Neuropsychological Deficits in Adolescent Unipolar Depression

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Abstract

Although neuropsychological deficits in adult depression are relatively well established, findings in children/adolescents have been inconsistent and thus require further investigation. The current study investigated verbal fluency (VF), cognitive speed, motor speed, and executive functions in adolescents with unipolar depression. Results indicated that adolescents with minor depression showed working memory deficits and poorer VF (letter task). Adolescents with major depression showed working memory deficits and processing speed deficits from the early stages of information processing to the later stages of motor output. Executive function deficits of set-shifting and response inhibition that are well established in adults were not found, but may reflect task differences. Thus, it appears that depression subtype or severity of symptoms may impact on neuropsychological functioning and may in part explain previous inconsistent results.

Keywords: Unipolar depression; Adolescent psychology; Neuropsychological assessment; Executive dysfunction; Cognitive processing speed; Verbal fluency

Introduction

There is growing evidence to suggest a wide range of neuropsychological deficits in adults with depression. Processing speed deficits are evident, probably related to psychomotor symptoms of depression (Pier, Hulstijn, & Sabbe, 2004). Slower performance compared with controls has been observed on a variety of tasks such as the Tower of London task (Purcell, Maruff, Kyrios, & Pantelis, 1998) and the Trail Making Test (TMT; Neu, Kiesslinger, Schlattmann, & Reischies, 2001). The type of depression may also have an impact. A study examining initiation and movement times of unmedicated adults with dysthymia and major depressive disorder (MDD), for example, found that the dysthymic group did not differ significantly from controls, whereas the major depression group was significantly slower in both initiation and movement times than controls (Pier et al., 2004). Similarly, another study found that patients with melancholic and non-melancholic depression showed motor slowing, whereas only the melancholic group showed additional cognitive slowing (Cornell, Suarez, & Berent, 1984).

Adults with depression also show impairments on executive function tests, which assess higher level organization and planning abilities and flexibility in thinking, and are associated with frontal lobe dysfunction (Lampe, Sitskoorn, & Heeren, 2004). Deficits in verbal fluency (VF) have been found in both adult outpatients and inpatients, regardless of medication status (Landro, Stiles, & Sletvold, 2001; Moritz et al., 2002; Ravnikilde et al., 2002; Trichard et al., 1995), probably reflecting left prefrontal dysfunction. There is no significant correlation between performance on VF and severity of depression, but there is some evidence that VF deficits normalize upon remission of depression (Trichard et al., 1995). Evidence for impaired performance in flexibility of thinking or ability to shift set has been found using the TMT (Franke et al., 1993; Grant, Thase, & Sweeney, 2001) and the Wisconsin Card Sorting Test (WCST; Degl’Innocenti, Agren, & Backman, 1998; Lampe et al., 2004; Merriam, Thase, Haas, Keshavan, & Sweeney, 1999) in adults with depression. Other studies have indicated poorer planning ability (Beats, Sahakian, & Levy, 1996) and poorer behavioral inhibition (Lampe et al., 2004; Ravnikilde et al., 2002). Deficits in inhibition were also evident in patients in remission from their depression (Trichard et al., 1995).
The majority of neuropsychological studies to date have been confined to heterogeneous adult populations, often experiencing recurrent episodes of depression. However, it is unclear whether similar impairments are present in children/adolescents, who are more likely to present with their first depressive episode, be medication naïve, and suffer from a non-melancholic subtype of depression. Results in children and adolescents are mixed, with one study (Cataldo, Nobile, Lorusso, Battaglia, & Molteni, 2005) finding that children with dysthymia or major depression were impaired in VF in the first 15 s (of the 60 s block), whereas others have not found such deficits (Favre et al., 2009; Frost, Moffitt, & McGee, 1989; McClure, Rogeness, & Thompson, 1997). Impairments in set-shifting have not been found in children with dysthymia (WCST and TMT; Frost et al., 1989), children with previous episodes of depression (Kyte, Goodyer, & Sahakian, 2005), nor in adolescents with major depression when compared with controls (TMT; Favre et al., 2009; Matthews, Coghill, & Rhodes, 2008; cf. greater set-shifting errors, Brooks, Iverson, Sherman, & Roberge, 2010) and when compared with other psychiatric outpatients (Korhonen et al., 2002). In a nonclinical population, boys with high self-reported anxiety and depression performed more slowly and made more perseverative errors on the TMT (Emerson, Mollet, & Harrison, 2005). McClure and colleagues (1997) found no planning deficits on a Tower task in a nonclinical group of adolescents who reported high depression scores. Although one study showed no Stroop inhibitory deficits in adolescents with major depression compared with psychiatric controls (Korhonen et al., 2002), another showed that Stroop performance was correlated with depression symptom severity (Cataldo et al., 2005). Findings in terms of processing speed are also mixed in adolescents with depression, some showing slower performance on tasks such as the Continuous Performance Test (Cataldo et al., 2005) and the TMT (Emerson et al., 2005), but not on others such as the Grooved Pegboard Test (Frost et al., 1989).

