of this study, we developed a 2-back task as this has been shown to be most sensitive in detecting differences between participants with MDD and HC (Nikolin et al., 2021a). During our n-back, participated were asked to indicate whether the current number is the same as the number presented two trials before. Numbers ranged from 1-9 and the stimuli presented at each prompt were randomized to reduce practice effects. Participants completed 35 trials of the task at each prompt. Stimuli were presented for 2000 ms in the centre of the screen and participants were given 500 ms to respond yes or no to indicate if the current stimuli had been presented two trials before. If participants did not respond within the 500 ms, this was recorded as no response. The outcome measure was total number of correct targets identified. Due to the limited number of trials, we did not compute d prime (*d'*) as

the outcome variable; *d'* requires a sufficient number of trials to produce stable and interpretable estimates (Stanislaw & Todorov, 1999) as it compares hits and false alarm rates. With only 35 trials in our ecological version of the task, if participants had few or no false alarms or misses, this would render *d'* values unreliable or undefined. Literature has shown that stable signal detection metrics typically require larger trial counts to minimize floor and ceiling effects (Hautus, 1995; Macmillian & Creelman, 2005).

3.2.3.1.4.2 Spatial Span. We designed the ESM version of this after the Corsi Block Tapping task (Corsi, 1972). Participants were presented with an array of blue squares at each trial, varying in number of squares at each trial. The blocks were illuminated for 500 ms in yellow at a rate of one second per block. The total number of blocks highlighted was randomized to either be 3, 5, or 7. The order of blocks illuminated at each survey prompt was also randomized to reduce practice effects. Participants were instructed to tap the blocks that were illuminated in the backwards order from what they were presented immediately after the final block is no longer highlighted. Participants had 10 seconds to respond and then were moved on to the next trial. Participants were presented with twelve trials at each prompt. The total number of trials with correct responses, trials where participants tapped all of the correct blocks in the correct sequence, was the outcome variable.

Perceived performance. Following completion of each ESM cognitive task, participants were asked to indicate what percentage, from 0-100%, of the trials on each of the cognitive tasks they believe that they got correct.

3.2.4 Statistical Analysis

Each participant completed up to 60 data points (i.e., four prompts per day for 15 days), only those who completed at least 20 ESM prompts were included in the analyses (*n* MDD group

= 54, *n* HC group = 61; see Table 3.1 for demographic information). Compliance thresholds of 20 out of 60 ESM prompts completed, or 33%, was pre-determined as inclusion criteria for analysis based on criteria used commonly in ESM literature (e.g., Myin-Germeys et al., 2009; Palmier-Claus et al., 2011; Verhagen et al., 2017). An a priori power analysis estimated a 75% completion rate of phone surveys (see Colombo et al., 2019 for a review in MDD and Wrzus & Neubauer, 2022 for a general review), for an estimated total of 45 prompts per participant, and we estimated that we would be able to achieve 80% power with a medium effect size with 115 participants in each group (Kleinman Lab, 2021).

Affect and Perceived Performance Accuracy were group-mean centred (Raudenbush & Byrk 2002). Missing data were handled with the maximum likelihood robust (MLR) estimator, which provides unbiased parameter estimates under the assumption that data are missing at random and is robust to non-normality (Yuan & Bentler, 2000). We ran two multilevel models to predict objective performance accuracy on the two cognitive tasks: n-back (Model 1) and Spatial Span (Model 2). Time, or ESM prompt number, was included as a Level 1 predictor and linearly coded with the first ESM prompt (i.e., Time 1) equal to 0, allowing us to control for the effect of completing the cognitive tasks multiple times (i.e., practice effect). At Level 1, negative affect, perceived performance, and their interaction predicted objective performance accuracy on each cognitive task. At Level 2, group (dummy-coded such that MDD = 0 and HC = 1) predicted objective performance accuracy, and the slopes of negative affect, perceived performance, and their interaction, allowing us to examine if the slopes differed between groups.

3.2.4.1 Equations

Level 1

Objective Cognitive Performance < -- b_{0j} + b_{1j}(Negative Affect) + b_{2j}(Perceived Performance) + b_{3j}(Negative Affect*Perceived Performance) + b_4(Time)$_{ij}$ + error$_{ij}$

Level 2

b_{0j} < -- γ_{00} + γ_{01}(Group)$_j$ + u_{0j}

b_{1j} < -- γ_{10} + γ_{11}(Group)$_j$ + u_{1j}

b_{2j} < -- γ_{20} + γ_{21}(Group)$_j$ + u_{2j}

b_{3j} < -- γ_{30} + γ_{31}(Group)$_j$ + u_{3j}

3.3 Results

3.3.1 Demographic Characteristics

The sample consisted of 54 individuals with a diagnosis of MDD who were experiencing a major depressive episode at the start of the ESM study period, as well as 61 HC. The average age of the MDD group was approximately 31 years old, and the HC group was approximately 29 years old. Groups did not differ significantly on age, sex, gender, or employment status. Groups differed significantly in ethnicity and education attainment. For detailed demographic information and descriptive statistics please see Table 3.1.

Table 3.1

Descriptive Characteristics of the Sample by Group

	MDD (*n* = 54))	HC (*n* = 61)	Statistic
Age *M* (*SD)*	31.77 (9.90)	29.39 (8.28)	$t(1, 103.80) = 1.38$, $p = .17$
Sex *n* (%)			χ^2 (2, N = 115) = 1.9, $p = .55$
Male	14 (25.9%)	15 (24.6%)	
Female	39 (72.2%)	46 (75.4%)	
Prefer not to answer	1 (1.9%)	0 (0%)	
Gender *n* (%)			χ^2 (3, N = 115) = 3.84, $p = .28$
Man	13 (24.1%)	14 (23%)	
Woman	36 (66.7%)	46 (75.4%)	
Trans	2 (3.7%)	0 (0%)	
Non-binary	3 (5.6%)	1 (1.6%)	
Ethnicity *n* (%)			χ^2 (7, N = 115) = 14.44, $p = .044$
White	33 (61.1%)	26 (42.6%)	
Hispanic/Latino	0 (0%)	1 (1.6%)	
African	2 (3.7 %)	0 (0%)	
Asian	9 (29 %)	22 (36.1%)	
Multiple identities selected	10 (18.5 %)	7 (41.2%)	
Other	0 (0 %)	4 (6.55%)	
No answer	0 (0%)	1 (1.6%)	
Education *n* (%)			χ^2 (4, N = 115) = 10.50, $p = .033$
High school	7 (13%)	1 (1.6%)	
College	11 (20.4%)	6 (9.8%)	
University	26 (48.1%)	34 (55.7%)	
Post-Graduate	8 (14.8%)	18 (29.5%)	
Other	2 (3.7%)	2 (3.3%)	
Employment status *n* (%)			χ^2 (6, N = 115) = 9.23, $p = .161$
Employed	27 (50%)	34 (55.7%)	
Unemployed	8 (14.8%)	2 (3.3%)	
Retired	0 (0 %)	2 (3.3%)	
Student	7 (13%)	11 (18%)	
Other	4 (7.4%)	1 (1.6%)	
Multiple selected	7 (13%)	10 (16.4%)	
No answer	1 (1.9%)	1 (1 (1.6%)	

Participants showed good compliance with the EMA protocol. Participants with MDD completed between 21 and 60 prompts ($M = 42.34$, $SD = 11.23$), with an average compliance of 70.57%. Participants in the HC group completed between 21 and 60 prompts ($M = 44.46$, $SD = 10.65$), with an average compliance of 74.1%. The MDD group had significantly higher average

negative affect than the HC group. Groups did not differ significantly on compliance (i.e., the number of prompts completed), average perceptions of performance accuracy on either cognitive task, or average objective performance accuracy on spatial span. The MDD group average objective performance accuracy on the n-back across the ESM period was marginally better than the HC group. For descriptive statistics and group comparisons on ESM prompt data see Table 3.2.

