Effects of searching for street parking on driver behaviour, physiology, and visual attention allocation: An on-road study

by

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Abstract

Urban areas with street parking exhibit a heightened crash-risk compared to similar environments that do not allow street parking. It is unknown whether drivers searching for parking engage in unsafe driving behaviours that contribute to this heightened crash risk. An on-road study was conducted to quantify the effects of searching for parking on drivers. Twenty-eight participants wearing physiological sensors and a head-mounted eye-tracker drove an instrumented vehicle in downtown Toronto. When searching for parking, participants had lower speeds and speed variability, and drove closer to the curb. They also exhibited fewer off-road glances under 1.6 seconds but an increased number over 1.6 seconds. While searching for parking, participants experienced a marginal increase in heart rate. These observations are in line with the self-reported increase in workload expressed by participants. Further research is needed to investigate how these changes affect the safety of the road environment.

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1 Introduction

The relatively low cost and limited availability of street parking makes it a coveted resource in many downtown areas. Street parking can be difficult to find on demand, forcing drivers to search for parking while on the road. Though an often-necessary driving task, searching for street parking is largely understudied. It is believed that it imposes additional mental and visual demand on drivers and produces changes in their driving behaviour, physiology, and visual attention allocation. Investigating how searching for parking affects drivers will bring insights into traffic behaviour in areas that allow street parking, as well as develop the body of research examining how tasks secondary to driving affect drivers and the road environment. This thesis reviews existing literature surrounding safety and crash risk regarding street parking and the search for street parking, highlighting gaps in the literature. It then presents an on-road instrumented vehicle study which was designed and conducted to address some of these research gaps. Findings from the study are presented and discussed to examine whether searching for parking results in changes in driving behaviour brought on by an increased workload and how these changes may affect the road environment. The remainder of this section provides a summary of the chapters of this thesis as well as an overview of the experimental findings.

Literature suggests that large proportions of city traffic may be “cruising for parking” during busy hours (Shoup, 2006), but research has been limited to specific cities and times and therefore fails to paint an adequate picture of the effect on traffic in general (Weinberger & Millard-Ball, 2017). However, regardless of the proportion of drivers searching for parking, it has been largely reported that areas that allow street parking exhibit higher crash rates than similar areas which do not (Box & Levinson, 2004). In the United States, 15-20% of urban crashes have been estimated to be related to street parking (Highway Research Board, 1971; Sisiopiku, 2001). There exists substantial research on how presence of street parking affects the safety of the driving environment (Cao, Yang, & Zuo, 2017; Edquist, Rudin-Brown, & Lenné, 2012; Humphreys, Wheeler, Box, & Sulliavan, 1979; McCoy, Ramanujam, Moussavi, & Ballard, 1990). Many reasons are suggested to explain the safety issues in these areas, including increased obstacles, reduced space for turning maneuvers, disruption of traffic flow by cars leaving their parked positions, disruption of traffic flow by cars parking, drivers or passengers exiting parked vehicles, and reduced sight distance (Highway Research Board, 1971). Others have also cited decreased road width as an issue (Cao et al., 2017; Greibe, 2003). These busy areas experience high traffic of pedestrians and vehicles, contributing to the complexity of the driving environment (Marshall, Garrick, & Hansen, 2008). Drivers searching for parking in this complex environment must navigate safely, vigilant of pedestrians and other vehicles, while also tending to the many facets and pressures of the parking-search. They are expected to read and understand parking signs, scan off-road for parking spaces, evaluate whether those spaces are vacant and legal, navigate through sometimes unfamiliar streets, and minimize the distance to their destination all while under the pressure of traffic to maintain a speed which is often unconducive to finding a parking spot. Searching for parking is expected to pose significant additional demands on drivers and cause changes in driving behaviour and driver physiology.

The emergence of parking-assistance technologies, such as mobile apps displaying vacant spaces, indicates that cities, research institutions, and consumers recognize the parking search as a problem worth solving. These systems, however, are largely in response to the inconvenience posed by traffic congestion and time spent searching for parking; no claims were found that suggest these technologies impact road safety. Similarly, studies exploring the effect searching for street parking has on traffic flow have been widely conducted, but the implications regarding safety remain unexamined (Brooke, Ison, & Quddus, 2014). As a first step in addressing this gap in the literature, this research focuses on the initial sub-task of searching for and locating a vacant parking spot. An on-road instrumented vehicle study was designed to explore the effects searching for parking has on the driver. This study does not attempt to examine how the act of parking affects drivers, rather it is an initial investigation into how an increase in demands brought on by searching for parking affects drivers. We were interested in how drivers alter their speed and lane position when searching for parking and whether our results agreed with studies of how increased visual and cognitive demands affect driving behaviour. We also wanted to examine if physiological signals, such as heart rate and skin conductance, would change to reflect an increase in stress or workload when searching for parking. We compared physiological measures recorded while participants searched for parking to a baseline condition as well as another driving task known to be high in visual demand with elevated crash risk: turning at intersections (Bao & Boyle, 2009; Harbluk, Noy, Trbovich, & Eizenman, 2007; Werneke & Vollrath, 2012). This analysis was exploratory as little research has been found that examined how physiological measures are affected during turns. Given the visual demands of searching for parking, it was important to quantify the difference in visual attention allocation resulting from the search task. The effects of visual demand from parking search were captured by tracking the number and duration of off-road glances using a head-mounted eye-tracker.

The on-road study was conducted in downtown Toronto and required participants to drive two pre-determined routes similar in length and complexity, with some overlapping road segments. Data was collected directly from the instrumented vehicle as well as from physiological sensors and a head-mounted eye-tracker worn by the participant. Participants drove each route under one of two task conditions, baseline and parking-search; the order of the routes and conditions was counterbalanced. When driving in the parking-search condition, participants were periodically asked to search for street parking and notify the researcher of any legal, vacant spaces they encountered. Each route contained four pre-determined sections where participants continuously searched for parking under the parking-search condition. Participants were asked to rate their subjective workload on the NASA Task Load Index (Hart & Staveland, 1988) questionnaire (Appendix K) after each drive. They also completed several other questionnaires that offered insight into their self-reported driving behaviour, experience, and attitudes.