Inconsistent findings in the child and adolescent literature may reflect the fact that most studies have combined participants with different subtypes of depression, do not use medication naïve participants or use nonclinical samples, and vary in their use of neuropsychological tests. Alternatively, inconsistent findings may reflect the possibility that neuropsychological deficits only become evident with multiple episodes of depression, are a result of antidepressant medication use, or occur only with more severe depressive symptoms, all of which are more likely to increase with age. In a study of adults, for example, Purcell, Maruff, Kyrios, and Pantelis (1997) found that younger patients were impaired on measures of attentional set-shifting and planning but not cognitive speed and concluded that younger patients with depression do not show the cognitive slowing that is reported in older adults. Consistent with the potential explanation of symptom severity being linked with greater neuropsychological deficits are the findings of a couple of adult studies that have shown neuropsychological deficits in more severe types of depression but not less severe types of depression (e.g., major depression but not dysthymia – Pier et al., 2004; melancholic depression but not nonmelancholic depression— Cornell et al., 1984). It is of course difficult to tease apart whether differences are due to symptom subtype per se, or as a result of symptom severity, as the two overlap.

The aim of the current study is to determine potential neuropsychological markers of depression in medication naïve adolescents presenting with their first episode of depressive disorder (aged 12–18 years). Neuropsychological processes deficient in adult depression, specifically VF, cognitive and motor speed (inspection time, movement initiation time, and movement execution time), and executive functions (response inhibition and set-shifting) were investigated largely through novel computer-based tasks (VF was the only neuropsychological task that was not computer-based). In addition, differences in neurocognitive ability between adolescents with major depression and minor depression (dysthymia or depressive disorder not otherwise specified [DNos]) were explored to investigate whether or not the previous use of mixed samples may in part explain inconsistent results in the literature. The literature suggests that, in adults at least, there are certain neuropsychological deficits that are evident in more severe subtypes of depression and that are lacking in their less severe counterparts (Cornell et al., 1984; Pier et al., 2004). Consistent with the adult literature and one child study (Cataldo et al., 2005), it was hypothesized that (1) adolescents with major and minor depression show poorer VF than controls. In line with the adults studied by Pier and colleagues (2004), it was also expected that (2) individuals with major depression, but not minor depression, show impaired cognitive and motor speed. In terms of executive functioning, where the adolescent literature showed no support for set-shifting deficits and mixed results for response inhibition, it was expected that (3) those with the more severe form of depression (major depression) show executive deficits, but not those with minor depression.

**Methods**

**Participants and Procedure**

The research was undertaken in compliance with, and approval of, Southern Health and Monash University Ethics Committees, as well as the Victorian Department of Education and Early Childhood Development (for recruiting controls from schools). Informed consent was obtained from participants and their parents/guardians. Participants recruited from an
adolescent depression treatment study in Melbourne, Australia (Tonge, Melvin, Gordon, Klimkeit & King, in preparation), were invited to participate in the neuropsychology research prior to beginning treatment.

Inclusion criteria. Participants (12–18 years old) met DSM-IV-TR (American Psychiatric Association, 2000) criteria for MDD, dysthymic disorder (DD) or DNos. Diagnosis was confirmed by administration of the Schedule for Affective Disorders and Schizophrenia for School-Aged Children – Present and Lifetime Version (K-SADS-PL) to both the adolescent and parents (Ambrosini, 2000). The K-SADS-PL is a semi-structured diagnostic interview with good inter-rater and test-retest reliability and criterion and predictive validity (Ambrosini, 2000). Other comorbid conditions were also diagnosed through use of the semi-structured interview and supplemented by adolescents’ self-reported anxiety and depression scores. Most participants were referred to the adolescent depression treatment study by their pediatrician or child and adolescent mental health service.

Exclusion criteria. Use of psychotropic medications, prior depressive episode, intellectual disability, significant general medical illness, organic brain syndrome, insufficient English language skill to engage in the assessment, diagnosis of primary substance abuse disorder, bipolar disorder, or psychosis were bases for exclusion.

Participants were 34 adolescents diagnosed with either major (MDD) or minor depression (DNos or DD). Twenty-two (65%) participants were diagnosed with major depression and 12 (35%) with minor depression. As can be seen in Table 1, the majority of adolescents diagnosed with MDD also had comorbid disorders, predominantly anxiety disorders, including generalized anxiety disorder, specific phobia, obsessive-compulsive disorder, social phobia, or anxiety not otherwise specified. Those that had no comorbid axis I disorders often had DSM-IV v-codes such as parent-child relationship problems. The majority of adolescents with minor depression also had comorbid disorders, but predominantly externalizing disorders such as oppositional defiant disorder and attention deficit/hyperactivity disorder.

