Implications of dysphoria on driving ability
A study using a driving simulator paradigm

Kenny Skagerlund

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Supervisors:
Ulrich Olofsson
Rita Kovordanyi
Abstract

The project of enhancing traffic safety is a continuous effort that will not cease in its aspirations. In fact, as technology evolves and additional digital artifacts are implemented into our cars, the attention to traffic safety becomes even more important. Driving a car through urban and rural environments is a cognitively challenging task that especially tax attentional resources, and as more artifacts compete for our attention during driving, the adherence to traffic safety is vital. Thus, factors that influence driving ability, such as sleep, nutrition and – perhaps - emotions are of great interest. An earlier study by Bulmash et al. (2006) hypothesized that individuals with Major Depressive Disorder would perform worse than controls in a study using a driving simulator; their hypothesis was confirmed. The purpose of this thesis is to investigate whether dysphoric individuals show reduced driving performance relative to controls. The notion of dysphoria refers to mild depression in a non-clinical sense. This was investigated using a driving simulator that measured Lateral Positioning (Standard Deviation of Lateral Position - SDLP) on the road, Brake Reaction Time (BRT) and performance on a secondary task (Peripheral Detection Task - PDT). Dysphoric individuals were identified using the Major Depression Inventory (MDI). The hypothesis was partly confirmed, as dysphoric individuals did indeed show more variable positioning on the road. However, performance differences on PDT and BRT were not significant. The results indicate that the negative influence of mood on driving ability is not a discrete phenomenon primarily manifested in individuals with clinical depression, but is rather a continuous phenomenon. The results should be of special interest to clinicians that evaluate individuals with depressive tendencies, as well as the academic community in general since the insights into the impact of emotions on cognitive performance are inconclusive and still not clearly understood. These results might also be of interest in other domains of high complexity, where human performance is of great importance, such as Command and Control, nuclear power plants and control rooms in general.
Acknowledgement
First and foremost I would like to thank my supervisors, Ulrich Olofsson and Rita Kovordanyi, at Linköping University. Their expertise on the subject investigated in this study proved invaluable to me, as well as their general support throughout the project. Many thanks go to Skyltfonden that provided funding of this project, thus making it possible to complete. I am also indebted to a friend and fellow student, Tomas Lundqvist, for his fruitful input and comments.
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1 Introduction

Traffic safety is an issue that is of imperative importance in today’s modern society, where ongoing improvements and studies are conducted to improve the safety as much as possible for the people situated in the traffic environment. Traffic situations are complex by nature, where massive amounts of visual information have to be processed and where humans have to attend to relevant elements in that information-heavy environment. Not only do humans have to attend to those elements, but they also have to do that as quickly as possible in order to avoid becoming a traffic liability. Furthermore, this complex environment is evermore evolving and becoming increasingly more complex as a result of the leaps made in the development of new technologies and artifacts, thus heightening the requirements of cognitive resources of humans. With this fact in mind, it becomes important to attend to the issue of traffic safety even more, and to study how this technological development will affect humans and their driving ability. Numerous studies have been conducted to study the effects of alcohol and sleep deprivation in relation to driving ability, but few studies have focused on emotional aspects and their impacts on driving ability.

Depression is a serious mental disorder that brings about several adverse implications in various areas of a person’s life; work, social relations and physical health can all be compromised. Different psychological aspects might be influenced, where cognitive abilities do not remain unaffected. Earlier studies have shown that, in particular, reaction time, decision making and attention are examples of cognitive abilities that are significantly influenced by depression (Lemelin & Baruch, 1998). Investigating the effects of depression on cognitive abilities, however, is an intricate and taxing endeavor since the effects of eventual antidepressants on individuals might affect the same abilities being investigated in the first place; hence those antidepressants might constitute a confounding variable. Earlier studies that have explored the relationship between depression, reaction time and driving ability, have measured this using a steering wheel and the time required to react to a hasty traffic event. Results have indicated that depressed individuals do in fact react slower than non-depressed individuals (Bulmash et al, 2006).

Curiously, there haven’t been any studies that have explored the possibility that non-clinical and non-severe depression – i.e. dysphoria – also can show the aforementioned relationship to reaction time and driving performance. It may be an eventuality that this kind of cognitive performance is correlated in a continuous manner, rather than as a discrete phenomenon primarily existing in clinically depressed individuals. Thus, this study has focused on exploring that contingency by applying similar principles and
research designs used in prior studies that have focused on depression while instead exploring the effects of dysphoria on cognitive abilities in a traffic environment. One favorable upshot of investigating dysphoria is the absence of antidepressants affecting the performance of the individuals in the study.

1.1 Purpose
This study has been conducted with the intention of exploring how dysphoria affects driving ability. Thus, it has delved into the possibility that not only clinically depressed individuals display poorer results on cognitive tests and resulting driving ability, but that even people of less severe negative affective states of mind - i.e. dysphoria – will exhibit impaired performance compared to controls in the same vein. The notion of dyshoria, as used in this study, regards individuals that do not fulfill the criteria to be diagnosed with depression as stipulated in the Diagnostic and Statistical Manual of Mental Disorders IV (DSM IV), but still reach a score of 43 on the MDI-questionnaire which is a standardized questionnaire used to diagnose cases of depression. The research questions and hypotheses are explicitly expressed below.