Participants reported a significantly higher workload in the parking-search condition compared to the baseline. One 540m stretch of road (Bloor St.) was driven in both routes and allows street parking in defined parking bays along the street. This area is highly trafficked by vehicles and pedestrians and contains semi-protected bike lanes in each direction. Participants drove this exact stretch twice, once in the baseline condition and once when continuously searching for parking. Data collected in this region was used to compare measures between task conditions, within participants. It was observed that participants drove slower when searching for parking compared to the baseline, with decreased speed variability. This overall reduction in speed is believed to be in compensation for the added demands brought on by the searching for parking task. Participants were also observed positioning their vehicles closer to the curb when searching for parking, though whether this was a compensatory measure to distance themselves from oncoming vehicles, or to better enable the inspection of parking bays, or to allow for reading signs is unknown. Electrocardiogram and skin conductance signals did not produce significant results, though there was a rise in heart rate approaching statistical significance ($p = .09$) when participants searched for parking. Physiological measures also did not reveal any significant results when comparisons were made to turns at intersections. When searching for parking, considerable evidence indicated drivers allocate their visual attention differently. Participants exhibited fewer glances under 1.6s compared to the baseline condition, but more glances between 1.6s and 2s and over 2s. We use thresholds of 1.6s and 2s common in distracted driving literature; studies have shown that few off-road glances over 1.6s are exhibited by drivers (Sodhi, Reimer, & Llamazares, 2002), and that off-road glances over 2s can increase crash risk (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). Our results suggest that drivers change their scanning behaviour to compensate for longer off-road glances (that provide them more information), by performing fewer short off-road glances. Drivers still spent a higher percentage of time looking off-road and exhibited longer off-road glances on average while searching for parking compared to when not.

Our experiment provides evidence that searching for street parking does affect drivers, leading to an increase in long off-road glances, and a reduction in speed, speed variability, and distance to curb. Participants also indicated that they felt increased workload when tasked with searching for parking. These results suggest that increased support for drivers searching for parking, such as mobile apps or changes in road design, may do more than mitigate traffic congestion and inconvenience posed to the driver. At the individual level, such support can reduce the workload and resultant behavioural changes of drivers caused by the parking search. While further investigation is needed to comment on how the effects on drivers impact the safety of the driving environment, this initial investigation provides a foundation for additional research. In addition, this work contributes to our understanding of driver workload and the effects on drivers of engagement in additional tasks.

2 Background

2.1 Parking in the Literature

2.1.1 Searching for Street Parking

Street parking in urban areas is often found in dense, high-traffic regions with businesses and pedestrians enjoying the close, convenient access it provides. It is not uncommon for drivers to circle city blocks in search of this coveted resource. A survey conducted by IBM found that finding parking in Toronto required an average search time of 13 minutes (Hasham, 2011). Traffic cruising for parking in dense areas contributes to congestion, air pollution, driver frustration, lost time and unnecessary fuel costs for drivers (Weinberger & Millard-Ball, 2017).

Some studies have been conducted with the aim of quantifying the proportion of traffic cruising for parking. A 2007 study conducted on 7th Avenue in Brooklyn found that 45% of total traffic was searching for a parking space during the 2-hour observed period (White, 2007). In a widely-cited report on cruising for parking, Shoup (2006) highlighted six studies in six different cities from 1927 to 2001 that found an average of 30% of traffic searching for parking at observed times, with an average parking search time of 8.5 minutes, however, it is not clear exactly where in each city and during which times these statistics were observed. A recent study challenging many of the early research strategies and reports of cruising for parking used GPS traces to determine the proportion of traffic searching for parking and found it to be between 5% – 6% in San Francisco, CA and 3% - 4% in Ann Arbor, MI (Weinberger & Millard-Ball, 2017). Another recent study concluded that a small percentage of traffic searching for parking was contributing disproportionally to the numbers of meters cruised, i.e., some drivers had parking search strategies that required them to drive far longer distances than most other drivers (Hampshire et al., 2016).

It appears that the proportion of traffic searching for parking can vary greatly across cities, regions and times of day and that little can be said to generalize the findings above. However, the existence of such literature shows that searching for parking is a topic of interest for urban planners and transportation experts. In addition, the influx of mobile applications and parking-assistance technologies, produced by both private corporations (Browne, Altan, & Rheaume, 2010; Schmitt. & Buchalo, 1999; Woodard & Catalano, 2012) and research institutions (Mathur et al., 2010; Nawaz, Efstratiou, & Mascolo, 2013), suggests that there are efforts to support drivers searching for street parking. However, the demands placed on drivers and the safety implications of parking searching remain unexamined. Interestingly, to the best of our knowledge, the demands of parking a vehicle and the safety implications of drivers parking are also unexamined. However, as an initial step in addressing these gaps, this study focused only on the demands placed on drivers by the parking search task.

2.1.2 Street Parking and Crash Risk

Street or curb parking refers to both angled and parallel parking allowed on the side of a road, though it is generally acknowledged that angled parking is the more dangerous and less preferable of the two (Humphreys et al., 1979). Studies have shown that street parking reduces the capacity of roads and can lead to increased crash risk (Guo, Gao, Yang, Zhao, & Wang, 2012). A 1971 Highway Research Board Committee report concluded that street parking was directly or indirectly responsible for 20% of all urban crashes in the United States (Highway Research Board, 1971). A Chicago Police report found that 23% of crashes in the city (property damage, non-fatal, and fatal) were due to a moving vehicle striking a parked car (Chicago Police Department, 1974). A more recent study estimated that 15% of crashes in the U.S. are related to street parking (Sisiopiku, 2001). Whether these crash statistics accurately depict the influence of street parking on crash risk is not clear: in crashes that do not involve parked cars, it is not always obvious if, and to what extent, street parking was a factor and thus figures can be expected to be higher than reported (Sisiopiku, 2001).