Controls were recruited through local secondary schools and completed the self-report measures but did not receive the semi-structured clinical interview (KSADS-PL). Instead, they were asked about their psychiatric and medication history at the start of the neuropsychological testing session. Recruitment information made it clear that controls were required to be free of current or historical psychiatric conditions. Forty-one controls from secondary schools in southern and eastern metropolitan regions in Melbourne (Swinburne Secondary College, Narre Warren Secondary College) and from a youth-group (based in Caulfield) participated. Eight participants were removed from the analysis due to prior reported psychiatric history such as attention deficit/hyperactivity disorder (n = 5), high depression scores (scores in the clinical range on the Reynolds Adolescent Depression Scale [RADS], n = 2), or high anxiety scores (1.5 SD above the mean on the Revised Children’s Manifest Anxiety Scale [RCMAS], n = 1). Data from 33 controls were thus used in the analyses.

Handedness, gender, and age ranges of the two clinical and one control group are presented in Table 2. The majority of the sample was right-handed females (with a more equal gender distribution in the minor depression group than the major depression and control group) ranging in age between 12 and 17 years. There was no significant difference in age between the three groups, F(2, 63) = 0.98, p = .38.

Table 1. Comorbidity in the clinical sample

<table>
<thead>
<tr>
<th>Group</th>
<th>Comorbidity</th>
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<tbody>
<tr>
<td></td>
<td>None</td>
<td>Anxiety disorders</td>
<td>Externalizing disorders</td>
<td>Other combinations</td>
<td></td>
</tr>
<tr>
<td>Major depression (n = 22)</td>
<td>6</td>
<td>14</td>
<td>1</td>
<td>1 Anxiety NOS + Enuresis</td>
<td></td>
</tr>
<tr>
<td>Minor depression (n = 12)</td>
<td>5</td>
<td>2</td>
<td>4</td>
<td>1 Social phobia + Oppositional Defiant Disorder</td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Gender, handedness, and age of the sample

<table>
<thead>
<tr>
<th></th>
<th>Major depression group (n = 22)</th>
<th>Minor depression group (n = 12)</th>
<th>Control group (n = 33)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>17 f (77%); 5 m (23%)</td>
<td>6 f (50%); 6 m (50%)</td>
<td>24 f (73%); 9 m (27%)</td>
</tr>
<tr>
<td>Handedness</td>
<td>19 rh (86%); 3 lh (14%)</td>
<td>11 rh (92%); 1 lh (8%)</td>
<td>31 rh (94%); 2 lh (6%)</td>
</tr>
<tr>
<td>Mean age (years; SD)</td>
<td>15.3 (1.6)</td>
<td>15.6 (1.5)</td>
<td>15.8 (1.2)</td>
</tr>
<tr>
<td>Age range (years)</td>
<td>12.08–17.42</td>
<td>12.75–17.83</td>
<td>12.5–17.83</td>
</tr>
</tbody>
</table>

Notes: f = female; m = male; rh = right-handed; lh = left-handed.
Outcome Measures

Participants completed the adolescent self-report measures, IQ screening, and neuropsychological tasks (in a counterbalanced order) prior to the commencement of treatment, as outlined below. Administration time of the neuropsychological battery and IQ screening was approximately 1.5–2 h.

Adolescent self-report measures

Reynolds Adolescent Depression Scale. The RADS is a 30-item self-report measure of the severity of depressive symptomatology in adolescents. Scores range from 30 to 120, and a score of $\geq 76$ indicates that the adolescent has clinical levels of depressive symptoms (Reynolds, 2002). The RADS is a reliable measure with internal consistency $\alpha = 0.91$ and test-retest reliability $r = 0.87$ (Reynolds & Mazza, 1998). Convergent and criterion-related validity have been established with high correlations ($r > 0.73$) between RADS and other recognized measures of adolescent depression, such as the Hamilton Depression Rating Scale (Reynolds & Mazza, 1998), the Children’s Depression Inventory (Reynolds, 1986), and the Children’s Depression Rating Scale-Revised (Shain, Naylor, & Alessi, 1990).

Revised Children’s Manifest Anxiety Scale. The RCMAS (Reynolds & Richmond, 1985) is a 37-item rating scale for children aged between 6 and 19. T-scores of $\geq 60$ indicate anxiety in the clinical range (Reynolds & Richmond, 1985). Internal consistency estimates are $\geq 0.80$ (Reynolds & Richmond, 1985) and test-retest reliability is 0.88 (Wisniewski & Mulick, 1987). The RCMAS has construct validity as demonstrated by its good correlations with other measures of anxiety such as the State-Trait Anxiety Inventory for Children (Reynolds, 1980).

IQ screening. The IQ screening comprised five subtests (Similarities, Block Design, Matrix Reasoning, Vocabulary, and Digit Span) of the Wechsler Intelligence Scale for Children-fourth edition (WISC-IV; Wechsler, 2003) or Wechsler Adult Intelligence Scale-third edition (Wechsler, 1997), depending on age, in order to the estimate level of IQ. Verbal Comprehension IQ scores were prorated as per instructions in the WISC-IV manual from Vocabulary and Similarity scores. Perceptual Reasoning IQ scores were prorated as per the WISC-IV manual from Block Design and Matrix Reasoning scores.