1.2 Research questions
Do dysphoric individuals display an impaired driving performance in a simulated traffic environment compared to controls? This research question generates the following hypotheses:

A) Dysphoric participants will show a longer reaction time than controls when braking as response to a car’s sudden deceleration situated ahead of the participant in the traffic.
B) Dysphoric participants will receive a longer reaction time than controls on the secondary task – peripheral detection task (PDT).
C) Dysphoric participants will have higher standard deviation of lateral position (SDLP) than controls.

The research questions formulated above all correspond to a respective performance measure. These performance measures assess overall driving ability, and respective measures could potentially be affected by depression and/or dysphoria since cognitive abilities such as attention, motor control and decision making are involved in actions that the performance measures are estimating. The peripheral detection task, for example, is a visually-based choice-reaction task involving fast motor reactions as well as load on attentional resources (Lemelin & Baruch, 1998). Thus, this particular kind of task is of interest since these cognitive abilities are influenced by depression.

1.3 Delimitations
There are innumerable ways to operationalize and measure driving ability where, due to time and complexity, one has to select a few and disregard others in order to have a feasible research design. Thus, three performance measures were chosen that had good face validity and had been used extensively in prior research. The respective measures are mentioned in the above section and will be further accounted for in section 3.2.1

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1 The DSM IV is the main diagnostic tool, compatible with the aforementioned MDI-questionnaire, used worldwide by psychiatric practitioners and was hence used as reference during this study.
1.4 Method
An electronic questionnaire was sent out to several student programs at Linköping University. The questionnaire consisted of a sample of two central items taken from the Major Depression Inventory (MDI), which served as a tool to roughly estimate the probability that the individuals could be classified as dysphoric on a test session of the MDI in its entirety. The purpose of this avoidance of completing the entire MDI was to save time for the individuals and thereby hopefully maximize the number of respondents. Another reason for this was to avoid the possibility that severely depressed individuals got a hold of this MDI, filling it out by themselves which might provoke and facilitate even more depressed emotions and thereby making them feel even worse. Individuals whose response indicated a likelihood of being dysphoric was invited to participate in the study and be included in the experiment group. Participants to be included as controls were selected in an identical fashion. The participants then participated in the experiment and completed the simulator tests, which consisted of highway driving that simulated a Swedish, rural environment. The participants were instructed to follow a car, and while traversing along the road the performance measures actively and continuously gathered participant data. Right before the participants began the session in the simulator, they filled out the complete MDI; the rationale being that this served as a tool to divide and screen the participants into respective group based on the answers given. The groups were then compared using a between-group design.

Driving performance was measured using the following measures: Brake Reaction Time (BRT) – the time it takes, in milliseconds, for a participant to brake as a response to the leading cars’ hasty deceleration serving as a stimulus. The second measure was the standard deviation of lateral position (SDLP), which basically is the standard deviation of the position within the car lane. The final measure was a secondary task: peripheral detection task (PDT) which measure the time it takes for the participant to press a button as a response to a visual stimulus in the peripheral visual area located next to the road.

1.5 Disposition
The report consists of this introduction, where the next part will serve as background material that elaborates on some relevant concepts vital to this study. The theoretical concepts are depression, dysphoria and cognitive aspects of these affective states. The ensuing part will clarify the method used, taking a closer look at the simulator paradigm and MDI, where subsequent results and discussion will be presented.
2 Theoretical background
The theoretical background will mainly focus on presenting the notion of depression as a psychological concept and how dysphoria relates to it. The presentation consists of a brief overview of the concept, whereby cognitive effects that follows from depression will be presented alongside an orientation of some prior studies of depression and cognition.

2.1 Depression and dysphoria
Depression is a mood disorder that can manifest itself in many different forms and guises, but there are two general forms of depression: major depressive disorder and bipolar disorder. Bipolar disorder will not be further elaborated in this report, set aside some rudimentary definitions below. The prototypical form of depression, the form of depression the general public mostly identifies with the term 'depression', is called major depression in clinical terms. A person suffering from major depression is said to have a major depressive episode, where a person fulfill at least five out of following nine criteria: (DSM IV, 2000)

- Depressed mood lasting entire days, most of the days.
- Radically diminished interest and diminished joy for everyday activities.
- Marked weight change and/or change of appetite.
- Insomnia or hypersomnia.
- Psychomotor retardation or agitation.
- Fatigue and lack of energy almost every day.
- Sense of worthlessness and unjustified feelings of guilt.
- Reduced ability to think clearly, indecision and difficulties concentrating.
- Recurring thoughts about death.

Holmes (1997) highlights that depressed individuals in a current depressive episode experience emotional, motivational and cognitive dysfunctions rendering them unable to find joy or satisfaction from everyday activities, hobbies and other recreational activities. People suffering from depression initiate actions by themselves to a lesser extent than non-depressive individuals and it is not a rare finding that they isolate themselves and avoid the company of others. According to Holmes (1997), symptoms such as slow speech and slow body movements are common as well as co-occurring slow rate of thought, which in effect will compromise and influence problem solving abilities.

Mood disorders are divided into two categories, where one of them is the aforementioned major depression. The second one is called bipolar disorder, which is also characterized by depressive symptoms. However, other symptoms of non-depressive nature accompany the depressive features in this disorder. Bipolar disorder is also characterized by episodes of mania, where an individual alternates between episodes of mania – periods of extremely elated mood and activity – and episodes of severe depression. (Ibid, 1997)

An individual might also display less severe depressive symptoms that stretch over
longer periods of time than with regular major depression. If an individual suffers from this prolonged state of mind for more than two years, that individual might be diagnosed with dysthymia. Bipolar disorder also features another less severe variation called cyclothymia that also is characterized by prolonged duration. (ibid, 1997)

See figure 1 below to receive an overview of the mood disorders and their relation to each other.