Many studies have explored why crash risk is heightened in areas that allow street parking (Cao et al., 2017; Edquist et al., 2012; Humphreys et al., 1979; McCoy et al., 1990). Numerous factors have been identified that are considered to contribute to the heightened crash risk. A Highway Research Board Special Report named five primary causes: increased obstacles (i.e., parked vehicles), disruption of traffic flow by cars leaving parking spaces, disruption of traffic flow by cars entering parking spaces, drivers or passengers exiting parked vehicles, and reduced sight distance of pedestrians (Highway Research Board, 1971). Supporting evidence regarding sight restrictions found that dart-out crashes, involving pedestrians crossing into the street, are more prevalent in areas where street parking is allowed, due to pedestrians emerging between parked vehicles where they cannot be seen by drivers (Sisiopiku, 2001). Parked vehicles also impose sight restrictions on drivers turning right onto or driving across streets with parked vehicles (Box & Levinson, 2004). The decreased road width imposed by parked vehicles has also been cited as an issue (Cao et al., 2017; Greibe, 2003), though it is difficult to directly attribute this factor to crashes.

While it appears that the presence of street parking affects the driving environment, some argue that it slows cars down to safer speeds (Daisa & Peers, 1997; Lerner-lam, Celniker, Halbert, Chellman, & Ryan, 1992; Marshall et al., 2008). For example, Daisa & Peers (1997) state that the high density of parking, large traffic volume, and reduced road width result in slower driving speeds, which can reduce the severity of crashes. It has also been argued that parked vehicles can protect pedestrians by separating moving traffic from the sidewalk (Lerner-lam et al., 1992). Despite these arguments and supposed safety benefits of street parking, crash risk appears to be elevated in areas that allow it.

While studies have identified potential ways the presence of street parking contributes to crash risk, we could only identify one study that aimed to quantify the demands placed on drivers and how their driving behaviour was affected by the presence of street parking. Edquist et al. (2012) conducted a driving simulator study measuring mental workload and driving behaviour when driving in an urban environment with a high occupancy of street parking. Participants drove in a simulator in four environments: Arterial (buildings were set far back) with no parked cars and no parking bays (Arterial No Parking), Urban ("a shopping strip style road") with no parking bays (Urban No Parking), Urban with parking bays and no parked cars (Urban Empty Parking), and Urban with parking bays 90% occupied by parked cars (Urban Full Parking). The four conditions were presented to each participant six times over three experimental drives. In each drive, participants drove each condition twice (order was randomized): once with a lead vehicle and once without. The experiment included a peripheral detection task and an unexpected pedestrian event. Participants were asked to complete a revised NASA Task Load Index questionnaire (rating physical demand was replaced with a question about safety) twice per condition when stopped at a red light immediately after driving it. The study found that vehicle speed decreased with increasing complexity of the environment, whereas speed variability increased. Drivers drove closest to the curb in the Arterial No Parking condition and farthest in Urban Full Parking. No significant difference was found in lane-keeping variability between conditions. Reactions to the peripheral target and the unexpected pedestrian event were found to be significantly slower in the Urban Full Parking condition compared to the other three conditions. Drivers reported the highest subjective workload in the Urban Full Parking condition, the least in the Arterial No Parking, and in between with the Urban No Parking and Urban Empty Parking conditions (with no significant differences between the two). The authors suggested that the decreased speed and position of the vehicle farther from the curb was a compensatory behaviour in response to increased workload.

From the Edquist et al. (2012) study, it appears that the visual complexity of an urban environment in the presence of parked cars can increase the workload of drivers and influence their driving behaviour. An interesting detail is that there was little difference between an environment that did not allow street parking and one with empty bays, suggesting that the presence of parked cars is the most significant contributor to workload in such areas. Although this study provided insights into driver behaviour and workload when driving on roads with parked cars, it did not focus on the parking task itself, nor the search for parking. To the best of our knowledge, no study exists that investigates how the task of searching for street parking affects driver workload and behaviour. An article detailing the environmental and economic impacts of searching for parking stated that the search for parking is an under-researched area and that further research is needed to identify the road safety impacts of the parking search (Brooke et al., 2014). Given that a large proportion of vehicles may be searching for parking in busy urban areas, it is crucial to understand how this task affects driver workload and influences driving behaviour.

2.1.3 Research Gaps

The effects of searching for parking on the driver remain unexamined. No studies were found that investigate demands on the driver of this task, their resultant effects, and whether the effects impact the safety of the driving environment. Further, while many emergent technologies exist that are meant to assist drivers searching for street parking, there was no research found to support how these technologies can help drivers at the individual level. By examining drivers engaged in searching for parking, we expect to bring greater understanding of the search for parking task, at the driver level. Our study focused on determining whether the demands of searching for parking result in changes in driver physiology, driving behaviour, and visual attention allocation.

2.2 Demands of Searching for Parking

Driving is a visual-manual-cognitive task that poses high attentional demands. Any additional task (visual, manual or cognitive) imposed competes for the limited resources of the driver and can impede them from adequately performing the driving task (Regan, Lee, & Young, 2008). While no studies were found that explored the specific demands of searching for parking on drivers, there is considerable related evidence that suggests drivers will experience an increased workload when tasked with searching for street parking. Areas where street parking is in high demand are often highly trafficked by both vehicles and pedestrians (Marshall et al., 2008). Increasing the number of moving vehicles in a scene can reduce situational awareness and the ability to avoid hazards (Gugerty, 1997). In addition, the reduced road width and presence of stationary parked cars contributes to an increased visual workload, as shown in the Edquist et al. (2012) study which documented differences between an urban road which allows street parking (and has many parked cars present) and another that does not. In this study presented in the earlier section in detail, drivers reduced speed and positioned themselves further from the curb, which was believed to be in compensation for the increased visual workload. Thus, merely having parked cars is expected to increase visual demand even when the driver is not searching for parking.

