Preliminary communication

Psychomotor disturbance in depression: Assessment using a driving simulator paradigm

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Abstract

Background: Psychomotor disturbance is an essential feature of Major Depressive Disorder (MDD) and has been associated with impaired functioning on cognitively demanding tasks. Given the psychomotor demands required to navigate a motor vehicle and the disastrous effects of motor vehicle accidents, patients with MDD present a population of clinical interest. The goal of this investigation was to examine the association between MDD and driving ability assessed within a simulated driving paradigm.

Methods: 18 outpatients currently meeting diagnostic criteria for MDD and 29 control participants completed four 30-min simulated driving trials at 10:00 am, 12:00 pm, 2:00 pm, and 4:00 pm. Participants also completed the Beck Depression Inventory (BDI) to assess for depression severity and the Epworth Sleepiness Scale (ESS) to assess for everyday sleepiness.

Results: After controlling for age and sleepiness, the depressed sample exhibited slower steering reaction times across trials (p < .05) and an increased number of crashes across trials (p < .05) when compared to controls. These differences were characterized by a medium effect size. No significant time-of-day effects were found.

Limitations: MDD patients were free of anti-depressant medication and findings may not generalize to medicated populations. Also, a rural highway driving route was used which may not generalize well to urban driving settings.

Conclusions: Patients with untreated MDD demonstrate impaired simulated driving performance. Further research into whether these findings translate into on-the-road impairment is important for public health and safety.

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Keywords: Depression; Psychomotor impairment; Driving simulator

1. Introduction

Motor vehicle accidents and car-related fatalities are a catastrophic problem with over 6,000,000 car accidents and 40,000 car-related deaths occurring each year in North America (Car Accidents Bulletin, 2005). With the rising use of potentially distracting in-car devices such as cellular phones and computer navigational systems adding complexity to the already demanding task of driving a motorized vehicle, interest into the causes and prevention of motor vehicle accidents has intensified.
One population of interest is made up of individuals with Major Depressive Disorder (MDD). A cardinal feature of MDD is observable psychomotor agitation or retardation that can include slowed thought processes, physical restlessness, or serious retardations in body movement (DSM-IV; American Psychiatric Association, 1994). These symptoms are widespread with manifestations reported in up to 69% of unipolar depressed samples (Nelson and Charney, 1980). For example, compared to control participants, patients with MDD typically exhibit slowed psychomotor reaction times (RT) on tasks that require effortful processing (Hasher and Zacks, 1979; Hammar et al., 2003). Much like on-the-road driving, effortful processing tasks demand a high degree of cognitive exertion through the recruitment of elaborate processes such as mental organization, decision making, or complex searching. Furthermore, depression has been associated with impairments in mental flexibility (Airaksinen et al., 2004), attentional set-shifting (Purcell et al., 2001), and visuo-motor control processes (Sabbe et al., 1999).

It is not surprising, therefore, that research has found a relationship between depression, its correlates, and the likelihood of driver accidents and driver error. Selzer et al. (1968) reported that 21% of drivers responsible for fatal accidents were clinically depressed compared with 7% in a control group. Furthermore, investigations have identified an association between accident likelihood and stress-vulnerability, sensitivity to emotional disturbance, and the number and severity of disturbing life events (Gulian et al., 1989; Holt, 1982; Selzer and Vinokur, 1975). More recently, Dreery and Filles (1999) cluster analyzed a large sample of youth drivers and identified a high-risk subtype characterized by elevated levels of depression, resentfulness and irritability. Not all research, however, has supported the depression and driving relationship. Ramaekers et al. (1997) found that driving performance was not causally related to the relief of depressive symptomatology in a depressed out-patient sample. However, participants in this study were assessed at three and six weeks into anti-depressant treatment and thus psychomotor performance may have been influenced by side-effects of the medication.

To the best of our knowledge, no study has directly investigated the driving performance of non-medicated depressed patients compared to a control group within a driving simulator paradigm. Assessment by means of a driving simulator affords a safe and ecologically valid method of examining the influence of MDD on driving-related psychomotor performance. Driving simulators have been successfully used to examine impairment in other clinical populations including schizophrenia (St. Germain et al., 2005), alcohol and substance abuse (Calhoun et al., 2004), and Alzheimer’s disease (Cox et al., 1998). In efforts to ensure a pure investigation of MDD and its related symptomatology without potentially confounding factors related to anti-depressant medication, non-medicated depressed individuals were assessed.