![Mood Disorders Diagram](image)

**Figure 1. An overview of the relation between the mood disorders**

Apart from the disorders and their respective variations mentioned above, DSM IV also distinguishes between several specifiers that further subdivide the nature of the disorders into even more intricate and specific state of affairs working as an attribute. This works as an instrument to further characterize different types of depressive episodes. An example of a specifier can be ascribed to a woman that has just given birth to a baby followed by an onset of a depressive episode. This woman might then be diagnosed with major depression with postpartum onset, or simply 'postpartum depression'. Another significant specifier is that of ‘melancholic features’. A person diagnosed with depression with melancholic features displays several stereotypical symptoms of severe depression, such as waking up very early in the morning unable to go back to sleep, feeling miserable during the entire day and suffering considerable loss of weight and appetite. Other melancholic features are substantial feelings of guilt and
hopelessness towards other people and life in general. Another salient feature of melancholy is that victims are completely unable to extract joy, satisfaction and appreciation from life events – even those that are intrinsically positive. (DSM IV, 2000)

The term ‘dysphoria’ has not gained much attention in the academic community since it is not as malevolent as depression and is not a clinical disorder. Hence, there is no consensus on how to define the term properly. In this report, however, dysphoria refers to a mild form of depression that is not a qualitatively different phenomenon in itself, but rather seen as quantitatively different in degree. Thus, in this report, the same mechanisms are assumed to be the cause for the development of dysphoria as in depression, as well as the apparent consequences on cognitive and sociocultural factors described in more detail below.

2.1.1 Prevalence
The prevalence in the general population of Europe is estimated, according to Holmes (1997) to about 5% at any given time. Approximately 17% of the population in Europe will experience a depressive episode some time in their lives. Half of the cases of depression are dealt with during the first three months and women are twice as likely as men to be victims of depressive episodes.

2.1.2 Models and causes of depression
There are indications that the prevalence of depression has a genetic factor, which studies of twins support (Holmes, 1997). The concordance rate between monozygotic twins has been estimated to 46%, whereas a mere 20% of dizygotic twins are estimated to suffer from depressive episodes sometime in their lives. Neurobiological mechanisms are thought to be a highly influential factor and cause of depression, where especially the interaction between the neurotransmitters serotonin and norepinephrine are main contributors and influences on mood. Rampello et al. (2002) claims that negative mood follow as a consequence of the imbalance between serotonin, norepinephrine, dopamine and acetylcholine.

Beside the biological model of depression, there are models of sociocultural causes that point to the fact that the prevalence of depression is higher in populations residing in economically disadvantaged situations while also higher in populations constituting ethnic minorities in society. Other stressors such as deceased relatives, separations and the like are also factors that might contribute to the inclination of depressive episodes (Holmes 1997).

One cognitive model of depression, developed by Abramson, Seligman & Teasdale (1978), asserts that depression is a result depending on the response to both positive and negative events, evaluated from three attributes:

- Is the cause of this event internal or external? That is, are internal or external factors responsible for this event?
- Will this event occur every single time, or is it changeable or random?
• Is the consequence of this event always going to follow, or does it follow sometimes?

According to Abramson et al. (1978), a depressed individual will ascribe negative events only to him- or herself, that this consequence always entails the event and that the event will happen indefinitely. In the same vein, the individual will ascribe positive events to external factors, randomness and that the positive event will not happen again. There are some empirically valid support, where studies have shown that this pattern of thinking do correlate with the prevalence of depression, although one cannot conclude that this cognitive pattern of thinking causes depressive states.

Another influential model within the cognitive framework is the “cognitive triad” developed by Beck (1970). The cognitive triad consists of thoughts about the self, events or people around us, and the future. These three aspects are subject to negative thoughts made in a manner of routine that are generalized, simplified and dichotomous in nature. The essence of this model share many similarities with the cognitive model mentioned above. Beck asserts that a depressed individual is influenced by an unconscious negative schemata made up of beliefs and statements about the world and him- or herself that are molded in childhood. For example, these kinds of schemata are subject to change in childhood caused by traumatic events that later might blossom in later adulthood by an event of similar character.

2.1.3 Treatments of depression

The typical treatments of depression can be divided into three categories: medication using antidepressants, psychotherapy and electroconvulsive therapy (ECT). These will be briefly elaborated below.

Prescribed antidepressants that are used to treat depression can be divided into two distinct types, depending on the mechanism in the central nervous system as well as the chemical compound of concerned substances (Holmes, 1997). The mechanisms of tricyclic substances are not unequivocally understood, but theories include the belief that tricyclics inhibit the reuptake of norepinephrine and serotonin in the neurons. Tricyclics are believed to be fairly effective, where about 60% of depressed individuals using this type of medication claims that the mood has been elevated as a result of the medication. Side effects such as dry mouth and fatigue are rather common accompanying the use of tricyclic medication. Another type of substance – SSRIs (selective serotonin reuptake inhibitors) – are claimed to have fewer side effects as well as less severe ones in contrast to tricyclics, which has resulted in an ever more growing and widespread usage since they are nearly as effective as tricyclic substances (ibid, 1997). As the name suggest, these antidepressants works by inhibiting the reuptake of serotonin in the neurons.