When drivers are new to an area or are unfamiliar with its parking policies, the search for parking often begins with determining whether parking is allowed in the area. Parking restrictions can be complicated, changing depending on time of year, time of day, day of the week and location; these restrictions are communicated by parking signs which are often hard to locate, read and understand (Figure 1). A 1966 study on street parking signs describes the same inconsistent positions, small letter sizing, large amount of information and confusing graphics that still exist today (Hanson, Bennett, & Radelat, 1966).

Figure 1: Two examples of parking signs in downtown Toronto

Drivers are expected to read and assess the parking restrictions of the area communicated by signs and road markings, and often do this in tandem with searching for a vacant space. Small letter sizing may require drivers to be close in order to read signs. Reading road signs at a close distance however would result in a higher angular velocity between the driver and the sign, possibly making signs more difficult to read without slowing down (Schieber, Burns, Myers, Willan, & Gilland, 2004). Maintaining a close distance to read parking signs may also make it more difficult for drivers to hold the road ahead of them in their field of view while reading, affecting their ability to react to events on the road. The existence of parked cars provides an obstacle to getting within reading distance of roadside signage and may further complicate the process of reading parking signs.

Drivers searching for parking in an urban centre could be further burdened with the task of navigating while searching for parking. Navigation imposes visual and cognitive demands on the driver; drivers are required to be aware of upcoming streets and may have to reference a map while remembering where they have been as they venture farther from their destination in their search. Wayfinding can contribute to driving errors due to increased mental demands (Burns, 1998). A recent review of the street parking search found that the time drivers spend locating a parking space is a major influencing factor in choosing a parking spot (Brooke et al., 2014). Time spent looking for parking is time removed from the driver’s ultimate destination, making the search for parking a task best done as quickly as possible. Time urgency has been shown to relate to driver stress and affect driving behaviour (Hennessy & Wiesenthal, 1999). In addition, as they search and obstruct traffic in busy areas, drivers can find themselves under the pressure of following vehicles, who may honk or keep close distances. This social pressure can contribute to the stress of the driver and pressure them to maintain a speed which makes the parking search more difficult. There is expected to be less demand on the driver in cases where the driver can simply stop or slow down to find a parking spot without consequences, compared to situations where slowing and stopping leads to the driver to interrupt traffic flow.

The more familiar a driver is with the area, the less workload they are expected to experience from several of the factors mentioned above. Sign reading, for example, may be unnecessary if drivers are aware of the parking restrictions in the area. Wayfinding and navigation would have less of an effect, as could time pressure, if drivers can better estimate parking search times and plan accordingly. It is expected that the demands of searching for parking would be higher and therefore more influential on drivers less familiar with an area. Thus, in our experiment, we collected data on the frequency of driving in downtown Toronto (where the study was conducted) and used this measure to analyze how familiarity with the area changed the way searching for parking affected drivers.

While it is believed that the workload of the driver will increase when searching for parking, and that this will result in changes in driving behaviour, it is not to say that all changes are inherently unsafe. Participation in secondary activities ancillary to driving can lead to drivers exhibiting compensatory strategies (e.g. reducing speed) that can contribute to a safer road environment (Regan et al., 2008). Our study seeks to measure and report changes in behaviour brought on when searching for parking as well as comment on whether these changes are potentially safe or unsafe strategies. Further investigation may be needed to determine whether any safe strategies provide sufficient compensation to mitigate the effects of unsafe behaviours.

2.2.1 Distracted Driving and Driver Performance

There exists a large body of research which explores how engaging in tasks secondary to driving affects driving performance and the safety of the road environment. Searching for parking is heavily reliant on the visual system of the driver, and thus is expected to be mainly visually distracting from the driving task. In general, distracting tasks that visually engage drivers have been shown to affect many measures of driving, such as lane position and lane position variability, speed and speed variability, reaction time to external events, and subjective workload (Regan et al., 2008). The tasks most commonly studied are voluntary in-vehicle tasks, e.g.

mobile phone use, that often have a manual component in addition to visual. Few studies were found that examined purely visual secondary tasks (without a manual component) or that examined distractions outside of the vehicle. Studies which focused on visual distractions with limited manual or cognitive components, e.g. referencing a paper map or doing a reading task, have shown that drivers exhibit a higher standard deviation of lane position when visually distracted (Dingus, McGehee, Hulse, Jahns, & Manakkal, 1995; Zhang, Smith, & Witt, 2006). Higher standard deviations in speed have also been observed (Metz, Schömig, & Krüger, 2011). Drivers also exhibit delayed reaction times to external events when using an in-vehicle navigation system or paper map (Srinivasan & Jovanis, 1997) and when driving in a more visually complex environment (Edquist et al., 2012). Self-reported measures have shown that drivers experience an increase in workload when visually distracted (Regan, Lee, & Young, 2008).

In some cases, visually distracting tasks can lead to behaviours that are concluded to be unsafe. However, drivers experiencing increased visual demand have also been observed performing compensatory behaviours such as reducing speed, which may increase their capacity to react to events in the road or reduce the severity of any crashes that occur. Concluding the degree to which an activity affects the safety of the road environment is dependent on a number of factors; generalizations often cannot be made about a particular behavioural change being regarded as safe or unsafe. However, distracted driving remains one of the leading cause of crashes (NHTSA, 2013). A recent analysis of the largest naturalistic driving study to date found that some observable type of distraction was involved in 68% of crashes and that extended glances to external objects (measured by proportion of time eyes were off the forward path, although the authors do not state what threshold is used for labeling a glance as "extended") were associated with a crash risk 7.1 times that of normal driving (Dingus et al., 2016). An on-road study using an eye-tracker revealed that drivers rarely glance off the road for longer than 1.6s (Sodhi et al., 2002). Further, naturalistic driving research has shown that glances off the forward roadway of over 2s double the risk of a crash (Klauer et al., 2006).