Neuropsychological tasks

VF task. The participant is given 1 min to generate words beginning with the letters F, A, and S (FAS) or to name words within a semantic category such as animals. Greater difficulty with the letter than the semantic task may reflect difficulties in devising a word search strategy. VF deficits have been found in adults with depression (Degl’Innocenti et al., 1998) but findings in children/adolescents have been inconsistent (Cataldo et al., 2005; McClure et al., 1997). Differential group performance in the total number of words generated for each letter/animal category and number of errors were of interest in this task.

Inspection time task. This task measures the time a stimulus has to be presented in order for participants to correctly identify this stimulus 80% of the time. As the processing speed task does not depend on reaction time, it is not confounded by response speed. This task has been found to differentiate between unmedicated adults with depression and controls (Tsourtos, Thompson, & Stough, 2002). All computer tasks were administered on a Toshiba Tecra notebook computer with a 1.7-GHz Intel Pentium Processor and a 12-inch screen. Participants responded using the keyboard. The inspection time task is described in detail in Johnson and colleagues (2004) and involved the presentation of a fixation point (a small filled circle) for 500 ms followed by a “pi” figure comprised of two vertical lines joined at the top with a horizontal line. The “pi” figure remained on the screen for a variable period of time and was followed by a “lightning mask” that remained on screen for 360 ms. For each trial, participants were required to judge which of the two vertical lines in the figure was longer. All participants were given a practice session of 10 trials with a stimulus duration of 200 ms. Practice trials were repeated until the participant was able to complete it perfectly. Stimulus presentation time was determined using a parameter estimation by sequential testing adaptive staircase algorithm (Taylor & Creelman, 1967), based on the accuracy of participant responses. Response speed (time taken for participants to indicate their decision regarding line length) was also measured by this task. Both inspection and response times were variables of interest in this task.

Serial choice reaction time task involving motor reprogramming. This task is described in detail in Rinehart, Bradshaw, Brereton, and Tonge (2001) and utilizes a response board measuring $480 \times 100$ mm in which there were 23 spring-loaded circular buttons set 30 mm apart. Red light-emitting diodes (LEDs) were embedded within the annuli and served as visual cues. The response board was connected to a Toshiba notebook computer. The task utilized only four buttons at the centre of the
response board. Participants began by depressing the first target button as quickly as possible in response to illumination of one LED. On pressing the first target button, the next target was illuminated and participants were required to move leftward and rightward (reciprocating) as quickly as possible between two target buttons. Reprogramming of direction was manipulated by the introduction of an unexpected “oddball” to the basic reciprocating sequence. The oddball only occurred once during a trial and involved movement of the same distance (to the adjacent button) but in a direction different to that expected. For example, during reciprocating movements between two buttons, instead of moving back to the left button after depressing the right button, a button to the right of the right button illuminated, requiring movement to the right. The number of leftward and rightward movements was constant across condition, the “oddball” occurring pseudo-randomly on the fifth, sixth, seventh, or eighth movement. Following the reprogrammed movement, the original reciprocating sequence was reinstated until 15 movements had been completed. All participants completed four blocks of eight trials, 32 in total. This task requires inhibition of the “typical” movement and subsequent reprogramming of directional movement to an unexpected button. This task examined movement preparation and execution times as well as error data. Difficulties in the ability to inhibit pre-programmed expected responses may be reflected in increased response times (relative to controls) for the “oddball” movement, and perhaps in reprogrammed movements after the “oddball” (via a Group × Movement Execution and/or Group × Movement Preparation interaction).

**Local-global task.** This task is described in detail in Bellgrove, Vance, and Bradshaw (2003) and involves presentation of stimuli on the computer screen composed of large “global” numbers graphically made up of smaller “local” numbers. Participants are directed to identify characters of one spatial scale (e.g., local), while ignoring those at the other (e.g., global). This task allows assessment of whether there is greater interference from stimuli at the irrelevant spatial scale in the clinical group compared with controls.