Beck (1976) developed a therapy method, named “cognitive therapy”, tailored to apply to depressed individuals. This method includes several behavioral elements, where Beck emphasizes change of thought patterns as well as activation of social behaviors as a key to successful therapy. The client is encouraged to challenge his own thoughts and try to realize the often irrational train of thought characterized by catastrophic scenarios and
generalizations. This ongoing therapy is accompanied with assignments, often using different kinds of homework assignments, to plan different joyful activities.

ECT – electroconvulsive therapy – is a controversial therapy method ordained as a last resort for those clients responding to neither psychotherapy nor antidepressants and who suffer from extreme forms of depression. ECT is a method where the client is administered a series of electric shocks, which is thought to be a quite effective short term solution but is not preferred as a long term treatment as it might have malevolent implications. (Holmes, 1997)

2.2 Depression and cognitive abilities

Besides the self reported cognitive impairments that depressed individuals tend to experience, such as self-reported inability to think clearly in general, several studies has identified several specific cognitive abilities that might be affected and not rarely in unison. If those specific mental impairments are co-occurring following a depressive episode, then that might indicate signs of psychomotor retardation. Psychomotor retardation is, in itself, one of the most common and recognizable symptoms of depression according to Nelson & Chaney (1981). Methods measuring reaction time has been devised to be used as tools to diagnose psychomotor retardation, where depressed individuals do not perform as well as non-depressed controls as has been shown by Bruder, Yozawitz, Berenhaus & Sutton (1980).

The notion of psychomotor retardation implies two separate fragmentary components that together are the building blocks of the overarching concept – psycho and motor. This entails the fact that there is assumed to be one cognitive aspect and one motor aspect that together form the retardation and might be measured separately using clever time measures. This can be performed by measuring the time it takes to initiate a response to a stimulus whereby the time it takes to complete the response action is assumed to be a valid measure of motor ability. Byrne (1976) applied the aforementioned methodology to a series of tests on depressed individuals as well as on healthy controls, where the results came back in favor of healthy controls on both the cognitive aspect as well as the motor aspect. However, the division of cognitive and motor aspects and the measurements used are naïve and need reconsideration and revising according to Cornell, Suarez & Berent (1984). That conclusion is made due to the apparent simplified and outdated view that cognitive and motor components are executed sequentially and not in parallel which is now a much more plausible proposition. They believe, rather, that one can only infer in relative terms and to what extent the cognitive and motor components contribute to psychomotor performance. Cornell et al. instead assessed the relative contributions to psychomotor performance by systematically varying the cognitive and motor demands on a given task while holding the other constant. This methodology was used to assess to what extent the different components affected the reaction time in subjects diagnosed with depression with melancholic features and subjects diagnosed with depression with nonmelancholic features in relation to healthy controls. They concluded that only depressed subjects with melancholic features showed a cognitive deficit as well as motor deficit, whereas nonmelancholic depressed individuals only displayed a motor impairment. Taken together however, Cornell et al. (1984) has shown that depressed individuals did
perform worse as a group in relation to healthy subjects on overall reaction time.

Psychomotor retardation also involves more explicit and publicly observable symptoms such as slower movement speed and slower speech. The ability to initiate and execute actions is impaired as well as reactivity to stimulus. (Widlöcher, 1983) Hartlage et al. (1993) found that the performance of the cognitive abilities was impaired as function of load on attentional resources. The more allocation and division of attention needed between tasks and the more attentional resources needed on one single task, the worse depressed individuals performed. A contemporary view is that attention plays a major role and is a central component of the cognitive impairments that might be displayed by depressed individuals. The fact that depressed individuals seem to perform on par with non-depressed individuals on tasks measuring simple reaction time, but significantly worse on attention heavy tasks involving choice reaction time such as the Stroop test seems to support this claim according to Lemelin & Baruch (1998). Moreover, Lemelin and Baruch (1998) have proposed some hypotheses about the nature of the connection between depression and attention deficit. They present some studies that has collocated neurological and psychiatric data that indicates that prefrontal cortex and activity carried out in that area seems to be inhibited in individuals diagnosed with depression with melancholic features. Prefrontal cortex plays a pivotal role in managing the executive functions such as divided attention and action initiation, thus probably constituting a prominent factor in the performance impairment on attention related tasks such as the Stroop test displayed by depressed individuals. According to Lemelin & Baruch (1998) even depressed individuals that do not meet the criteria for psychomotor retardation perform less well than controls on tasks measuring divided attention.

Another possible cause of the displayed performance impairment in individuals suffering from depression is the fact that depressive individuals tend to ruminate and concentrate on self-focused thoughts, which diverts attention from more pressing tasks at hand. This possibility has been shown to impair performance on a range of memory tasks, such as in Hertel (1998), making it a plausible cause of displayed performance impairment in people with dysphoria as well.
3 Method
This section presents the general methodology, ranging from topics such as the simulator paradigm as such, as well as the performance measures used in the study. A brief description of the participants and the process of inclusion and exclusion of the participants is also presented.

3.2 Simulator paradigm
The simulator is based on a PC-platform and is hence implemented on two personal computers running a Windows operating system. The software used consists of a program used to model simulated worlds that a client can connect to and engage in. Connected to the PC one can find a composition of devices, namely a steering wheel, pedals and a gear stick manufactured by Logitech (see Fig. 2.). The participant is seated in a genuine car seat placed in front of three 32” monitors with the driving apparatus placed in a manner as to match reality as much as possible. This study, however, did not make use of the featured gear stick as it was judged to be placed in a too inaccurate position to be represented in an adequate manner. The simulator system is named “Desktop T&D” and is developed by ST Software BV.