Given that visual secondary tasks and glances away from the forward road are particularly detrimental to safety, it is important to understand how searching for parking affects drivers' off-road glances. Further, in addition to its effects on off-road glances, searching for parking may also increase cognitive demand and stress as discussed earlier, leading to further increases in driver workload and declines in performance. Thus, in addition to its effects on glance behaviours, we also investigated the effects of parking search on drivers' workload as measured through self-reported workload, physiological changes, and changes in driving behaviour.

2.2.2 Measuring Workload in Drivers

Workload has been defined as "experienced load" which is both task- and person- specific; this is seen as a measure of the effect of the demand (of a task or scenario) on the human (de Waard, 1996). Workload can be measured in several ways. Generally, multiple types of measures are preferred as they give a variety of results that can be cross-validated. Subjective measures, such as questionnaires, provide information on how a person feels their workload increased or decreased; the NASA Task Load Index (TLX) (Hart & Staveland, 1988) is frequently used as a self-reported measure of workload in driving research (de Waard, 1996).

Other measures of workload in driving include physiological measures, driving performance, glance behaviour, and secondary task performance (de Waard, 1996). Physiological signals, such as electrocardiogram (ECG) signals and galvanic skin response (GSR) have shown high correlations with stress and cognitive demand (Healey & Picard, 2005; Mehler, Reimer, Coughlin, & Dusek, 2009). Speed, speed variability, lane position and lane position variability are common measures of longitudinal and latitudinal vehicle control and have been used to capture changes in workload as well as give an assessment of unsafe (or safe) driving behaviours, e.g. (Horberry, Anderson, Regan, Triggs, & Brown, 2006; Reimer, Mehler, Coughlin, Roy, & Dusek, 2011). As described in detail earlier, drivers have been shown to exhibit slower driving speeds and increased lane keeping variability when engaged in visual tasks. These driving measures can indicate increased visual demand (Engström, Johansson, & Östlund, 2005). Measuring eye glance patterns can also give an indication of both visual and cognitive demand (Lee, Lee, & Ng Boyle, 2007; Liang, Lee, & Yekhshatyan, 2012; Victor, Harbluk, & Engström, 2005). High cognitive demand decreases the variability of glances; drivers have been observed to scan their periphery less when performing mentally demanding secondary tasks (Harbluk et al., 2007). Performance on secondary tasks is another factor that can also be used to measure spare capacity of the driver, acting as a measure of workload (de Waard, 1996).

It was important to consider multiple measures of workload when designing our experiment, and to use current methods so that our results could be compared to relevant and recent research. We collected heart rate and skin conductance measures in addition to glance information. Further, speed, speed variability, lane position, and lane position variability were assessed. We opted not to add a secondary task (a tertiary task in our context where the primary task is driving and searching for parking is the secondary task), as we wanted to explore solely the effects of searching for parking. Another option would have been to measure success locating a valid parking space, though we decided that this measure would not be an accurate one given that it was impossible for us to control for the amount of vacant parking spaces available on the experimental route. In addition, during the experiment participants were observed to make very few incorrect identifications of legal parking spaces, thus it was not a sensitive enough measure in this particular experiment.

2.3 Hypothesis

We propose that searching for parking imposes visual and cognitive demands on drivers that result in a change in driving behaviour, physiology, and visual attention allocation relative to driving when not searching. Self-reported measures were expected to reflect a subjective increase in workload. In this case, we used the NASA Task Load Index, and it was predicted that participants would report that they felt a higher workload when searching for parking than in the baseline condition.

The addition of a visual task has been shown to result in drivers lowering their speed and increasing their lane keeping variability (Dingus et al., 1995; Engström et al., 2005; Zhang et al., 2006). The same behaviour was found when drivers drove in an environment with higher visual complexity (Edquist et al., 2012). Similar results were anticipated when drivers are tasked with searching for parking. We expected drivers to reduce their speeds and increase the variability of their lane position while they searched for parking. In addition, because sign reading is predicted to be a significant aspect of finding street parking, we expected drivers to drive closer to the curb when searching to allow them to read posted parking restrictions, particularly due to the small letter sizing (Schieber et al., 2004). Heart rate and skin conductance are known to rise under increased stress and cognitive load (Healey & Picard, 2005; Mehler et al., 2009). It was expected that the demands of searching for parking would increase the stress and cognitive load on the driver, thus increasing their heart rate and skin conductance. Visual attention allocation was predicted to significantly differ when drivers are searching for parking. Visual search is the premier component of searching for parking and requires drivers to scan the environment on the side of the road to locate and confirm vacant spots as well as read posted parking restrictions. Drivers were expected to allocate an increased percentage of time glancing off-road, as well as exhibit more glances off-road, while they searched for parking. In addition, it was expected that drivers familiar with driving in downtown Toronto would be more knowledgeable of the parking situation and restrictions in the area, and thus exhibit fewer off-road glances when searching for parking than their counterparts who were not as familiar. Familiar downtown drivers were also expected to experience less severe effects on their driving behaviour and physiology when searching for parking compared to drivers who do not drive downtown often.

3 Methodology

To study the effects of searching for parking on driving behaviour, physiology, and attention allocation, an experiment must adequately simulate the parking search task in a controlled environment and allow for relevant measures to be recorded under multiple conditions for multiple participants. While a driving simulator provides a high level of experimental control, it may not be able to produce the same demand as a real-world complex environment with heavy traffic (Matthews, Sparkes, & Bygrave, 1996). For example, it is assumed that the social pressure of blocking traffic is a contributor to the demands on the driver while searching for parking; this pressure likely cannot be induced in a simulator. In addition, sign reading and visual scanning are key components of searching for parking, and simulators are limited in the resolution and visual detail they can provide, making them less effective in studies that rely on visual scanning (Kaptein, Theeuwes, & Van Der Horst, 1996). An on-road study was therefore preferable to a simulator study and as a first step in exploring the effects of searching for parking, a controlled instrumented vehicle experiment was conducted.