Table 3.2

Descriptive Characteristics of ESM Prompts

	MDD (n = 54)	HC (n = 61)	Statistic
Compliance *M* (*SD)*	42.34 (11.23)	44.46 (10.65)	$t(1, 113) = -1.023$, $p = .31$
Negative Affect *M* (*SD)*	21.95 (5.71)	11.87 (5.57)	$t(1, 113) = 9.84$, $p < .001$
Subjective Performance Accuracy *M* (*SD)*			
Spatial Span	39.54 (18.52)	42.90 (20.95)	$t(1, 113) = -.89$, $p = .37$
n-back	58.56 (22.55)	58.41 (25.67)	$t(1, 113) = .035$, $p = .97$
Objective Performance Accuracy *M* (*SD)*			
Spatial Span	45.47(14.58)	43.04(19.98)	$t(1, 109.19) = .75$, $p = .46$
n-back	84.49(14.29)	77.56(23.15)	$t(1, 101.53) = 1.94$, $p = .06$

3.3.2 Preliminary Analyses

Preliminary analyses were run in Statistical Package for the Social Sciences (SPSS Version 25; IBM Corp., 2019) to obtain descriptive statistics and correlations at both the between- and within-individual level.

To assess whether negative affect changed significantly over the ESM study period, and whether this differed between groups, we ran a multilevel model with time predicting negative affect at Level 1, and Group at Level 2 predicting the intercept of negative affect and the affect-time slope. Group predicted the intercept, and the MDD group had significantly higher average negative affect than HC, $b = 21.58$, $SE = .71$, $p < .001$. Group did not predict the slope of

negative affect, b = .013, SE = .019, p = .50, indicating no significant change in affect in either group across the study period. The time slope overall was not significant, b = .024, SE = .014, p = .096, suggesting no significant effect across the study period.

All participants in the depression group were recruited while in an episode of major depression, and because depression is an episodic illness, we wanted to assess whether self-reported depressive symptoms changed significantly across the ESM window in the MDD group. We ran a multilevel model with time predicting depressive symptoms at Level 1. We did not find that depression symptoms changed significantly across the 15-day EMA window, b = .011, SE = .006, p = .08.

We ran correlations between negative affect, perceived performance, and objective performance accuracy across both cognitive tasks in participants with depression only (see Table 3.3), healthy comparison participants only (see Table 3.4), and all participants together (see Table 3.5) at the between and within level. Notably, at the within level, higher negative affect was significantly associated with lower perceptions of performance on both cognitive tasks in each group, as well as in the whole sample, but was not related to objective performance accuracy. Additionally, higher perceptions of performance were significantly associated with objective performance accuracy in each group and the whole sample. At the between level, negative affect was not significantly associated with perceptions of performance in the MDD group or the HC group, however the relationships were significant in the entire sample. Negative affect was not related to objective performance accuracy. In each group and in the whole sample, perceived performance was associated with actual performance on both cognitive tasks.

Table 3.3.

Within- and Between-Individual Associations of MDD participants Momentary Affect, Perceived Performance, and Objective Performance.

Variable	1	2	3	4	5
1. Negative Affect	1	.05	-.09	.02	-.09
2. Perceived Performance Spatial Span	-.14***	1	.70***	.33*	.22
3. Perceived Performance n-back	-.09**	.24***	1	.34**	.41**
4. Spatial Span Accuracy	-.02	.31***	.20***	1	.69***
5. n-back Accuracy	-.02	.07	.54***	.22***	1

Note. Between-individual correlations are shown above the diagonal; within-individual correlations are shown below the diagonal. $N = 54$. *$p < .05$, **$p < .01$, ***$p < .001$

Table 3.4

Within- and Between-Individual Associations of HC participants Momentary Affect, Perceived Performance, and Objective Performance.

Variable	1	2	3	4	5
1. Negative Affect	1	-.25	-.24	-.16	-.22
2. Perceived Performance Spatial Span	-.09*	1	.63***	.50***	.06
3. Perceived Performance n-back	-.09**	.34***	1	.52***	.40**
4. Spatial Span Accuracy	-.01	.35***	.23***	1	.56***
5. n-back Accuracy	-.05	.14***	.54***	.22***	1

Note. Between-individual correlations are shown above the diagonal; within-individual correlations are shown below the diagonal. $N = 61$. *$p < .05$, **$p < .01$, ***$p < .001$

Table 3.5.

Within- and Between-Individual Associations in all participants Momentary Affect, Perceived Performance, and Objective Performance.

Variable	1	2	3	4	5
1. Negative Affect	1	-.19*	-.18*	-.08	-.07
2. Perceived Performance Spatial Span	-.12***	1	.67***	.42***	.01
3. Perceived Performance n-back	-.09***	.29***	1	.44***	.39***
4. Spatial Span Accuracy	-.01	.33***	.21***	1	.61***
5. n-back Accuracy	-.03	.12***	.54***	.22***	1

Note. Between-individual correlations are shown above the diagonal; within-individual correlations are shown below the diagonal. $N = 115$. *$p < .05$, **$p < .01$, ***$p < .001$

3.3.3 Multilevel Models

The intraclass correlation (ICC) is a way to measure the appropriateness of a multilevel modelling approach to data. In our models, we were evaluating the amount of variance in cognitive performance that is within and between individuals. The cut-off indicating appropriateness for multilevel modelling is an ICC larger than .10 (Bolger & Laurenceau, 2013) and suggests that the dependent variable varies at both the within and between levels. The ICC for the spatial span model was .605, which indicated that 60.5% of variability in cognitive performance was due to between person differences, and that up to 39.5% of the variance could be explained by differences within participants across prompts. In the n-back model, the ICC was .657, indicating 65.7% of variability in cognitive performance was due to between person differences, and up to 34.3% could be explained by differences within participants across prompts.

Results for all multilevel models can be found in Table 3.6. We ran two separate models for each cognitive task, n-back (Model 1) and spatial span (Model 2). In both models, the negative affect slope was significant, indicating that higher negative affect predicted better objective performance accuracy, suggesting that individuals performed better on the cognitive tasks when negative affect was elevated, contrary to hypotheses. Similarly, the perceived performance slope was significant, indicating that higher perceived performance predicted better objective performance accuracy, suggesting that when participants self-reported that they were performing well, they also had better performance on both cognitive tasks. The interaction between negative affect and perceived performance on objective performance accuracy was not significant, suggesting that the relationship between perceived and objective performance accuracy on the n-back did not change as a function of affect. Notably, these effects were significant above and beyond the effect of Time, which we controlled for in our model by including a Time-Negative Affect slope at Level 1.

At Level 2, we tested whether group status (MDD vs. HC) predicted average performance on the cognitive tasks and predicted the Level 1 slopes. Group did not significantly predict the intercept, indicating no overall difference in average objective performance accuracy between participants with MDD and HC. Additionally, group did not significantly predict the slope of negative affect, suggesting that the relationship between negative affect and objective performance did not differ across the groups. Further, group did not significantly predict the slope of perceived performance, indicating that the relationship between perceived performance and objective performance accuracy on both tasks did not differ between participants with MDD and HC. Finally, group did not significantly predict the interaction between negative affect and perceived performance.