![Figure 2. The driving simulator](image)

The simulator part of the study was divided into two parts, where the first part mainly consisted of a five minute test drive. During this trial the participant gets the chance to familiarize with the devices as well as the physics engine implemented into the
simulator world. During the five minute trial, the participant is instructed to follow a lead car preprogrammed to drive on a rural highway. The actual test follows after the test drive is completed, whereby the participant is instructed to drive 20 minutes on a highway identical to the one previously completed with an identical lead car. Several variables are being recorded in a continuous manner throughout the driving session, while a few of these variables are the performance measures previously mentioned. These performance measures are further described below.

### 3.2.1 Performance measures

**Brake reaction time (BRT)**
The participant is continuously following a lead car. Intermittently, the lead car will brake hard when certain criteria are fulfilled, such as time and distance to the lead car, forcing the participant to brake hard as well. The brake lights of the lead car will serve as the stimulus from which the variable is being measured. The reaction time is measured in milliseconds from the point of stimulus presentation – the brake lights – to the participant’s physical appliance of the brakes. The color and appearance of the lead car remained constant, to keep the visual saliency of the brake lights constant for all participants.

**Lateral position (SDLP)**
Data was collected and measured using the centre of the car as reference point which was compared to the position in relation to the right driving lane’s geometrical middle. This variable was gathered continuously throughout the entire driving session where the standard deviation from the reference point was calculated as a performance measure.

**Peripheral Detection Task (PDT)**
This measurement consists of a visual stimulus being presented on either side on the road in the peripheral visual area. The stimulus is composed of a red square measuring 2 x 2 centimeters. When the participant attends to and identifies this stimulus the task is to apply the corresponding lever located right behind the wheel. For example, if the stimulus is presented on the right side of the road, the participant should apply the right paddle. The reaction time in milliseconds is measured in this choice reaction time task from the point of stimulus presentation to the point where the participant applies a paddle, regardless if it is the correct paddle or not.

### 3.3 Major Depression Inventory (MDI)
The MDI was used to assess the probability that a certain individual is dysphoric and hence served as a criteria to be fulfilled by the participant as to be included in the study. The MDI is a questionnaire containing 10 items where two items are further subdivided into one subsequent item each, making it to a total of 12 items. All the items fit on one page, which is filled out by the participant prior to the simulator session. The items all correspond to symptoms and terminology used in the DSM IV, except for one item concerning self-esteem which – in the DSM IV – is incorporated in the item regarding guilt. During the preliminary screening of probable research participants featured online
via e-mail, only two items were selected to be used rather than the entire questionnaire. These two items were not randomly selected, but was chosen due to the essential nature of them; they are necessary and central symptoms of depression, thus judged to be sufficient. The MDI has proven to be both a reliable and valid assessment of depression (Olsen et al, 2003). The MDI used in this study was slightly modified, where minor alterations such as translations from English to Swedish were trivial. Questions regarding driving frequency and gaming frequency were added, as can be seen in the attached modified MDI in the appendix. One modification that was not as trivial as the previous ones, was the decision to eliminate question 6. This question regards suicidal tendencies, and the literal inquiry is as follows: “Have you felt that life isn’t worth living?”. Due to ethical concerns, this question was ruled out. Both the MDI and the modified MDI can be found in the appendix.

3.4 Participants
The participants, N=15, were exclusively university students recruited through e-mail and the featured questionnaire. The participants were all between 20-36 years of age with a mean of $\bar{x}=24.8$ ($SD = 4.6$) where 10 were female and 5 male. A necessary requirement for the participants was the possession of a driver’s license. The participants were also required to be of good health, not taking any antidepressants or any other medications with cognitive implications, in which case they would have been excluded. The familiarity with video games was a variable controlled for as well as length of driving experience. 5 participants were deemed to be dysphoric after completing the MDI and hence constituted the experiment group leaving 10 individuals to be included in the control group. The participants were not permitted to drink caffeinated beverages prior to the experiment session. After completing the session, the participants were given one movie ticket following a debriefing with the possibility of asking questions about the study.

3.5 Material
An electronic questionnaire, containing two items from the MDI, was used to give a preliminary indication of dysphoria in the pool of students available. Prior to the actual simulator session the MDI was used in its entirety to assess the mood of the participants. The MDI can be found in the appendix. The simulator was built on a PC platform which rendered the simulator world created solely for this project using built-in software, with hardware consisting of a set of devices from Logitech – a driving wheel, a gear stick, pedal platform – complimented by a driver’s seat. The simulator world was rendered onto three 32” Samsung monitors placed in front of the seat.