The stimuli (Fig. 1) were presented on a Toshiba notebook computer, with participants making their responses by pressing response keys on the keyboard. Participants were instructed to respond if they saw either a 1 or a 2 at the directed level. The alternative level (e.g., the local level if directed to respond to the global task) consisted of digits from the same set of numbers, and thus trials could be classified as congruent (e.g., a global 2 composed of local 2s), neutral (e.g., a global 1 composed of local 3s), or incongruent (e.g., a global 1 composed of local 2s). Participants responded, by pressing designated buttons on the keyboard, to 1s or 2s at the spatial scale instructed by the experimenter. Participants fixated on a dot presented centrally, prior to the presentation of the digit stimulus. Reaction time and accuracy were recorded for each trial. Participants were required to respond within 4000 ms, after which the trial was recorded as a “no response”. A practice block with performance feedback of at least 12 trials preceded each of the experimental blocks. Both local and global experimental blocks consisted of 72 trials, with 24 trials per consistency condition presented in a pseudo-random fashion. The order of the blocked local and global tasks was counterbalanced across participants. Separate analyses were conducted for reaction time and error data. It was of interest to determine whether the clinical group was overall slower and more error-prone than controls and also whether the major depression group showed greater interference than controls from stimuli at the irrelevant spatial scale, which may be reflected, for example, by longer reaction times to incongruent than neutral trials.

In an additional set-shifting component of the task, participants were asked to respond to stimuli that could appear unpredictably at either local or global spatial scales (Fig. 2). Participants were instructed to respond to either 1s or 2s at either the local or the global spatial scale. A practice block of 12 trials, including performance feedback, was followed by four experimental blocks of 33 trials (132 in total; half local, half global) without feedback, separated by rest periods. The trials were parsed into those that did and those that did not require a shift of spatial scale of attention across consecutive trials: Local-to-global and global-to-local (attention switch), and local-to-local and global-to-global (no attention switch). Since the first trial of a block had no previous trial on which to compare the spatial scale of the target, the number of analyzed trials was reduced to 128 (32 in each of the four blocks). It was of interest to determine whether the major depression group showed greater set-shifting deficits, as reflected by being slowed down more considerably than controls and/or making more errors than controls, under the set-shifting condition.

**Data Analysis**

In order to minimize the impact of outliers on reaction time data, participants’ median scores were calculated for each measurement point, rather than their mean score for the local-global task, and serial choice reaction time (SCRT) task. Unlike mean scores, which may be easily over-inflated by outlier reaction times, median scores are less likely to be impacted in this way and are thus the preferred method for managing potential reaction time outliers (Ratcliff, 1993). Demographic differences in IQ variables were explored to determine whether analyses of the neuropsychological tasks required statistical
Fig. 1. Stimuli used in the local-global task at the local (a and b) and global (c and d) levels. Trials were (i) congruent, (ii) incongruent, and (iii and iv) neutral.
control of demographic variables. Group differences on the neuropsychological tasks were analyzed using regression analyses or analyses of variance (ANOVAs), as described in detail in the results section below.

Results

IQ Screening and Adolescent Self-report Measures

As seen in Table 3, while the mean IQ subtest scores (Vocabulary, Similarities, Block Design, Matrix Reasoning, and Digit span) and Index scores (Verbal Comprehension and Perceptual Reasoning Index) of all groups fell in the range classified as average, controls appeared to score higher than the two clinical groups, on verbal tasks (significant group differences were
observed for Similarities and the Verbal Comprehension Index) and the working memory task (Digit Span). Self-reported depression and anxiety scores appeared to follow the expected pattern of increasing scores (reflecting more symptoms) in the order of controls, minor depression group, and major depression group.

**VF (Letter and Category) and Inspection Time Task Results**

The number of words and errors generated on the VF tasks, and inspection and reaction times in the inspection time task are shown in Table 4. Six VF variables (FAS, animal category) and two inspection time task variables (reaction time and inspection time) were regressed onto depression status (major, minor, reference group none), masculine gender, and verbal IQ (Table 5). The pattern of VF results suggests that participants with minor depression scored most poorly on both letter and animal fluency tasks. Significant results emerged for word generation in the letter, but not the animal category task, for the minor depression group relative to controls, but not for the major depression group. There were no significant differences in error rates and gender had no significant impact on this verbal task. Verbal Comprehension scores had an impact on letter fluency but not animal category fluency, with higher letter fluency scores associated with higher Verbal Comprehension IQ scores. Inspection time results, also shown in Table 5, indicated significantly slower inspection time scores for the major depression group compared with controls, but not the minor depression group. Although there was no emphasis on response speed in this task, reaction time scores were also examined, and slower reaction times were also evident for those with major depression. Gender and Verbal Comprehension IQ scores did not impact significantly on performance on the inspection time task.

**SCRT Task Involving Motor Reprogramming Results**

ANOVAAs were performed separately for movement time (motor execution), down time (movement preparation), and error data. Motor preparation and execution for the following movements were analyzed: Three movements prior to the oddball, the oddball movement, and the two movements after the oddball. Pairwise comparisons included Bonferroni correction for multiple comparisons.