Table 3.6

Multilevel Model Results

Model	Level	Effect	*b*(SE)	*p*	LL CI/UL CI
Model 1 (n-back)	**Level 1**	**Objective n-back Performance Accuracy Intercept (b_0)**	**83.15(1.93)**	**< .001**	**79.98, 86.33**
	Level 1	**Objective n-back Performance Accuracy ← Negative Affect (b_1)**	**.077(.038)**	**.043**	**.014, .14**
	Level 1	**Objective n-back Performance Accuracy ← Perceived Performance Accuracy (b_2)**	**.35(.027)**	**< .001**	**.305, .40**
	Level 1	Objective n-back Performance Accuracy ← Negative Affect*Perceived Performance Accuracy (b_3)	.00(.004)	.919	-.007, .006
	Level 1	Objective n-back Performance Accuracy ← Time (b_4)	.009(.018)	.61	-.02, .038
	Level 2	b_0 ← Group	-2.40(2.88)	.405	-7.13, 2.34
	Level 2	b_1 ← Group	-.059(.056)	.291	-.152, .033
	Level 2	b_2 ← Group	.028(.04)	.481	-.037, .093
	Level 2	b_3 ← Group	.008(.005)	.156	-.001, .017
Model 2 (Spatial Span)		**Objective Spatial Span Performance Accuracy Intercept (b_0)**	**45.47(1.83)**	**< .001**	**42.47, 48.48**
	Level 1	**Objective Spatial Span Performance Accuracy ← Negative Affect (b_1)**	**.086(.043)**	**.047**	**.015, .16**
	Level 1	**Objective Spatial Span Performance Accuracy ← Perceived Performance Accuracy (b_2)**	**.296(.029)**	**< .001**	**.25, .34**

Level 1	Objective Spatial Span Performance Accuracy ← Negative Affect*Perceived Performance Accuracy (b_3)	.002(.003)	.45	-.003, .007
Level 1	Objective Spatial Span Performance Accuracy ← Time (b_4)	.017(.016)	.288	-.009, .044
Level 2	b_0 ← Group	-.034(2.76)	.99	-4.58, 4.51
Level 2	b_1 ← Group	-.011(.086)	.902	-.15, .13
Level 2	b_2 ← Group	.02(.04)	.621	-.046, .086
Level 2	b_3 ← Group	-.004(.005)	.471	-.012, .005

Note. *SE*: standard error; LL CI: lower-level 95% confidence intervals; UL CI: upper-level 95% confidence intervals. Betas are unstandardized. Significant effects are bolded.

3.5 Discussion

We aimed to understand the relationships between momentary affect, perceived performance accuracy, and objective performance accuracy on two cognitive tasks in a sample of individuals experiencing MDD and healthy comparison participants. We used an experience-sampling design and found that, contrary to hypotheses, higher negative affect was significantly associated with better performance on both cognitive tasks in both groups. Also in contrast to hypotheses, we found that perceived performance on the cognitive tasks was significantly associated with objective performance accuracy in both groups, such that if participants self-reported that they performed well on the cognitive tasks, this was associated with higher objective performance accuracy. Finally, contrary to hypotheses, we did not find that there were any significant differences between participants with depression and healthy comparison participants in the patterns of relationships of negative affect and perceived performance with objective performance accuracy.

To our knowledge, this is the first study to assess cognitive ability using ESM in individuals currently experiencing depression. Our findings are in contrast with previous literature demonstrating that deficits across multiple domains of cognition, including working memory, are a core feature of depression when assessed with traditional laboratory-based measures of cognitive ability (Bora et al., 2013; Lee et al., 2012; Rock et al., 2014; Semkovska et al., 2019). However, the magnitude of cognitive impairment tends to be variable in depression (see Parkinson et al., 2020 for a meta-analysis). In order to better understand the discrepancies shown in cognition in depression literature, we used two mobile-administered working memory tasks that we designed to obtain a more ecologically valid assessment of cognitive functioning. Research has shown that ESM-based assessments can provide insights into day-to-day fluctuations and subtle changes in cognition that single-timepoint assessments often miss (Moore et al., 2017; Crawford et al., 2022). As we are one of the first studies to implement the use of ESM cognitive tasks in depression, future research should examine whether similar results emerge using other ESM cognitive tasks and domains.

Our average compliance rates were 70.57% in the depression group and 74.1% in the control group, which are consistent with compliance rates in other ESM studies assessing cognition, with compliance averages ranging from 71-80% (Daniéls et al., 2020; Lancaster et al., 2020). A meta-analysis of nearly 500 articles reported that across various ESM study designs found an average compliance of 79% (Wrzus & Neubauer, 2022). Our results are consistent with a more recent study which found currently depressed participants were less likely than never-depressed controls to respond to ESM survey prompts (Seidman et al., 2022). The use of ESM to assess cognition is an evolving literature area, however limited research has explored ESM

compliance in the context of cognition and depression and researchers should continue to explore compliance rates in currently depressed populations.

The finding that higher negative affect was associated with better cognitive performance in our multilevel models was surprising. As this is a novel research area, literature has not yet tested the associations of negative affect and cognition in depression using ESM. We based our hypotheses on literature that demonstrates that higher depressive symptoms are associated with lower cognitive performance in depression (Douglas & Porter, 2009; Gorwood et al., 2008). Negative affect is related to depressive symptoms (Crowe et al., 2019; Koval et al., 2013; Schoevers et al., 2020) and has demonstrated variability across time (Myin-Germeys et al., 2018; Peeters et al., 2003; Schoevers et al., 2020). The few studies that have explored the relationship between affect and cognition using ESM have mixed findings, with some studies demonstrating higher negative affect is associated with worse cognitive performance (Brose et al., 2012; Fittipaldi et al., 2024; Neubauer et al., 2019; Riediger et al., 2011), and others demonstrating that negative affect is related to improved cognitive performance (Bomyea et al., 2021; Yitzhak et al., 2023).

Experiencing negative affect has been shown to promote a focus on immediate tasks, rather than a more global focus which tends to be associated with increased positive affect (Schwarz & Clore, 1983), and higher negative affect is associated with increased analytic thinking (Gabel & McAuley, 2022). Thus, a higher negative affective state may be associated with better performance on cognitive tasks under specific circumstances. As the literature exploring how affect relates to cognitive performance in ESM in depression is scarce, the pattern of the relationships between momentary negative affect and cognition in depression remains

unclear. Much of the literature base focuses on healthy individuals, and continued research is needed to explore these dynamic relationships in individuals experiencing depression.

We found that participants were generally accurate in estimating their performance on both cognitive tasks, with better self-perceived performance corresponding to better objective task accuracy. This finding contrasts with our hypotheses which were based on several in person, cross-sectional cognitive assessment studies, where individuals with depression tend to overestimate the degree of their cognitive impairments (Lahr et al., 2007; Petersen et al., 2019; Schwert et al., 2018; Svendsen et al., 2012). One possible explanation for our contrasting results may be that perceived cognitive abilities are typically assessed retrospectively, relying on a recall across a broad range of contexts and domains, which may be impacted by the tendency to have an overgeneral memory that is common in depression (e.g., "I always fail at things"; Williams et al., 2007). Indeed, a recent ESM study found that participants reported more frequent memory lapses when retrospective recall was used as compared to daily reports using ESM (Mogle et al., 2022). Taken together, it is possible that the short recall period in our ESM tasks may have allowed for a more accurate self-appraisal, though more research is needed to determine whether this pattern of results replicates across other samples and tasks.

3.5.1 Implications

Our finding that perceived performance aligned with objective performance accuracy during ESM tasks suggests that individuals with depression may have greater metacognitive accuracy during brief, low-demand cognitive tasks. While these results are in contrast with research emphasizing the tendency to overestimate cognitive impairments in depression (e.g., Lahr et al., 2007; Schwert et al., 2018), our findings highlight the potential importance of context and task duration when evaluating metacognitive insight. Individuals with depression might be

more effective at capturing accurate self-perceptions of ability in ESM contexts as compared to traditional trait-based measures that rely on retrospective recall, are completed with an examiner present, occur after longer assessments in a sterile/formal environment, which could activate negatively biased cognitions in depression. Clinicians and researchers may consider employing real-time assessment of moods and self-perceptions in therapeutic interventions to help challenge overgeneralized negative appraisals to potentially foster more accurate meta-cognitive insight.