As this experiment is the first known study examining the effects of searching for parking, it was preferred to focus on areas that are expected to pose the highest demands on drivers. We wanted the real-world environment to include the major stresses of dense urban areas: complex visual environment, erratic traffic flow, and high occupancy of pedestrians and cyclists. We also chose to conduct the study on roads with many parked cars; although they did not study the parking search itself, Edquist et al. (2012) showed that areas with many empty parking bays did not elicit the same visual demands on drivers as when there were many parked cars (90% of bays occupied).

Multiple areas of downtown Toronto were examined to gain an idea of their street parking availability, restrictions and signage, and environmental visual complexity. The Bathurst and Bloor area of downtown Toronto was chosen as it met these criteria; the area has a mix of residential and retail buildings that are set close to the road, is heavily trafficked by both vehicles and pedestrians, offers street parking with a variety of posted restrictions, and at busy times is at near-capacity of street parking. Over the course of several months, many pilot studies were conducted in developing the experiment. It was important to test the clarity of the experimental instructions as well as the equipment used for data collection. There were six pilot testers, and two of them completed the experiment in its near-final design. The study was approved by the University of Toronto Research Ethics Board.

3.1 Participants

Participants were recruited via posters (Appendix A) placed around the university campus and on online forums (e.g., Craigslist, Kijiji, NOW, Indeed). Posters contained a link to a screening survey (Appendix C) and participants were contacted based on their answers. Due to insurance constraints, participants were required to be between the ages of 35 – 54 and have a full G license (or equivalent) for at least 3 years. In addition, because of the restrictions of the head-mounted eye-tracker, participants had to drive without glasses and thus could not require glasses to drive legally, though contacts were allowed. Twenty-eight participants (14 male, 14 female) completed the experiment, however due to equipment malfunctions not all participants had full sets of data (discussed in more detail in the Results section). About 80% of participants reported that they drive a few days a week or more, with 35% of participants reporting that they drive in downtown Toronto a few days a week or more. There was no correlation found between frequency of driving in general and frequency of driving downtown (Pearson chi-square test: $\chi^2(1, n = 26) = 2.10, p = .15$). Participants were compensated at $15/hr.

3.2 Apparatus

The instrumented vehicle used was a 2014 Toyota Rav4 with a Controller Area Network (CAN bus) connection for obtaining vehicle measures directly from the vehicle. A computer and monitor in the back seat (Figure 2) allowed for real-time monitoring of data.

Figure 2: Back seat of the instrumented vehicle

A MobilEye device (Figure 2) was used to sample data from the CAN bus connection and also provided measures calculated through image processing techniques applied to video from its internal camera (such as lane position). Another camera was mounted on the dashboard (Figure 2) and provided video of the front-view of the vehicle. Measures recorded directly from the vehicle were speed and distance to the left lane. These measures were used to calculate speed, speed variability, lane position, and lane position variability.

Figure 3: MobilEye and front-facing camera mounted in the vehicle

Devices were used to measure electrocardiogram (ECG) and galvanic skin response (GSR) activity. ECG signals were used to determine heart rate and GSR sensors produced measures of skin conductance. The ECG and GSR sensors were produced by Becker Meditec and recorded data at 240 Hz; three electrodes were placed on the chest to read the ECG signal (Figure 4) and two electrodes were placed on the bottom of the left foot to obtain the GSR signal.

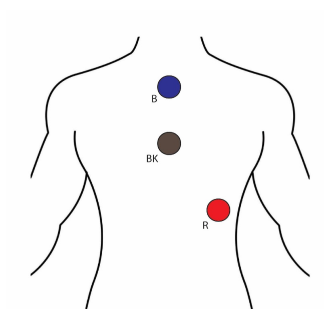

Figure 4: Placement of the ECG electrodes

Gaze position was captured using the head-mounted Dikablis Eye-Tracking Glasses (Figure 5), produced by Ergoneers. Given that the study was on-road and not in a simulator, a head-mounted eye tracker was preferred as it allowed drivers the freedom to move and turn their head in the car without compromising the accuracy of pupil detection.

Figure 5: Driver outfitted with Dikablis eye-tracking glasses

When calibrated, this device uses two cameras pointed toward the eyes to determine gaze position (tracked at 50 Hz) and overlays the gaze position on video data captured by its front-view camera. The data from all devices was synced with vehicle data during data collection by D-Lab, software produced by Ergoneers.

3.3 Experimental Design

Workload is person-specific (de Waard, 1996) and measures of workload lend themselves well to within-subjects experimental designs. Thus, each participant drove under both baseline and parking-search conditions. The experiment was a repeated measures design with one factor, task condition, which had two levels: baseline and parking-search. As mentioned earlier, the participants completed two experimental routes (Appendix K). The two routes were pre-determined, and participants drove the first route under one task condition (baseline or parking-search) and then completed the other route under the other task condition. The order of the routes and conditions was counterbalanced. The two separate routes were used to minimize learning effects, but they contained some overlapping sections in order to allow for direct comparisons between conditions.

3.4 Parking-Search Task

Participants were asked to verbally identify legal, vacant parking spaces that were in their direction of travel and on the same street they were on. In the parking-search condition, there were four predetermined sections of each route where participants were asked to search for parking continuously. They were told to verbally announce each space they encountered which they understood to be vacant and legal. After each announcement, they were told whether the space was legal or why it was not. They then continued to search for parking. As we were only interested in the effects of *searching* for parking (and not of parking itself), participants were not asked to stop, nor park. Not asking participants to park the vehicle lessened the potential impact of their parking ability and adaptation to the instrumented vehicle on the experimental findings and alleviated the potentially confounding stress brought on by the task of parking. However, it is recognized that in a real-life scenario, the pressure of parking the car after finding a space likely contributes to the workload of the parking search. Participants were given turn-by-turn directions during the experiment (in both conditions) to eliminate the navigation component of the parking search; this component is expected to further distress drivers in real-life scenarios.