3.6 Procedure
Each participant completed the experiment session in a simulator room located at Linköping University. Due to the fact that people have different circadian rhythms, it was decided that each session was to be conducted between 10.00 and 17.00 in order to rule out any performance anomalies that could be attributed to the time of day. The sessions were completed individually, one participant at a time. The participants began
with the MDI questionnaire on paper, this time in its entirety and not merely the two questions used in the electronic screening process. The rationale behind this process was to assess the actual MDI index, to see whether the mood of the individual had changed during the time that had elapsed from initial preliminary estimation to the day of the experiment. After completion of the questionnaire the actual simulator session took part. The participant was instructed to take a seat in the simulator whereby written instructions followed that explained the practice trial. The practice trial on the rural highway was over after five minutes had elapsed, whereby the live experiment began. The main part of the experiment consisted of 20 minutes of continuous driving on the same highway environment previously encountered in the practice trial, where the performance measures were gathered as data throughout the remaining session. This session featured a rural highway milieu exclusively, where the participant had to follow the lead car throughout the entire session. During the session, the lead car frequently accelerated and decelerated in order to acquire a dynamic distance between the cars resulting in the need for the participant to brake. After completion of the session, the participant was given the opportunity to ask questions over a cup of coffee as well as earning a movie ticket.
4 Results

The participants were divided into "dysphoric" and "non-dysphoric" groups, where non-dysphorics served as controls, on the basis of the results from the MDI. Subjects that had provided a rating of 3 or lower to at least one of the first three (diagnostic) questions of the MDI as well as total score of 42 or less were assigned to the "dysphoric" group. There were a total of 5 participants with a total score of 42 or less (mean age = 22.8, SD = 2.17). Participants with a score of 52 or higher were selected to the control group (10 participants, mean age = 25.2, SD = 4.57). Three participants with scores ranging from 44 to 48 could not readily be classified as "dysphoric" or "non-dysphoric" and were excluded from further analyses. The performance measures were analyzed using independent sample t-tests. Prior driving experience was also analyzed using t-test to ensure equality between the samples. A Mann-Whitney U test was used to analyze computer gaming frequency and weekly driving frequency. The results from the performance measures and controlled variables are displayed in the tables below.

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<td>Dysphoric</td>
</tr>
<tr>
<td>Brake RT</td>
</tr>
<tr>
<td>Control</td>
</tr>
<tr>
<td>Dysphoric</td>
</tr>
</tbody>
</table>

The results indicate that the variability in lateral position (SDLP) was significantly larger for the “dysphoric” group, \( t(13) = 2.36, p < 0.035 \). The data from the peripheral detection task (PDT) did not, however, show any significant difference \( (p > 0.05) \). Although the mean Brake RT was higher for the dysphoric group, it was not statistically significant \( (p > 0.05) \).
Table 2. Years with drivers license

<table>
<thead>
<tr>
<th>Years w. drivers license</th>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Control</td>
<td>10</td>
<td>6.60</td>
<td>4.86</td>
</tr>
<tr>
<td></td>
<td>Dysphoric</td>
<td>5</td>
<td>3.80</td>
<td>2.78</td>
</tr>
</tbody>
</table>

The data from the controlled variables showed no significant difference across the samples. Years with drivers license was non-significant \( (p > 0.05) \). Weekly driving frequency and computer gaming frequency was analyzed using the Mann-Whitney \( U \) test and showed no significant difference across the samples \( (p > 0.05) \).
5 Discussion

Although not all the hypotheses were confirmed, dysphoric individuals did indeed perform more poorly on the lateral position measure which serves as a measure of driving ability. These results will be discussed as well as the practical implications of said results below. Some methodological considerations and concerns will also be addressed in the method section in order to highlight aspects that can be improved in future studies on these particular hypotheses and related research questions.

5.1 Results

The prediction was that dysphoric individuals, due to mild impairments on attentional resources, would not perform equally as good as non-dysphoric controls on measures of driving ability. This prediction was partially confirmed, where dysphoric individuals exhibited more variable positioning within the car lane than controls whose positioning was more stable. According to the results on the PDT, there was no significant difference between the two groups. This particular measure and its results are interesting, especially since this measure *prima facie* should be implicated if attentional resources are weakened in dysphoric individuals. Remember that the PDT is a choice-reaction task that requires allocation of mental resources to a secondary task, hence dividing the attentional resources which should give rise to undermined performance on that task. On first glance, this might seem perplexing and non-intuitive. Possibly, however, it might be the case that dysphoric individuals carried out this secondary task adequately only to implicate and reduce performance on the primary task – driving itself. This would explain the variability within the car lane. Even if individuals indeed allocated mental resources between tasks, one cannot deduce the resource ratio between those tasks in this study, which might be subject to subjective preferences in individuals. For example, one individual might consider – consciously or not – that the secondary task is quite important and needs to be allocated a given amount of attentional resources; this while another individual considers the same secondary task trivial and allocates his/her mental resources accordingly. This concern about individual preference and uncertainty about allocation of attentional resources is something that should balance out however, given that a sufficient quantity of subjects is included in the study. The point is, rather, that it is hard to predict how the different tasks and measures might influence one another. Further, one should note that the mean reaction times for braking and on the PDT are higher for the dysphoric group than controls; even though it was not significantly so, one might consider it a tendency worthy of additional attention through the use of a higher quantity of participants in a follow-up study.

This study has focused on investigating whether dysphoric individuals perform worse than controls on measures of driving ability. The results indicate that they do perform worse; however, the study has not delved into the deeper question of exactly what cognitive mechanisms are responsible for the manifested driving behavior. It would be interesting to pinpoint the primary causes and investigate whether it is psychomotor retardation or other cognitive deficits – such as self-focused thoughts - that impair performance. Since dysphoric individuals performed worse on lateral positioning, one might be prone to conclude that is a motor aspect that is the primary cause of variable positioning on the road. However, as already mentioned, it is difficult to separate motor processes and cognitive processes. One might imagine that the lack of attentional
resources forces the participant to adhere to the cognitively demanding tasks and as a result perform worse on the motor aspect. Thus, it is difficult to conclude exactly what mechanisms are responsible for the apparent impairment in driving ability in dysphoric individuals. Perhaps some dysphoric individuals have impaired motor responses, whereas some individuals primarily exhibit cognitive deficits. What one can deduce from this study is merely that dysphoric individuals generally perform worse than controls, however it cannot identify the exact causes of that performance discrepancy. Nevertheless, it is an open question that might be investigated in the future.