Additionally, the variability that we observed in cognitive performance within individuals highlights the potential value of assessing cognition under more ecologically valid conditions using ESM tools. In contrast to longer traditional laboratory-based cognitive assessments, our results suggest that briefer, repeated measures of cognition may be particularly useful in capturing dynamic patterns of cognitive fluctuations. Future research should explore whether similar patterns emerge across other cognitive domains, and whether task difficulty, duration, or environmental context influence objective and perceived performance.

Finally, the finding that higher negative affect was associated with better cognitive performance has implications for understanding how affective states can enhance, not just impair, cognitive functioning under certain conditions. Future studies should examine the conditions under which negative affect enhances or impairs cognitive performance in depression. This could have potential implications for treatment models and psychoeducation in understanding how dynamic affective states can impact individuals in several ways.

3.5.2 Limitations

Our sample was highly educated, which may limit generalizability outside of this demographic. We excluded participants with a compliance of less than 33%, thus resulting in lower power to detect cross-level interactions. Participants who stayed engaged across the study

period and were included in analysis may have different characteristics than those who did not comply with the ESM procedures. Future research should aim to recruit a larger sample and to explore if different patterns emerge between groups, or whether the same pattern of results emerge. Additionally, our participants with MDD were recruited from diverse settings; while this may better represent the homogenous symptom presentation of the disorder, a sample with predominantly more severe cognitive and symptom presentations in inpatient or outpatient clinical settings might produce alternate findings. Finally, as with any ESM study, we had several design choices that may limit our conclusions. Both of our cognitive tasks assessed working memory which may not fully generalize to other cognitive domains. Future research should continue to explore the utility of using ESM to assess how other domains known to be impaired in depression relate to affect over time.

Chapter 4

General Discussion

4.1 Summary of Findings

The present studies aimed to expand on the existing literature base exploring factors associated with underestimating cognitive ability, what the consequences of underestimation are, and to examine how cognition, affect, and perceptions of ability manifest in daily life for individuals who are depressed. Across two related studies, this work highlights the importance of exploring appraisals of ability in depression, even if these are discrepant from objective ability, and points to the potential utility of novel ESM cognitive tasks for exploring these constructs in those who are depressed.

In Chapter 2, traditional assessment tools were used with individuals with depression and healthy comparison participants to assess objective cognitive ability, subjective views of cognition, and symptoms. We found that individuals with depression overestimated the degree to which they experience cognitive impairments as compared to objective assessments of cognitive ability, and that depressive symptoms and dysfunctional attitudes predicted the degree to which individuals overestimate their cognitive impairment. We also found that individuals with depression underestimated their performance relative to healthy comparison participants on the easiest level of a cognitive task, despite not having any objective performance deficits relative to healthy comparison participants. Finally, we found that in individuals with depression, overestimating cognitive impairment significantly mediated the relationship between objective cognitive ability and withdrawal from cognitive challenge in daily life, pointing to a potential real-world consequence of underestimating one's abilities. The results from this study highlight the importance of assessing and addressing perceptions of cognitive ability in those with

depression and suggest that even within a sample that was on average not objectively impaired on a brief, traditional cognitive battery, they may withdraw from cognitive challenge.

Chapter 3 introduced novel ecological momentary assessment tasks that I designed to assess how objective cognitive performance varies over time, and to explore how this variance is related to affect and perceived performance. Contrary to hypotheses, we did not find significant differences between our depression and healthy comparison groups in objective cognitive performance, or in how affect and perceived performance related to objective cognitive performance. We found that higher negative affect was related to better cognitive performance in both groups, which was in contrast with our hypotheses. Finally, participants were accurate at perceiving their performance; a finding that held regardless of current affective state, also contrary to hypotheses. Results from this study contribute preliminary data to the sparse literature on how cognition manifests in daily life for those with depression and the potential differential relationships of affect and perceived performance from what we know from laboratory cross-sectional studies. The findings from Chapter 3 were not in the direction we expected and require some consideration of whether using novel methods to assess these constructs in depression have a different pattern of results from laboratory-based assessments.

4.2 Theoretical and Research Implications

Our contrasting results in Chapter 2 and Chapter 3 highlight important considerations for future research in measurement of cognition and perceived cognitive abilities in depression. Cross-sectional laboratory-based studies demonstrate a replicable pattern of overestimation of cognitive impairments in individuals with depression (Lahr et al., 2007; Petersen et al., 2019; Schwert et al., 2018; Svendsen et al., 2012). Our results in Chapter 2 replicated these cross-sectional laboratory-based studies. We found that individuals with depression overestimated their

cognitive impairments on a brief battery that covered domains of working memory, executive functioning, processing speed, verbal learning, and verbal fluency. This overestimation was predicted by depressive symptoms and dysfunctional attitudes. However, contrasting with these results, in Chapter 3 we found that participant's perceptions of their performance were aligned with objective performance on brief working memory tasks using ESM. Our results suggest that when assessing perceptions of cognitive ability in cross-sectional laboratory-based settings, individuals with depression tend to overestimate their cognitive impairments, whereas they may be accurate in assessing their cognitive ability when using brief ESM surveys to assess cognitive performance. This study is one of the first to explore perceptions of performance in an ESM context in depression.

A recent ESM study explored differences in retrospective recall of memory lapses and in-the-moment assessment of memory lapses using ESM (Mogle et al., 2022). The authors found that when using retrospective assessments, participants recalled memory lapses significantly more than when using ESM tools to assess daily memory lapses (Mogle et al., 2022). Our commonly used tools to assess subjective cognitive abilities require participants to recall their cognitive abilities broadly, which can result in reporting the worst or most recent difficulties with cognition resulting in a biased estimate of cognitive ability (Costa & Fardell et al., 2019). Indeed, participants with depression have negative biases that can impact retrospective recall and self-report measures (Williams et al., 2007). Taken together, the brief nature of ESM tasks to assess an experience in the moment may help us to understand the discrepancies in results across Chapter 2 and 3. As this is a novel research area, we contribute preliminary data to our understanding of perceptions of ability in depression using different methodology. More research is needed to understand how perceptions of ability manifest in the context of daily life and

researchers may consider exploring in under what conditions participants with depression are able to accurately perceive performance using real-time assessments.

The finding that higher negative affect was associated with better objective cognitive performance was contrary to our initial hypotheses. While cross-sectional and laboratory-based literature has demonstrated that higher negative affect in depression is associated with worse cognitive ability (Rock et al., 2014; Snyder et al., 2013), the literature using ESM is limited and the findings are mixed. Some ESM studies demonstrate that higher negative affect is associated with worse cognitive performance (Brose et al., 2012; Neubauer et al., 2019; Riediger et al., 2011), whereas others found that negative affect is associated with better cognitive performance (Bomyea et al., 2021; Veal et al., 2023; Yitzhak et al., 2023). We based the majority of our hypotheses on data that was collected in laboratory settings, which may have a different pattern of results than those found in ESM studies. For example, Veal and colleagues (2023) found that in women with breast-cancer, higher self-reports of negative affect (i.e., fatigue and depressed mood) were associated with better performance on an ESM processing speed task, contrasting with their in-person testing results demonstrating that higher fatigue and depressive symptoms were associated with worse processing speed and visuospatial skills (Veal et al., 2023). Differences in the assessment contexts and methodology may reveal that cognitive performance in the moment might be a function of the dynamics of both mood state and context. For example, in traditional assessment contexts there is an examiner present, and the testing occurs over longer periods in a formal environment, which could possibly activate more depressive beliefs and hinder performance. As this is an emerging literature area, future research should continue to investigate how momentary affect and its fluctuations relate to cognitive performance in

depression and explore the conditions under which affect may help or hinder cognitive performance.