2. Methods

2.1. Participants

The depressed outpatient sample was recruited through the Neuropsychiatry Clinic at Toronto Western Hospital. The control sample was solicited via poster advertisements from the community. All participants were required to be between the ages of 18 and 65, have a valid Canadian driver’s license, and at least five years of driving experience to be considered for the study. During the course of the screening procedure, staff psychiatrists trained in diagnostic interviewing assessed for the presence of MDD by means of a clinical, semi-structured, non-standardized interview based on DSM-IV-TR criteria for Axis-I disorders. This interview was conducted in-person and was also designed to assess general medical history, the presence of head trauma, cognitive difficulties, physical health, and fitness to engage in the driving study. Participants were excluded if they had previously suffered any serious head injuries, had a neurological or medical condition, or presented with a psychotic or substance use disorder. Participants were required to be free of anti-depressant medications for the following periods: Four weeks if being treated with fluoxetine, two weeks if being treated with monoamine oxidase inhibitors, one week for all other antidepressant medications including sertraline, mirtazapine, and any benzodiazepine, and one week for herbal treatments with putative anti-depressant affects including St. John’s Wort. These differential periods were determined based on each drug’s half-life.

Eighteen outpatients (5 men, 13 women) met the general screening criteria in addition to DSM-IV-TR criteria for MDD and comprised the depressed group. This group also featured elevated depressive symptomatology according to the self-report Beck Depression Inventory (BDI) (M=27.4, S.D. = 11.5), scoring substantially above the recommended MDD cut-off score of 15 or greater (Beck, 1967). Thirty participants from the community who met screening criteria for inclusion and did not meet criteria for a current episode of MDD comprised the control group. Only twenty-nine (19 men, 10 women) of the thirty control participants were
included in data analyses as a mid-simulation power shortage resulted in the loss of one participant’s driving simulation data. Gender distribution was significantly different between groups, $\chi^2 (1)=6.33$, $p<.05$. Age was also higher in the depressed group ($M=42$ years, S.D.=$12.1$) when compared to the control group ($M=31$ years, S.D.=$11.7$), $t(45)=3.06$, $p<.05$.

2.2. Procedure

Participants arrived at approximately 9:30 am on the morning of testing. After written consent was obtained, participants were instructed on how to operate the simulator and given a 10-min practice driving trial. Thirty-minute driving sessions took place at 10:00 am, 12:00 pm, 2:00 pm and 4:00 pm. In between driving sessions all participants engaged in a similar range of activities including reading magazines and watching television. Participants were not permitted to drink caffeinated beverages prior to or during testing. After the final driving trial, subjects were debriefed as to the nature of the experiment and asked for their feedback. Participants generally enjoyed the experiment and did not report any symptoms of vertigo or headaches sometimes associated with real-time computerized simulations.

2.3. Measures

2.3.1. Epworth Sleepiness Scale (ESS)

The ESS (Johns, 1991) is a self-administered questionnaire which measures one’s propensity to experience sleepiness in everyday situations. Eight scenarios such as the likelihood of dozing off while in the midst of conversation are rated on a four-point scale, and summed to yield an overall sleepiness score out of 24. The ESS is a reliable and valid measure of everyday sleepiness (Johns, 1994).

2.3.2. Beck Depression Inventory (BDI)

The BDI (Beck et al., 1961) is a self-report questionnaire measuring severity of depressive symptomatology. The questionnaire consists of 21 items reflecting depressive symptoms. Each are rated along a four-point scale and summed to yield an overall score of depression severity. The BDI is a widely used, reliable, and valid measure of depression severity (Beck, Steer, and Garbin, 1988).

2.3.3. York driving simulator

The York Driving Simulator operates on a personal computer connected to a realistic steering wheel, accelerator pedal, and brake pedal. The participant is seated in a driver’s chair and is positioned towards a computer monitor. The 30-min driving trial requires the participant to navigate a rural highway-driving scenario. The driver is instructed to obey posted speed limits and stay in the centre of the right-hand lane. The participant is also informed that other cars will occasionally pass in the left hand lane and that periodically, randomly generated wind-gusts force the subject to remain ‘on task’ through corrective steering maneuvers.

Variables recorded by the simulator include road position, speed, speed deviation, steering RT, and number of crashes. Specifically, road position is a numerical representation of the car’s on-road location measured on a scale of 0–100 with a score of 0 representing the absolute right side of the road and a score of 100 representing the absolute left side of the road. Speed is the car’s average velocity in kilometers per hour (km/h). Speed deviation is the average difference of car speed from the posted speed limits. Steering RT is the average corrective steering response time in reaction to driving obstacles. Finally, crashes represent the combined number of times contact is made with other on-road vehicles and the car is steered outside of preset lane boundaries.