**Movement time/movement execution data.** A two-way repeated-measures ANOVA with the factors Group (major depression, minor depression, controls) and Movement Execution (pre-oddball 3, pre-oddball 2, pre-oddball 1, oddball, post-oddball 1, post-oddball 2) showed a main effect of Movement Execution; $F(5, 300) = 473.34, p < .001$. As can be seen in Fig. 3, all groups slowed down considerably for the oddball movement, and then became faster to execute the reprogrammed movements (after the oddball). There was also a main effect of Group; $F(2, 60) = 8.65, p = .001$, with the control group showing faster movement execution (364 ms, $SD = 15.3$) than the major depression group (461 ms, $SD = 17.8$; pairwise comparison $p < .01$). The minor depression group (404 ms, $SD = 25.2$) performed somewhere in between the controls and major depression group, and their movement time did not differ significantly from these. There was no significant interaction, suggesting that even though the major depression group was overall slower, the pattern of movement execution with faster

<table>
<thead>
<tr>
<th>Table 4. Results for the letter verbal fluency, animal categories verbal fluency, and the inspection time task for the three groups</th>
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<tbody>
<tr>
<td>Mean words and errors</td>
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<td></td>
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<tr>
<td>Mean F total words</td>
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<tr>
<td>Mean A total words</td>
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<td>Mean S total words</td>
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<td>Mean F errors</td>
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<td>Mean S errors</td>
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<td>Mean FAS total errors</td>
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<td>Mean animal category total words</td>
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<tr>
<td>Mean animal errors</td>
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<td>Inspection time task: Inspection time (ms)</td>
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<td>Inspection time task: Reaction time (ms)</td>
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programmed than reprogrammed and oddball movement was consistent among the three groups. Controlling for Verbal Comprehension IQ had no significant impact on the results.

**Downtime data/movement preparation time data.** A two-way repeated-measures ANOVA with factors Group (major depression, minor depression, controls) and Movement Preparation (pre-oddball 3, pre-oddball 2, pre-oddball 1, oddball, post-oddball 1, post-oddball 2) showed a significant effect of Movement Preparation; $F(5, 300) = 30.32, p < .001$. Fig. 4 indicates that all groups were faster at preparing for reprogrammed movements (after the oddball) than for preparing for programmed movements (pre-oddball).

There was a significant effect of Group, $F(2, 60) = 6.5, p = .003$, with the control group performing significantly faster than the major depression group ($p < .01$), but no other significant group differences apparent with pairwise comparisons. There was no significant interaction, suggesting that despite the fact that the major depression group was slower to prepare for movements overall, all groups showed a similar pattern of movement preparation for programmed, oddball, and reprogrammed movements. Controlling for Verbal Comprehension IQ had no significant impact on the results.
Error data. Error data were recorded for oddball movements, with errors constituting pressing the incorrect button during the oddball condition. A one-way ANOVA, comparing the number of errors between the groups, showed no significant effect of Group, \( F(2, 62) = 0.16, p = .85 \), with the major depression (mean error = 4.7, \( SD = 9.9 \)), minor depression (mean error = 4.7, \( SD = 9.9 \); coincidentally identical to the major depression group), and control groups (mean error = 4.13, \( SD = 4.1 \)) making a similar number of errors. Again, Verbal Comprehension IQ had no significant impact on results.

Local-Global Task Results

Separate analyses were conducted for reaction time and error data. In all analyses, the data were submitted to a three-way ANOVA, with a between-subjects factor of Group (controls, major depression, minor depression) and a within-subjects factor of Spatial Level (local or global) and Congruence (neutral, congruent, incongruent). Interactions were decomposed using analyses of simple main effects, and pairwise comparisons were Bonferroni corrected to control for multiple comparisons. Only interactions of interest (those including interaction with Group) are discussed.

Reaction time data. Local-global reaction time data for the three groups are depicted in Fig. 5. ANOVA results indicated a main effect of Group, \( F(2, 64) = 12.6, p < .01 \), with the major depression group showing a mean reaction time of 642 ms (24.2 \( SD \)), the minor depression group a reaction time of 574 ms (32.8 \( SD \)) and the control group 487 ms (19.8 \( SD \)). Pairwise comparisons indicated a significant difference between the major depression and the control group (\( p < .01 \)), but not the minor depression and control group (\( p < .05 \)), nor between the major and the minor depression groups (\( p > .05 \)).

There was a significant main effect of Spatial Level, \( F(1, 64) = 46.5, p < .01 \), with participants performing faster at the global level (609 ms, \( SD = 18.7 \)) than the local level (527 ms, \( SD = 13.3 \)). There was also a significant main effect of Congruence, \( F(2, 128) = 55.98, p < .01 \), with participants performing faster on congruent (533 ms, \( SD = 13.5 \)) than incongruent trials (586 ms, \( SD = 17.2, p < .01 \)) and on congruent than neutral trials (583 ms, \( SD = 15.5, p < .01 \)). There was no significant difference between reaction times for neutral and incongruent trials (\( p > .05 \)). There were no significant interactions involving Group, suggesting that there was no greater interference from stimuli at the irrelevant spatial scale in the clinical groups compared with controls. (The only significant interaction was a Congruence \( \times \) Spatial Level interaction, \( F(2, 128) = 13.83, p < .01 \), which was driven by slower incongruent-than-neutral trial performance at the global but not local level.) Controlling for Verbal Comprehension IQ had no significant impact on results.