Our results that greater overestimation of cognitive impairments mediated the relationship between lower objective cognitive ability and greater withdrawal from cognitive challenge in everyday life highlights potential research implications for examining the long-term consequences of withdrawal from cognitive challenge in depression. Much of our understanding of withdrawal from cognitively stimulating activities and the resulting cognitive decline comes research in older adults (Hanushek et al., 2025; Wenzel et al., 2024). The "use it or lose it" framework is often a helpful consideration in these studies, whereby the more individuals withdraw from cognitively stimulating environments, the more cognitive skills decline (Hultsch et al., 1999; Hanushek et al., 2025; Small et al., 2012). At present, limited research has explored whether a pattern of disengagement from a cognitively stimulating environment results in longer-term cognitive decline in younger individuals with depression. Future research may seek to explore these questions in longitudinal studies in individuals with depression. Additionally, as the literature demonstrates that functional disability persists despite improvements in depression symptom severity (Adler et al., 2006; Kennedy et al., 2007), researchers may also seek to explore whether cognitive withdrawal is a mediator of long-term functional impairment in depression.

Finally, the results in Chapter 3 highlight the potential for future research on the utility of exploring within-person variation in cognitive functioning. In Chapter 3, we found that 34-40% of variance in cognitive task performance occurred within participants over the study period, indicating that cognitive performance fluctuated over time and was not a stable, trait-like ability. Cognitive deficits in depression are commonly thought of as a trait feature of the disorder (Conradi et al., 2011; Hammar et al., 2011; Hasselbalch et al., 2011). Research has begun

characterizing cognitive deficits in depression using a within person approach, demonstrating that when measuring cognitive functioning with traditional tools relative to premorbid estimates of cognitive functioning, 62.2% of the sample was classified as impaired, as compared to only 25% when using traditional assessment tools alone (Tran et al., 2021). Taken together, complimenting traditional assessment tools that capture cognitive ability at a given time point with ESM tools may allow us to explore how cognitive performance fluctuates over time and in specific contexts. Future research should explore how momentary factors, such as activated depressive schemas, may interfere with an individual's resources needed to perform well on cognitive tasks.

4.3 Clinical Implications

Our findings across both studies have implications for interventions that target cognitive impairments and self-perceptions in major depressive disorder. Cognitive remediation treatments are the gold standard treatment for cognitive complaints in major mental disorders; they aim to improve cognition through drill-and-practice techniques and discussion of strategy use (Bowie et al., 2020). While cognitive remediation has demonstrated evidence for improving cognitive abilities in depression (Goldberg et al., 2023; Legemaat et al., 2021), there is less evidence for the translation of improvement of cognitive abilities to everyday functioning (Legemaat et al., 2021; McGurk et al., 2007). In sum, this suggests that interventions need to treat not only cognitive impairments themselves, but also individual's beliefs about their abilities. For example, results from Chapter 2 demonstrated that individuals with depression underestimate their cognitive ability, even in the absence of objective deficits, pointing to metacognitive beliefs as a target in cognitive remediation. Clinicians may consider incorporating self-ratings of performance after cognitive training trials, and then review objective performance accuracy with

patients to help build a more accurate analysis of performance over time. Moreover, clinicians could also work with patients to explore under what conditions they notice cognitive ability fluctuate, and to build awareness of these fluctuations as part of a normative process that is not necessarily indicative of a permanent deficit.

Our results from Chapter 2 may also have implications for how beliefs of individuals with depression can impact their approach of challenge. We found that greater underestimation of cognitive ability relates to higher withdrawal cognitive in daily life. Thus, if an individual doubts their ability to engage in cognitively demanding activities (e.g., I need to submit paperwork for my insurance claim, but I'll get it wrong or leave something out; it's too confusing), this may have behavioural consequences, including withdrawing from of cognitive challenge (e.g., delaying submitting the claim, asking someone else to do it, avoiding submitting at all). Cognitive remediation treatments may consider incorporating behavioural activation home practice where patients are encouraged to approach cognitive challenge throughout the week and track outcomes in real-time. Using real-time tracking may reduce the tendency to negatively recall past events that can occur in depression (Williams et al., 2007). Emerging cognitive remediation treatments incorporate many of these proposed metacognitive approaches, including Action Based Cognitive Remediation (ABCR). A randomized control trial exploring ABCR outcomes to traditional cognitive remediation found that patients who participated in ABCR had greater functional outcomes and higher perceived competence to approach cognitive challenge than those in traditional cognitive remediation (Bowie et al., 2017). Thus, clinicians may consider combining approaches from cognitive behavioural therapy with cognitive remediation to help patients with depression challenge negative perceptions of ability and approach cognitive challenge in the real-world.

In clinical settings where applying cognitive remediation treatment approaches is not available, clinicians may still consider using cognitive behavioural therapy principles to encourage the approach of cognitive challenge in daily life. For example, clinicians may explore the automatic thoughts and underlying assumptions patients have about their ability to approach a specific challenging task (e.g., if I try to get groceries, I'll become overwhelmed and won't be able to cope). Clinicians could work with patients to design a series of behavioural experiments to help patients gradually engage with a challenging task and record outcomes (e.g., starting with making a grocery list, then going to the store to purchase a small list of items). As depression is associated with functional disability that often persists into periods of remission (Kennedy et al., 2007; Lam et al., 2014), targeting mechanisms that interfere with functioning may help those recovering from depression to attain functional recovery.

Lastly, clinicians may consider applying tools like ESM to assess experiences of symptoms in daily life. When patients attend appointments, clinicians tend to assess symptoms over the last week or several weeks through the use of questionnaires, symptom interviews, or verbal check ins where patients try to recall their experiences. However, this method of assessment might not capture fluctuations experienced throughout a day, and more continuous recording throughout the day might be helpful to obtain a more accurate measurement of a patient's experiences. Emerging studies are exploring the use of ESM to monitor outcomes throughout treatment (Moore et al., 2016; Quadackers et al., 2025). Moore et al., 2016 found that patients who that tracked symptoms using ESM had more changes in mindfulness, depression, and anxiety symptoms following a mindfulness-bases stress reduction treatment. Incorporating tools like ESM could allow clinicians to review symptoms that are reported in real time to capture the emotional experience throughout the day, and to eliminate the tendency for depressed

individuals to engage in a retrospective bias in recalling symptoms and experiences. Clinicians may consider working with patients to explore how affect dynamics play out throughout the week, and how these relate to the context of everyday life.

4.4 Limitations

Our sample had several characteristics that may limit the generalizability of our findings. First, our sample of individuals with depression had a relatively mild degree of cognitive impairment, which may limit how our findings generalize to individuals with more pronounced cognitive deficits. Additionally, participants across both studies were highly educated and recruitment was mainly through self-referral in the community. As a result, we may have recruited a high functioning sample that was interested in a cognitively demanding research study. Participants who sought out participation in this type of study may have more positive attitudes towards cognitive challenge, and this may not be representative of individuals who experience more pronounced deficits in cognition or negative beliefs about their cognitive abilities. Samples with more severe cognitive impairments and symptom presentations recruited through inpatient or outpatient clinical settings may have a different pattern of results.