3. Results

3.1. Preliminary analysis

Table 1 summarizes correlations between the five driving variables of interest. Mean scores across driving time trials for both the control and depressed samples were included in the analysis. The strongest correlation occurred between speed and speed deviation. This was not surprising as these variables are similarly derived and systematically vary together. Road position and number of crashes were also significantly correlated. This suggests that as the car’s lane position shifts increasingly closer to the adjacent lane of oncoming and passing traffic, crashes occur more frequently. Finally, steering RT was significantly correlated with number of crashes.

Table 1

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**p<.01, *p<.05.**
crashes indicating that as steering RTs become slower, the number of crashes increases.

To assess whether sample differences in gender, age, and sleepiness significantly influenced any of the driving performance variables, a series of analyses were conducted. First, it was determined that in addition to the significant group differences found for gender and age, the depressed group (M=9.2, S.D.=3.9) exhibited higher levels of general, on-task sleepiness as measured by the ESS when compared to the control group (M=6.6, S.D.=3.2), t(45)=2.51, p<.05. Thus, gender, age, and sleepiness scores were analyzed. Gender was not significantly related to any of the driving variables of interest, specifically road position, r(45)=1.13, p=.26, speed, r(45)=.21, p=.84, speed deviation, r(45)=.20, p=.84, steering reaction time, r(45)=1.61, p=.11, and number of crashes, r(45)=.84, p=.40. In contrast, bivariate correlation analysis revealed that age was significantly associated with both steering reaction time r(45)=.37, p<.01, and number of crashes, r(45)=.31, p<.05. Level of sleepiness was also associated with the driving variables of speed, r(45)=.31, p<.05, and speed deviation, r(45)=.32, p<.05. Therefore, age and sleepiness, but not gender, were included as covariates in the subsequent multivariate analysis.

3.2. Main analysis

To assess for group differences in driving performance, a mixed model repeated measures analysis of covariance (ANCOVA) was conducted with each of the driving simulator variables entered as dependent variables (Using SPSS v. 13.0). Age and sleepiness scores were entered as covariates. Group differences were investigated using the F statistic and effect sizes were calculated using eta-squared (η²) values. Effect sizes of .138, .059, and .010 when using eta-squared (η²) are considered to be large, medium and small, respectively (Cohen, 1988).

Table 2 summarizes the results obtained for the depressed and control groups on the five performance variables recorded by the driving simulator. Analyses revealed a significant multivariate effect for depression on steering reaction time. More specifically, across time-of-day participants with a diagnosis of MDD experienced significantly slower steering RTs when compared to control participants. This difference was characterized by a medium effect size. No significant multivariate effects were present for the driving variables of road position, speed, or speed deviation. Interestingly, there were no significant time-of-day effects present for any of the driving variables. There was also no group by time-of-day interaction for any of the driving variables. As these omnibus within-subjects and interaction analyses did not yield any significant results, no further time-of-day effects were examined.

To further explore the relationship between depression, slowed steering RT, and increased crashes, bivariate correlation analyses were conducted using the depression scores obtained on the BDI. This afforded an assessment of whether the severity of depressive symptomatology affected simulated driving performance. Only BDI scores for the MDD sample were included in this analysis to examine the effect of depressive symptom severity within a clinically diagnosed episode of major depression. As well, the steering RT and crash variables were specifically assessed as they were significantly associated with depression in the initial multivariate analysis. No significant relationship was found between BDI scores and RT or BDI scores and crash rate. This indicated that within the depressed sample, depression severity was not significantly associated with steering RT or number of crashes experienced.

4. Discussion

The MDD sample exhibited significantly slower steering RTs and experienced significantly more crashes across driving trials when compared to the control sample. Within the depressed group, severity of depressive symptomatology was not significantly associated with slowed RT or increased crash risk. Furthermore, no significant differences were found for

| Table 2 |
| Driving simulator variables for control and MDD samples |
| Mean (S.E.) | Mean (S.E.) | F | η² |
| Road position | 29.20 (.82) | 28.55 (1.09) | .19 | – |
| Speed (km/h) | 89.12 (1.20) | 89.80 (1.58) | .10 | – |
| Speed deviation (km/h) | .71 (1.18) | 1.15 (1.56) | .04 | – |
| Reaction time (s) | 1.04 (.07) | 1.30 (.09) | 4.09* | .087 |
| Crashes | 1.14 (.66) | 3.83 (.87) | 5.16* | .107 |

Note. Adjusted means based on covariate model reported. MDD=Major Depressive Disorder. η²=Eta Squared. * p<.05.
road position, speed, or speed deviation, nor was there a statistically significant time-of-day effect.