3.5 Procedure

The experiment was run between July and October, on Saturdays or Sundays starting at either 10:30 AM or 1:30 PM. Running experiments only on weekends offered some control over the number of pedestrians in the area and ensured that there would be no road work or waste collection interruptions during the experiment. In addition, the relatively good weather ensured that road conditions and environmental stressors were consistent (i.e., no snow or icy conditions). The experiment contained both an off-road and on-road component and took an average of 2 hours (participants were told it could take up to 3 hours). Participants first read and signed the informed consent form (Appendix B). They provided their driver's license to verify their age and license type and were aware that a scanned record was made for insurance purposes.

In order to gain insights into participants' driving behaviour and history, three vetted questionnaires were then administered, the Susceptibility to Distracted Driving Questionnaire (Feng, Marulanda, & Donmez, 2014) (Appendix D), a 24-question U.S. version of the Manchester Driving Behaviour Questionnaire (Reason, Manstead, Stradling, Baxter, &

Campbell, 1990) (Appendix E), and the Arnett Inventory of Sensation Seeking (Arnett, 1994) (Appendix F). The participants also filled a short questionnaire which gathered information on their driving history (Appendix G). Following their completion of the surveys, participants were given an instructional booklet (Appendix H) which gave a brief overview of parking rules in Toronto and explained the restrictions of some parking signage found along the experimental driving route (see example in Figure 6).

You may park on the right side of the post between 10:00am - 10:00pm for maximum 1 hour. You may not park on the right side of the post between 10:00pm - 10:00am from Monday to Saturday and on Sunday between 12:01am - 10:00am, except by permit. You may park on the left side of the post from Monday to 10:00am on Sunday by permit only. After 10:00am on Sunday, you may park on the left side of the post without a permit until 12:00am on Monday.

Figure 6: Example of sign explanation in parking instructions booklet

After going through the booklet on their own, participants were administered a five-question quiz (Appendix I); they were assured that their performance on the quiz would not affect their participation in the rest of the experiment. The multiple-choice quiz tested their understanding of parking signage; after each question, if they chose an incorrect response, the investigator discussed the correct answer with the participants. The purpose of the booklet and quiz was to ensure that all participants had the same baseline level of exposure and understanding of the parking restrictions and signs in the area.

Participants were then taken to the instrumented vehicle and seated in the driver seat. They were given time to adjust the seat position and mirrors. The lead investigator sat in the passenger seat; another research assistant was seated behind the investigator, operating the data collection computer. Participants first completed a 5-10-minute familiarity drive to allow them to get used to the vehicle which brought them to the starting point of the experimental drives. They were told that the investigator would provide them with turn-by-turn directions, and that they should ask questions about operating the vehicle during this drive as talking during the experiment would be discouraged. The familiarity drive took them from the University of Toronto St. George Campus to a parking lot in the Bathurst and Bloor neighbourhood. After stopping the vehicle, the participant was outfitted with the physiological sensors and the head-mounted eye-tracking device, which was calibrated at this time. Because the eye-tracking device can be uncomfortable, participants were assured that they would be able to remove it between drives if they would like to. Regardless, the eye-tracker was calibrated once more after the first drive. After the familiarity drive, participants completed the two experimental drives, one with the searching for parking task and the other serving as the baseline condition. Each drive took about 15 to 20 minutes. Depending on which experimental condition (parking-search or baseline) they were about to complete, the verbal instructions given to participants were as follows:

> **Baseline Condition:** *"In this drive, drive as you normally would and follow the turn-by-turn directions I give you. This drive will take 15 – 20 minutes. Please keep talking to a minimum unless necessary."*
>
> **Searching for Parking Condition:** *"In this drive, drive as you normally would and follow the turn-by-turn directions I give you; there will be a searching for parking component to this drive. When looking for parking, I want you to consider only parking spaces on the street (either paid or free), that are on the same street we are on and facing the same direction. That means that on one-way roads, you should consider parking on both sides of the street but other times you should only consider parking on the right side. When I instruct you to start searching for parking, please continue driving and verbally announce when you have found a legal and vacant parking spot that you feel this car can fit into. You are not expected to stop or park. Once you have announced that you found a spot, I will confirm and tell you to keep driving and continue searching or I will tell you to continue driving and stop searching. You will be searching for parking for a few continuous sections of the route. I will provide you with directions the entire drive. The amount of parking available may vary greatly along the route and in some areas, there may be many vacant and legal parking spaces; in this case please just continue to announce all of them. This drive will take 15 – 20 minutes.*

Apart from when you are announcing parking spaces, keep talking to a minimum unless necessary."

Each drive ended at the same parking lot where the experimental drives began. After both experimental drives, participants completed the NASA Task Load Index (Hart & Staveland, 1988) (Appendix K). As part of the questionnaire, they were required to complete a pairwise comparison of six types of workload based on which they felt contributed more to their workload during the entire drive. This calibration was done only once per participant after the first drive. For both drives, drivers rated the extent to which they felt the six different types of demand (e.g. mental, physical) during the drive. After the second drive, participants switched seats with the investigator and were driven back to campus and given their compensation.

4 Analysis

The experiment produced physiological, vehicle and eye-tracking data from 28 participants who each drove two 15- to 20-minute-long routes under the baseline and parking-search conditions. While both routes were similar in length and complexity, they contained a variety of different streets and intersections. However, both routes did include the same 540m stretch of Bloor St. (Figure 7) which was driven west to east by all participants, once under the baseline condition and once while searching for parking.