Participants in our healthy comparison group were assessed to screen for any past or current psychiatric disorders. Only participants who did not meet criteria for current or past psychiatric disorders were enrolled as healthy comparison participants. This type of control group may limit of our understanding of how individuals experiencing depression compare to the general population, including those with other mental health diagnoses. For example, future research may explore how individuals with a primary anxiety disorder compare to individuals with a primary mood disorder to explore how perceptions of one's ability in different psychiatric conditions relate to engagement with cognitive challenge.

In Chapter 3, we excluded participants who had compliance rates below 33%, resulting in a relatively small sample size. This likely impacted our statistical power to detect small effects and cross-level effects. As effect sizes in cognition literature in depression tend to be small to medium (Rock et al., 2014; Synder et al., 2013), we may have been underpowered to detect small effects, especially cross-level effects looking at how our groups differed on our Level 1 variables. Future research should continue to explore within- and between-group effects in cognition in depression with larger sample sizes.

Finally, the brief design of our ESM surveys meant that our cognitive tasks had fewer trials than typical cognitive assessments. As a result, we were able to obtain a sample of cognitive performance at each survey, however, the limited number of trials may have limited our ability to detect small effects.

4.5 Conclusions

Depression is a multifaceted condition characterized by impairments in neurocognition and negative thought patterns. This dissertation aimed to explore how different features of depression relate to neurocognitive functioning using both traditional assessments and assessment in daily life. We also examined the consequences of negative thought patterns for withdrawal from cognitive challenge. Our results highlight the importance of assessing subjective perceptions of cognitive ability, which may be present even in the absence of objective impairment and are related to withdrawal from cognitive challenge in daily life. We also found a different pattern of results emerged when assessing these constructs using brief phone surveys in daily life, where participants accurately perceived their cognitive performance and performed better when they were experiencing higher of negative affect. There is a need for

further research to examine the long-term consequences of these patterns in depression and how features of depression relate to cognitive functioning when it is measured in daily life.

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Appendix A:

Research Ethics Board Approval

Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (HSREB)

HSREB Initial Ethics Clearance

July 12, 2022

Miss Chelsea Wood-Ross
Department of Psychology
Queen's University

TRAQ #: 6035034
Department Code: PSYC-256-21
Study Title: "PSYC-256-21: Cognition in Major Depressive Disorder: Investigating Variation Over Time and Associations with Depressive Symptoms"
Co-Investigators/Supervisor: Mrs. Tammy Vanrooy, Ms. Stephanie Woolridge, Dr. Christopher R Bowie
Review Type: Delegated
Date Ethics Clearance Issued: July 12, 2022
Ethics Clearance Expiry Date: July 12, 2023

Dear Miss Wood-Ross:

The Queen's University Health Sciences & Affiliated Teaching Hospitals Research Ethics Board (HSREB) has reviewed the application and granted ethics clearance for this study as of the date noted above.

Document Name	Comments	Version Date
Letter of Information/Consent Form (combined document)	MDD LOI/Consent	2022/06/27
Letter of Information/Consent Form (combined document)	HC LOI/Consent	2022/06/27
Other document	Example of master log of participant IDs	2022/07/11
Questionnaire	Case report form version 2	2022/06/20
Confidentiality Agreement	Confidentiality agreement version 2	2022/06/19
Debriefing Form/Letter	Debrief form version 2	2022/06/19
Recruitment Letter/Email/Notice/Poster	Email session confirmation version 2	2022/06/19
Recruitment Letter/Email/Notice/Poster	Email response	2021/10/25
Recruitment Letter/Email/Notice/Poster	MDD phone script	2021/10/25
Recruitment Letter/Email/Notice/Poster	HC recruitment flyer	2021/10/25
Recruitment Letter/Email/Notice/Poster	MDD group recruitment flyer	2021/10/25
Recruitment Letter/Email/Notice/Poster	HC phone script	2021/10/25

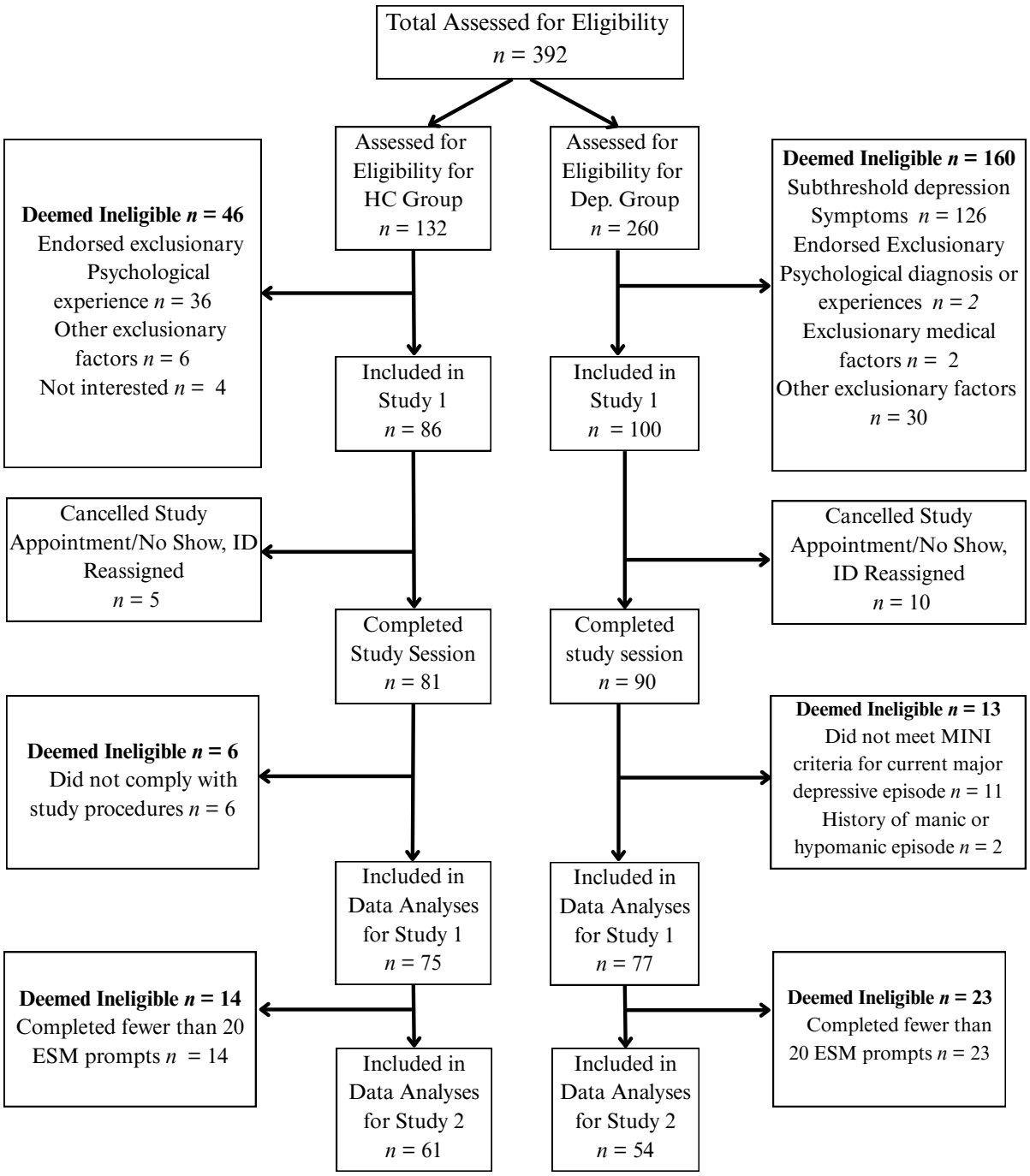
Documents Acknowledged:

- Ethics Training Certificates
- Supervisor's Approval
- Validated questionnaire: MINI screening tool

Amendments: No deviation from, or changes to the protocol, informed consent form and conduct of study should be initiated without prior written clearance or an appropriate amendment event from the HSREB, except when necessary to eliminate immediate hazard(s) to study participants or when the change(s) involves only administrative

Appendix B:

Recruitment Flowchart



Note. HC = healthy comparison participant; MDD = major depressive disorder.