Error data. The three-way ANOVA revealed a significant main effect of Group, \( F(2, 64) = 4.3, p = .018 \). The minor depression group appeared to make overall less errors (0.94, \( SD = 0.008 \)) than the major depression group (0.97, \( SD = 0.006 \)) and the controls (0.97, \( SD = 0.005 \)). Pairwise comparisons revealed a significant difference between the minor
depression group and controls \( (p < .05) \) and the minor and the major depression groups \( (p < .05) \). There was no significant difference between the major depression group and controls \( (p > .05) \). There was also a main effect of Congruence, \( F(2, 128) = 24.7, p = .00 \), but no other significant effects. This reflects the fact that the greatest number of errors occurred in the congruent condition \( (0.979, SD = 0.003) \), followed by the neutral condition \( (0.960, SD = 0.005) \) and the incongruent condition \( (0.943, SD = 0.006) \). Pairwise comparisons indicated that all comparisons were significant \( (p < .05 \) for all pairwise comparisons). Controlling for Verbal Comprehension IQ had no significant impact on results.

**Local-Global Task Set-shifting**

Reaction times and errors were compared in separate analyses on trials which required shifting attention (switch) and trials on which attention was maintained at the same spatial scale (no switch), using Group (major depression, minor depression,
controls) × Set-change (switch, no switch) ANOVAs. Differences were further analyzed with Bonferroni-corrected pairwise comparisons.

**Reaction time data.** The reaction time analysis revealed a significant Group effect, $F(2, 64) = 11.04, p < .001$. Pairwise comparisons revealed that the control group performed significantly faster (mean = 899 ms, $SD = 31.5$) than the major depression group (mean = 1131 ms, $SD = 38.5$; $p < .001$) but not the minor depression group (mean = 1029 ms, $SD = 52.2$; $p > .05$). There was no significant difference between the major and minor depression groups ($p > .05$). There was also a significant effect of Set-change, $F(1, 64) = 14.1, p < .001$, with participants showing faster reaction times on no-switch trials (mean = 984 ms, $SD = 21.0$) than switch trials (mean = 1056 ms, $SD = 21.0$). However, there was no significant Group interaction, suggesting that the clinical and control groups were not differentially affected by the set-shifting condition. Controlling for Verbal Comprehension IQ scores did not impact significantly on results.

**Error data.** The error data analysis revealed a significant effect of Set-change, $F(1, 64) = 10.8, p = .002$, with participants making less errors in the no-switch (2.83, $SD = 0.004$) than the switch (2.87, $SD = 0.014$) condition. The effect of Group failed to reach significance, $F(2, 64) = 3.1, p > .05$, and there were no further interactions. Again, controlling for Verbal Comprehension IQ scores did not impact significantly on results.

**Discussion**

The aim of this study was to investigate neuropsychological deficits in adolescents suffering from major and minor depressive disorders. In terms of group differences on IQ testing, these were only evident for verbal tests (Similarities and the Verbal Comprehension IQ score) and a measure of working memory (Digit Span). This is consistent with the literature which indicates that depression affects performance of adults on verbal and working memory tasks (Landro et al., 2004). Unlike other child studies (Frost et al., 1989; McClure et al., 1997), this study found significant VF deficits (number of words generated but not number of errors) for participants with minor depression only, on the letter task. Thus, participants with minor depression may potentially have difficulties devising effective word search strategies. It is possible that mixed findings in the literature previously may reflect the use of mixed samples and highlights the need of separating out depression subtypes in future studies. Alternatively, it is possible that because the minor depression group tended to have more comorbid externalizing conditions than the major depression group, that VF deficits may be a result of the externalizing condition *per se*, or that having both externalizing and internalizing conditions may be associated with cumulative deficits. VF and organizational deficits in externalizing conditions are well documented in the literature (Speltz, DeKlyen, Calderon, Greenberg, & Fisher, 1999). However, eyeballing of the available data did not suggest that the scores of those participants with comorbid externalizing conditions were substantially reducing the mean VF scores of the minor depression group.

Both cognitive and motor processing speed deficits have been consistently shown in adults with depression (Pier et al., 2004), but not consistently in children and adolescents with depression. In addition, most child/adolescent studies have used reaction time as a measure of processing speed, which reflects both cognitive and motor speed. In this study, various aspects of processing speed were investigated: Inspection time, movement preparation time, and movement execution time. Movement preparation time measures the speed of perception and encoding of a stimulus as well as initiation of a motor action, whereas movement execution reflects motor action. Inspection time reflects the speed of early stages of information processing and is not confounded by motor speed.