The relationship between depression and cognitive performance has, since long, been established by, among others, Lemelin & Baruch (1998) and Bulmash et al (2006). However, it has not been considered whether the impairment of cognitive performance is a continuous variable that varies as a function of severity of depression. The results from this study sympathize with that contingency, and perhaps severity of dysphoria correlates with performance. Thus, it seems that the relationship between emotions and cognitive performance is rather complex, and the results from this study suggest that a deficit in driving ability caused by emotional processes is not something that is exclusively present in major depression.

The fact that even non-severe depression noticeably implicates driving performance should be of general interest to concerned parties and authorities, such as the Swedish Road Administration as well as clinicians who are consulted by individuals with depressive tendencies. However, one should be careful in translating the variability in lane positioning, or performance more generally, into increased accident risk. The translation might seem valid at face value, but it remains to be established empirically.

5.2 Method
The method used in this study worked well, which was no surprise since the overall methodology has been used in similar contexts before, such as in Bulmash et al (2006) and Jonsson (2009) and have proven to be productive. There are, however, some evident concerns that might be addressed in order enhance the future prospects of research within this interesting topic.

5.2.1 MDI and screening process
The screening process, with the included MDI and electronic proxy, was generally satisfactory, albeit inefficient. The lack of efficiency was due to the fact that some potential dysphoric individuals that responded accordingly in the electronic questionnaire could at the day of the experiment not be classified as such after completing the MDI in its entirety. The time that elapsed from the moment that subjects filled in the electronic questionnaire, to the time they were in the actual experiment situation could be a couple of weeks. Not surprisingly, the longer the time between test sessions, the higher the probability of variable mood. Thus, the final amount of dysphoric subjects in this study was fewer than initially desired. An alternative approach, which will be used in a follow-up study, is to test individuals in real-time. This might be realized by testing many individuals, perhaps prior to or after a university class, and then send willing and suitable subjects to the simulator task directly. This procedure will ensure the desired amount of individuals, but will be a laborious task in
itself. The upshot is that no time in the simulator will be in vain, which has been the case in the present study where prospective dysphoric individuals turned out to be non-dysphoric.

The decision to eliminate the question regarding suicidal tendencies might seem controversial, and a decision that undermines the validity; however, due to ethical concerns, it would have been even more controversial to include it. It is a rather unfortunate corollary that the validity is reduced somewhat, and the modified MDI should therefore not be used in a clinical setting where instances of major depression is to be assessed. Although with that in mind, it does not seem justified to render the results in this study devoid of any significance. Rather, the results are suggestive and should of course be replicated with the excluded item regarding suicidal tendencies for optimal validity.

To optimize the study and its power, it was decided that three participants would be excluded from the data analysis. The rationale behind this decision was that their score on the MDI could not be clearly classified as either dysphoric or control. Their score constituted a gray area that would diminish the power of the study. The data analysis was made in such a manner as to only include clearly dysphoric individuals in the experiment group and clearly non-dysphoric individuals in the control group. It is important to emphasize that this does not entail that dysphoric individuals were compared to individuals in a positive mood, which in itself would undermine any interpretation of the current hypotheses, since no item on the MDI can be attributed to any positive aspect of mood. The only inference that can be made from the MDI is the presence or absence of depressive tendencies. Given a sufficient amount of research participants, this procedure might not have been necessary. Nevertheless, the current interpretation that dysphoric individuals do exhibit more variable positioning on the road remains as a valid result.

5.2.2 Driving simulators as tools

The simulator used in this study served its purpose to a satisfactory degree. It was a low-fidelity simulator that enabled quick configuration and programming, and without any financial load due to outsourcing and intricate equipment. The driving scenario used in this study was not very complex; the scenario was deliberately designed for simplicity, so as to avoid any confounding variables due to complexity. Intricate driving situations that include pedestrians and animals on the roadside were considered for implementation, but were ultimately abandoned for the reason stated above. Complex events would only interfere and undermine performance measures, such as lateral positioning. Hence, it was intentionally decided to optimize the study in favor of the performance measures rather than give priority to ecological validity. Thus, the results obtained in this study should be replicated using other simulator setups and scenarios in order to generalize to real urban environments. While the simulator used in this study was satisfactory, there is a considerable debate raging in the academic community about simulators and its ecological validity. This concern was investigated by Engström et al. (2005); they compared data collected from a simulator with data from real driving and their findings indicated strong similarities. A breakdown of attention, judgment and vehicle management in a simulator environment therefore predicts the same
characteristic behavior in reality, but is of course no guarantee. If interesting results are found in a simulator study, these should be replicated using other simulator setups and, ultimately, in reality if possible. This fact leads to another concern - the fact that there are numerous different simulator constellations on different software platforms using different hardware. It is therefore imperative that studies thoroughly describe the simulator used, what configuration was running and so on, in order to optimize the probability that genuine, valid results are found and brought to light.