Appendix C:

Mood Module Screener

"In the last two weeks...."

Question	Response: No (N); Maybe (M); Definitely (D)		
(1) Have you been feeling depressed or down most of the day nearly every day? (At least some of the day, some days of the week?) *If YES,* When did it start? How long did it last? [*If at least TWO WEEKS & caller is currently experiencing problem, circle D*]	N	M	D
"During this time..."	----------		
(2) Have you lost interest or pleasure in doing things that you usually enjoyed? (Is there anything that you're doing less of? Do you find you have to push yourself to do things?)	N	M	D
(3) How has your appetite been? (Have you lost or gained any weight? Are you trying to lose weight as part of a diet?)	N	M	D
(4) Any difficulties sleeping? - Insomnia or hypersomnia (Any trouble falling asleep? Waking up in the middle of the night? Waking up too early in the morning and not being able to get back to sleep?)	N	M	D
(5) What is your energy like? (Tired all the time? – Distinguish between low energy and sleepiness)	N	M	D
(6) How have you been feeling about yourself in this time period? (Have you been hard on yourself? About what? What about feeling guilty about things you have done or not done?)	N	M	D
(7) Do you have trouble thinking or concentrating? What are you having trouble thinking about or concentrating on? (Is it hard to make decisions about everyday things?)	N	M	D
(8) Have you been so fidgety or restless that you are unable to sit still? (What about the opposite, like you are talking or moving more slowly than usual? Like you're moving through thick mud?)	N	M	D
[At least 3 of the above symptoms need to be coded 'D'. *Discontinue as soon as these criteria are met*]	-----		

How many separate times in your life would you say you have had periods of low mood similar to the one you are experiencing now?
[If less than 2, EXCLUDE]

Appendix D:

Descriptive Statistics of Participants Included and Excluded in ESM analysis

MDD Group

	Completed < 20 ESM prompts n=23	Completed > 20 ESM prompts n = 54	Statistic
Age *M* (*SD*)			
Sex *n* (%)			χ^2 (2, N = 77) = .620, *p* =.73
Male	5 (21.7%)	14 (25.9%)	
Female	18 (78.3%)	39 (72.2%)	
Prefer not to answer	0 (0.0%)	1 (1.9%)	
Gender *n* (%)			χ^2 (3, N = 77) = 1.35, *p* =.72
Man	4 (17.4%)	13 (24.1%)	
Woman	15 (65.2%)	36 (66.7%)	
Non-binary	2 (8.7%)	3 (5.6%)	
Multiple identities selected	2 (8.7%)	2(3.7%)	
Ethnicity *n* (%)			χ^2 (6, N = 77) =12.4, *p* = .054
White	8 (34.8%)	33 (61.1%)	
Hispanic/Latino	1 (4.3%)	0 (0.0%)	
African	0 (0.0%)	2 (3.7%)	
Asian	8 (34.8%)	9 (16.7%)	
Middle Eastern	1 (4.3%)	0 (0.0%)	
Multiple identities selected	4 (17.3%)	10 (18.5%)	
Other	1 (4.3%)	0 (0.0%)	
Education *n* (%)			χ^2 (4, N = 77) = 5.69, *p* = .22
High school	3 (13%)	7 (13%)	
College	4 (17.4%)	11 (20.4%)	
University	16(69.6%)	26(48.1%)	
Post-Graduate	0 (0.0%)	8 (14.8%)	
Other	0 (0.0%)	2 (3.7%)	
Occupation *n* (%)			χ^2 (5, N =77) = 8.04, *p* = .15
Employed	5 (21.7%)	27 (50%)	
Unemployed	3 (13%)	8 (%)	
Student	4 (17.4%)	7 (13.0%)	
Other	4 (17.4%)	4 (7.4%	
Multiple selected	7 (30.4)	7 (13.0%)	

No answer	0 (0.0%)	1 (1.9%)	
Cognitive Composite Score *M* (SD)	-.13(.65)	-.11 (.58)	$t(37.9, 77) = -.095$, $p = .92$
Baseline Depression Symptoms (MADRS) *M* (SD)	28.13 (7.07)	27.89 (5.75)	$t(35.2, 77) = .146$, $p = .885$

HC Group

	Completed < 20 ESM prompts n=23	**Completed > 20 ESM prompts n = 54**	**Statistic**
Age *M* (*SD*)			
Sex *n* (%)			χ^2 (1, N = 75) = 1.89, $p = .17$
Male	6 (42.9%)	15 (24.6%)	
Female	8 (57.1%)	46 (75.4%)	
Gender *n* (%)			χ^2 (2, N = 75) = 2.45, $p = .29$
Man	6 (42.9%)	14 (23%)	
Woman	8 (57.1%)	46 (75.4%)	
Non-binary	0 (0.0%)	1 (1.6%)	
Ethnicity *n* (%)			χ^2 (6, N = 75) =3.73, $p = .71$
White	9 (64.3%)	26 (42.6%)	
Hispanic/Latino	0 (0.0%)	1 (1.6%)	
Asian	4 (28.6%)	22 (36.1%)	
Middle Eastern	0 (0.0%)	1 (1.6%)	
Multiple identities selected	0 (0.0%)	7 (11.5%)	
Other	1(7.1%)	3 (4.9%)	
No answer	0 (0.0%)	1 (1.6%)	
Education *n* (%)			χ^2 (4, N = 75) = 2.46, $p = .65$
High school	0 (0.0%)	1(1.6%)	
College	3 (21.4%)	6(9.8%)	
University	6 (42.9%)	34 (55.7%)	
Post-Graduate	5(35.7)	18 (29.5%)	
Other	0 (0.0%)	2 (3.3%)	
Occupation *n* (%)			χ^2 (6, N =75) = 2.6, $p = .86$
Employed	10 (71.4%)	34 (55.7%)	
Unemployed	0 (0.0%)	2 (3.3%)	
Student	3 (21.4%)	11 (18.0%)	

Other	0 (0.0%)	1 (1.6%)	
Retired	0 (0.0%)	2 (3.3%)	
Multiple selected	1 (7.1%)	10 (16.4%)	
No answer	0 (0.0%)	1 (1.6%)	
Cognitive Composite Score *M* (SD)	.08 (.59)	-.02 (.55)	$t(18.57, 75) = .59$, $p = .57$

Appendix E:

Cognitive Subscales z Scores MDD Group

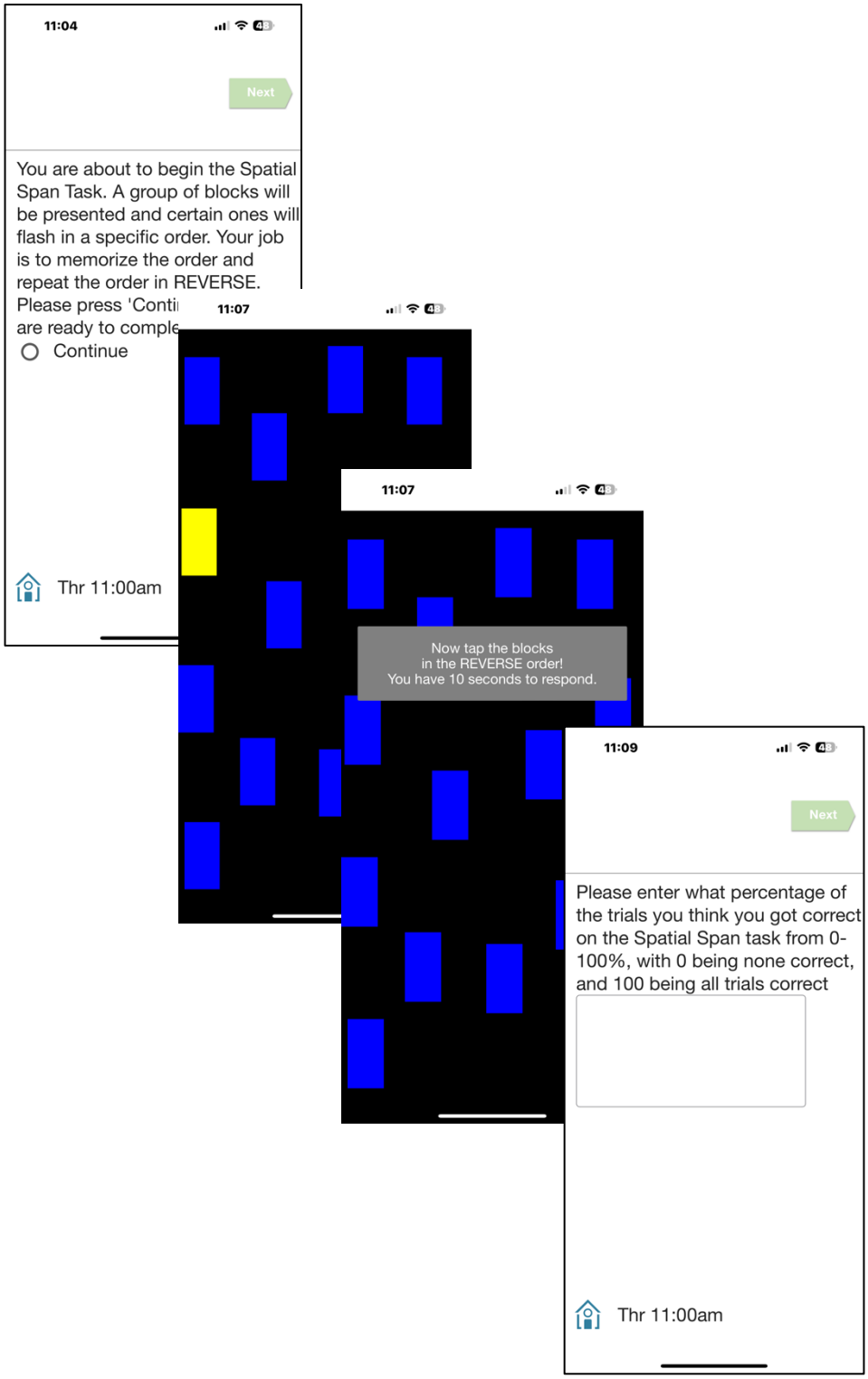
Cognitive subscales (z scores) using HC sample to create z scores for MDD group

	MDD (*n* = 77) *M* (SD)
Executive functioning	-.12 (1.03)
Working memory	.01 (.80)
Learning memory	-.04 (.84)
Processing speed	-.21 (.84)
Verbal fluency	-.25 (.87)

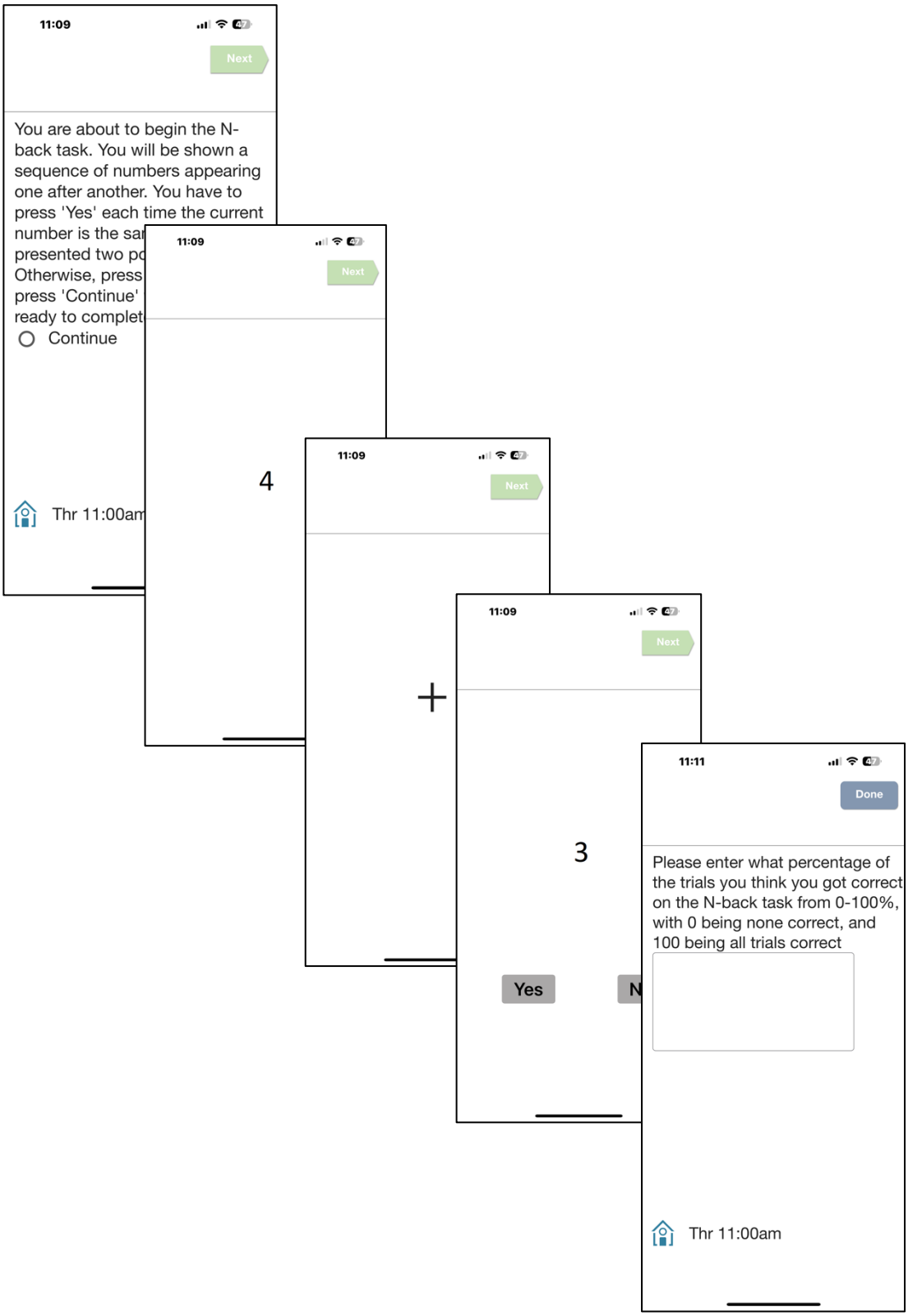
Appendix F:

Screenshots from Cognitive ESM Tasks

Spatial Span Task



n-back Task


11:09
Next
You are about to begin the N-back task. You will be shown a sequence of numbers appearing one after another. You have to press 'Yes' each time the current number is the sa
presented two p
Otherwise, press
press 'Continue'
ready to complet
Continue
Thr 11:00am
11:09
Next
4
11:09
Next
+
11:09
Next
3
Yes
N
11:11
Done
Please enter what percentage of the trials you think you got correct on the N-back task from 0-100%, with 0 being none correct, and 100 being all trials correct
Thr 11:00am