Adolescents with major depression showed significantly slower cognitive processing speed, as indicated by their inspection times, than the control group. The major depression group was also significantly slower than controls to make a motor response (reaction time) in this task, even though there was a lack of emphasis on response speed in this task. Scores for the minor depression group fell in between those of the major depression and the control groups, but did not differ significantly from these. It is likely that the lack of significant differences reflects small sample size of the minor depression group. Movement preparation and execution times were investigated in two tasks (the SCRT task involving motor reprogramming and the local-global task) and were both found to be consistently slower for the major depression group than the control group. (Again, response speed scores for the minor depression group fell in the middle of those of the major depression and control groups and did not differ significantly from either group.) Thus, it appears that like adults, adolescents with their first episode of major depression show signs of psychomotor retardation on neuropsychological tasks, with deficits evident from the early stages of information processing to later stages of motor output. As such, negative findings, such as those in Purcell and colleagues’ (1997) study of young adults with depression, are more likely to reflect the use of mixed
samples, including use of medicated participants, and the nature of the task used to measure processing speed, rather than the absence of processing speed deficits per se.

The clinical groups were not significantly more error-prone on any of the tasks, despite participants with major depression tending to perform more slowly overall. In fact, the only significant finding in terms of error rates was in the more complex local-global task where participants with minor depression made significantly less errors than both the control and the major depression groups. They did not perform significantly slower on this task, so there is no evidence that they were trading speed for accuracy.

Executive functioning was examined in two of the neuropsychological tasks. The SCRT task required inhibition of the prepotent movement and subsequent reprogramming of directional movement to an unexpected button. While the major depression group showed slower movement preparation and execution than controls, their overall pattern of results was very similar. That is, they showed a similar pattern for being faster to execute programmed movements (prior to the oddball), slowing down for the oddball, and then becoming faster again after the oddball when executing the reprogrammed movements. There was no evidence of inhibition difficulties (as reflected by increased response time relative to controls for the oddball movement or by increased errors). On the local-global task, participants were required to respond to characters of one spatial scale, while ignoring those at another. The clinical groups showed normal patterns of global advantage (i.e., faster performance at the global rather than local level; Bellgrove et al., 2003) and were not unduly affected by the consistency manipulation. The lack of a Group × Consistency effect indicates that the clinical groups were affected by interference from stimuli at the irrelevant spatial scale in a comparable fashion to controls and thus show no evidence of increased distractibility. (Interference effects in the local-global task may arise because of potentially time-costly attempts to ignore the irrelevant distractor.) It is possible that interference effects found previously with the Stroop task may reflect the differences in the locus of the effects in these tasks. It has been proposed that interference effects within the local-global paradigm may place higher demands on earlier stimulus-processing operations, rather than the later response-selection operation of the Stroop task (e.g., Bellgrove et al., 2003). Future studies employing the two tasks together may help to clarify whether depression may indeed be associated with interference at later, rather than earlier stages of information processing.

The set-shifting component included in the local-global task showed that while overall the major depression group performed more slowly than controls, and all participants took longer to react to trials, and made more errors, in trials which required set-shifting than those that did not, both clinical groups were not differentially affected by the set-shifting condition compared with controls. The lack of a set-shifting deficit is consistent with previous findings in the child/adolescent literature (with the exception of one study by Brooks et al., 2010, who found more set-shifting errors).

Overall, the results indicate that deficits in working memory and processing speed (cognitive and motor speed) are evident in medication naïve adolescents with their first episode of major depression, similar to those seen in adults. The executive function deficits of VF, set-shifting and inhibition evident in adult depression, however, are less clear in child and adolescent samples. Results of the current study found no significant evidence of VF, set-shifting, or inhibitory deficits in adolescents with major depression. There appeared to be performance differences in adolescents depending on their subtype of depression (major or minor), with the minor depression group showing deficits in VF (letter task) and working memory, but not significantly slower processing or motor speed. We note however, that this study’s ability to detect significant effects may be somewhat limited due to small samples size (particularly that of the minor depression group) and is in need of replication with a larger sample. Interpretation of results for the minor depression group is limited not only by small sample size, but also by the presence of comorbid externalizing conditions, which may also affect neuropsychological task performance. Further limitations of this study include not controlling for demographic variables such as socio-economic status, and parental income, and education, which may also have had an impact. In addition, the use of largely experimental neuropsychological measures rather than standardized tests may limit the generalizability of findings. It is possible that differences in findings in this study compared with previous studies may simply reflect task differences. Unfortunately, it is not clear, for example, that how well-response inhibition deficits on these experimental tasks correlate with response inhibition deficits on other tasks. Future studies may like to combine experimental and standardized tasks to investigate how well these measures correlate.

It appears from the current study that the processing speed deficits in adolescent depression may depend on the depression subtype or severity of the mood disturbance, with significant cognitive and motor slowing found in the major depression group only. If they are indeed related to the latter, it would be interesting to investigate further, whether deficits dissipate with partial or full remission of the depression or when under medication. Further, investigations should focus on neuropsychological testing of individuals during their first and later episodes of depression in order to investigate potentially progressive brain changes.
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References