The finding of overall slowed steering reaction time is consistent with past research associating depression with RT deficits on cognitively effortful tasks (Hasher and Zacks, 1979; Hammar et al., 2003). The driving simulator resembles real-life driving in that cognitive resources are spent both in monitoring and attending to multiple driving sub-tasks such as controlling speed, on-road positioning, and adjusting steering in response to environmental obstacles. From this perspective, it is possible that the slowed RT resulted from depression-related impairments in allocating cognitive resources amongst various cognitively complex driving subtasks. Support for this possibility comes from Dreery and Fildes (1999) who reported that drivers characterized by depressive symptoms were the least proficient in completing a cognitively challenging subtask while driving.

In light of the finding of slowed steering RT it is not surprising that the depressed group also experienced significantly more crashes than the control group. Logically, the group exhibiting slower steering RTs would also display an elevated risk of accident because the slower initiation of corrective steering maneuvers would increase susceptibility for collisions. This is consistent with past research associating slowed foot RT with crash risk (Margolis et al., 2002), and case studies (Rubinsztein and Lawton, 2004) and empirical work (Selzer et al., 1968) associating depressive tendencies with motor vehicle accidents.

When the relationship between major depression, slowed RT, and increased crash rate was explored along dimensional lines, the severity of depressive symptoms did not correlate with the level of impairment. This indicates that while the ‘yes’ or ‘no’ categorical diagnosis of MDD was a significant predictor of decrements in steering reaction time and increased on-road collision risk, variation of symptom intensity within a categorical MDD diagnosis was not a significant factor. This is an interesting finding given that past research has associate elevated BDI scores with the increased likelihood of psychomotor retardation and agitation (Schotte et al., 1997). It is important, therefore, to note that the current depressed sample featured BDI scores ranging from a minimum of 15 to a maximum of 55, with an average score of 27.4. Thus, generalization may be specific to MDD populations featuring a similar range and level of symptom intensity.

Conceptually, vulnerability for driver error fits with the characterization of depression as a disorder marked by indecision, impaired concentration, and disturbances in motivation. This pattern of symptomatology is often related to a preoccupation with worrying or melancholic thoughts which can translate into attentional lapses when dividing attention between multiple subtasks such as checking blind spots, controlling speed, and changing lanes. Indeed, research has associated rear-ending collisions and right-of-way violations with driver indecision possibly caused by failures in driver attentiveness or a low motivation for on-task observation (Parker et al., 1995).

One of the advantages of the present study was that it afforded control of everyday sleepiness. Many distinguishing features of MDD are related to alertness, including insomnia, hypersomnia, a loss of energy, and feelings of chronic fatigue (APA, 1994). Furthermore, approximately 20% of automobile accidents are sleep-related (Horne and Reyner, 1995). It is important to note, therefore, that the MDD sample exhibited impaired RT and a greater crash risk even after controlling for general, everyday sleepiness.

No time-of-day effects on driving performance were found. This was noteworthy given that MDD is often characterized by diurnal variation of mood; however, as the present results suggest, it does not necessarily follow that time-of-day fluctuations in driving performance would also be present. Furthermore, marked diurnal mood variation is not invariably present in MDD and when present tends to be idiosyncratic with patterns unique to the individual patient (Carpenter et al., 1986). This may explain the absence of a time-of-day effect.

An interesting line of future investigation would be to assess the driving performance of depressed patients in remission to examine whether performance deficits reflect a trait-related or state-related impairment. Recent studies on remitted depressed patients have found continued performance deficits in visual information processing, general psychomotor performance and spatial working memory (Weiland-Fiedler et al., 2004). This suggests that driving-related psychomotor deficits may persist following the remittance of a depressive episode.

There were a few limitations associated with the current study. First, in an effort to minimize the potential influence of anti-depressant medication on psychomotor performance, depressed participants undergoing anti-depressant treatments were excluded. Current findings, therefore, might not generalize to medicated depressed patients. Second, the data collection phase of the current investigation took place over many months, during which time multiple participants operated the driving simulator. It is possible that the repeated usage of the simulator led to slight differences in the driving
experience from the first to the final driving participant (e.g.: gas peddle pressed with more ease). However, this unlikely significantly influenced results as research technicians frequently calibrated the simulator. Finally, the driving course consisted of a 30-min rural highway drive with few passing cars, changes in speed limits, or pedestrians. This rural scenario presented a relatively uneventful route compared to possible urban driving experiences. Varying the driving scenario as well as the type and frequency of obstacles would be valuable for generalizing results to both highway and city driving and urban and rural settings.

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