Driving a car in a fast paced traffic environment is a potentially hazardous activity which, in a worst-case scenario, might lead to fatal consequences. Considering the many interesting studies and hypotheses that one can try to resolve, conducting them live in real traffic situations, however, might pose a direct threat to the individuals involved. An alternative approach is to use driving simulators that try to mirror as many aspects of real driving as possible. Today there are numerous different types of simulators, ranging from simple lab settings using game-like features and equipment to complex simulators with moving, hydraulic bases. Technological advances have led to simulators with increasing levels of physical fidelity with the assumption that higher fidelity will generate more valid and accurate results. Östlund, Carsten et al. (2004) reports, however, that the influence of fidelity of simulators on results is miniscule and that minor differences in results between simulators and real driving could be explained by visual and haptic cues. With these elucidations in mind, while taking financial and time-consuming factors into consideration, the choice of current driving simulator in this study was deemed justified.
6 Conclusions
The purpose of this thesis was to investigate the implications of dysphoria on driving ability. To this end, a research design using a driving simulator was developed that mirrored a Swedish, rural highway. The initial hypotheses stated that dysphoric individuals would react slower in response to stimuli in traffic situations, perform poorly on a secondary task that taxes attentional resources, and would display more variable road positioning. Findings include that dysphoria indeed affected driving performance, primarily through variable positioning on the road, perhaps due to strained attentional resources and/or psychomotor retardation and self-focused thoughts. According to the results, it is possible that the relationship between emotions and performance is complex, and that performance is implicated in a continuous manner, rather than primarily existing in emotional extremes such as major depression. This finding is not exclusively relevant within the realm of traffic and transportation systems, but should be taken into consideration in other complex systems where human performance is essential, such as cognitively demanding environments including control rooms, Command and Control, as well as cockpit environments. Nutrition and sleep has been extensively recognized as imperative variables that influence human performance, but with the current results from this study in mind, it seems reasonable to assume that one should not ignore the implications of mood on performance.

6.1 Future research
As already mentioned, future research should maximize the amount of participants and be replicated in other simulator setups with different configuration. Assessment of driving ability using the performance measures used in this study is just one, albeit important, factor that influences traffic safety. Other important factors to investigate further include how dysphoria might influence risk taking and risk evaluation. It would be interesting to investigate whether severity of dysphoria within the dysphoric group, is correlated with – for example – deviation of lane position. The current study focused on a relatively uneventful route through a rural highway, which makes it an intriguing prospect to study the emotional impact in a more complex environment such as city driving, where one might suspect that the implications of mood on human performance are manifested even more. It would also be interesting to investigate the effects of emotions on other abilities than driving; for example, it should be relevant in professional settings where cognitive performance is valued, such as highly complex systems such as nuclear power plants or Command and Control settings. Simulator studies are extensively used in various other domains, making it a sensible prospect to investigate the effects of emotions in those domains.
References


# Appendix

## MDI

![Psychiatric Research Unit Logo](image)

**Major (ICD-10) Depression Inventory**

The following questions ask about how you have been feeling over the last two weeks. Please put a tick in the box which is closest to how you have been feeling.

<table>
<thead>
<tr>
<th>How much of the time ...</th>
<th>All the time</th>
<th>Most of the time</th>
<th>Slightly more than half the time</th>
<th>Slightly less than half the time</th>
<th>Some of the time</th>
<th>At no time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Have you felt low in spirits or sad?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>2 Have you lost interest in your daily activities?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>3 Have you felt lacking in energy and strength?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>4 Have you felt less self-confident?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>5 Have you had a bad conscience or feelings of guilt?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>6 Have you felt that life wasn’t worth living?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>7 Have you had difficulty in concentrating, e.g. when reading the newspaper or watching</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8a Have you felt very restless?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>8b Have you felt subdued or slowed down?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>9 Have you had trouble sleeping at night?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10a Have you suffered from reduced appetite?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>10b Have you suffered from increased appetite?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

*Name:* ____________________________  *Date:* ________________

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## Modified MDI

**Älder:** _____

**Hur många år har Du haft körkort?** _____

- [ ] Kvinna
- [ ] Man

<table>
<thead>
<tr>
<th></th>
<th>4-7 ggr i veckan</th>
<th>1-3 ggr i veckan</th>
<th>1-3 ggr i månaden</th>
<th>mer öllan</th>
<th>aldrig</th>
</tr>
</thead>
<tbody>
<tr>
<td>I genomsnitt, hur ofta kör Du bli under ett år?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I genomsnitt, hur ofta spelar Du bilspel (tv-konsol eller dator)?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Frågorna nedan gäller hur Du känt Dig i allmänhet under de senaste två veckorna**

<table>
<thead>
<tr>
<th></th>
<th>Hela tiden</th>
<th>Större delen av tiden</th>
<th>Drygt halva tiden</th>
<th>Knappt halva tiden</th>
<th>Mindre del av tiden</th>
<th>Inte alle</th>
</tr>
</thead>
<tbody>
<tr>
<td>Har Du känt dig ledsen och nere?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Har Du saknat intresse för dina dagliga sysslor?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Har Du saknat kraft och energi?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Har Du känt minskat självförtroende?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Har Du haft dåligt samvete eller skuldanslor?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Har Du haft besvär med att koncentrera Dig, när Du t ex läst tidningen eller sett på TV?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Har Du känt Dig rastlös?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Har Du känt Dig mer tyst?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Har Du haft besvär med att sova på natten?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Har Du haft nedsatt aptit?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Har Du haft ökad aptit?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Written instructions

Testkörning


Är det några oklarheter under körningen är det bara att fråga försöksledaren.

Experimentkörning