Figure 7: Bloor St. stretch from Markham St. to Major St. (map source: City of Toronto)

This region was the focus of analysis for examining the resultant changes of driving behaviour, physiology, and visual attention allocation when searching for parking. In addition, changes in physiology were compared to changes exhibited by drivers when executing turns at intersections, in order to investigate how searching for parking affects drivers differently than a task known to be high in visual demand. Intersections are known to have an elevated crash risk (Ministry of Transportation of Ontario, 2014; NHTSA, 2013). Thus, turning at an intersection was used as a benchmark to evaluate the practical significance of our findings.

The Bloor St. stretch contains a single lane in each direction, each with a separated bike lane (Figure 8). There is paid street parking allowed at parking bays indicated by pavement markings, signs and bollards; parking was observed to be almost fully-occupied at the times when the experiment took place (by reviewing recorded video after the experiment), with 3 or 4 spaces free in the region out of approximately 25 (depending on the size of the vehicles) and only considering parking on the right side of the street. Figure 5 shows a snapshot view from the driver of the environment in this area, which is considered to be similar to that of the Urban Full Parking condition in the Edquist et al. (2012) study.

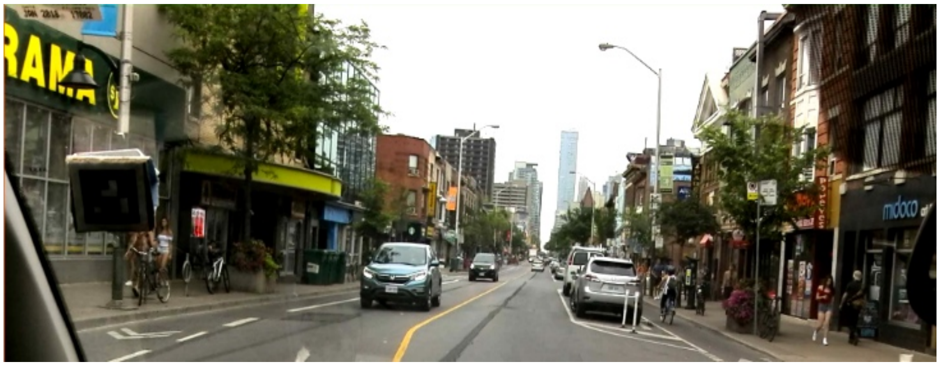

Figure 8: Snapshot of Bloor St. taken from the head-mounted camera

Experimental control was limited in this real-world environment; therefore, it was important to check for any other effects that may influence results such as order or learning effects. For each measure listed below, it was validated that route and order were not significantly affecting the results of the experiment.

4.1 Vehicle Measures

We were interested in both longitudinal and lateral effects on driving behaviour, in this case speed and lane position as well as their variability, measured as standard deviation. Traffic flow, signal status, and pedestrian behaviour could not be controlled, thus there are many instances where drivers on Bloor St. were forced to stop or slow down, regardless of the speed they would normally choose. The term “elapsed time” used in this thesis refers to the total time it took the participant to drive the Bloor St. stretch, regardless of interruptions. It was observed that during the “elapsed time”, speeds under 15 km/h were driven when participants were either slowing or stopping due to interruptions in the road such as: a red light, vehicles parking, pedestrians crossing, or congested traffic. Therefore, when calculating average speed and standard deviation of speed, only speeds above 15 km/h were used for analysis. Drivers drove above 15 km/h, on average, 68.8% of the time when driving the Bloor St. stretch, regardless of the task condition (i.e., baseline or parking-search). For all other vehicle and physiological measures, the entire set of data from the stretch was used.

Lane position was measured using the Distance to the Left Lane value provided by the MobilEye, calculated using image processing algorithms on images collected by its internal camera. The MobilEye is optimized for use on roads with consistent, clear lane markings and cannot calculate lane position at intersections (where markings cease); while the lane marking conditions on Bloor St. varied, the noise this produced in calculations was consistent between drives and therefore the measure was deemed adequate for comparisons of lane position and standard deviation of lane position between drives on the same street. Paired t-tests were carried out to compare vehicle measures within subjects between the two conditions (baseline and parking-search) while participants drove the Bloor St. stretch.

4.2 Physiological Measures

The ECG signals were analyzed using a publicly available MATLAB tool called HRVTool, which produced measures of heart rate (HR) (Vollmer, 2017). The tool calculated the average HR of participants for their drive through the entire Bloor St. stretch. was also calculated; this measure Average skin conductance was also calculated; this measure has produced results in detecting stress and cognitive demand in drivers (Healey & Picard, 2005; Mehler et al., 2009). Paired t-tests were carried out to compare physiological measures within subjects between the two conditions (baseline and parking-search) while participants drove on the Bloor St. stretch.

4.2.1 Physiological Measures during Turns

The changes in physiology between baseline and parking-search conditions were also compared to physiological measures recorded during four turns. Data from a left and right turn from each of the two experimental routes for each participant (i.e., four turns per participant) was extracted and used as a comparison benchmark. Turns were considered to start at the point where the vehicle slowed approaching the turn until after the vehicle had turned and the steering wheel returned to base position. The average GSR wasas calculated as a measure of skin conductance activity during the turn. All measures (heart rate and GSR) were averaged across the four turns for each participant. Comparison of physiological measures was conducted using a repeated measures ANOVA with three levels: parking-search, baseline, and turns.

4.3 Glance Behaviour

As mentioned earlier, glance behaviour was recorded using eye-tracking glasses worn by the participant while driving. Using two cameras facing the pupils, the exact location of the driver's gaze was automatically determined and overlaid on video from the head-mounted camera (Figure 9).

Figure 9: Eye gaze position indicated by the red crosshair overlaid on video from the head-mounted camera

Glances were coded by watching this video while drivers drove the Bloor St. stretch and determining the time periods during which the driver was looking off-road, through the left window, through the right window, and at the rear-view mirror. Measures of glance duration included both the fixation on the area of interest as well as the saccades to the area, as defined by the International Organization for Standardization (ISO 15007-1). Off-road glances included any glance outside of the road perimeter ahead, indicated in Figure 10.

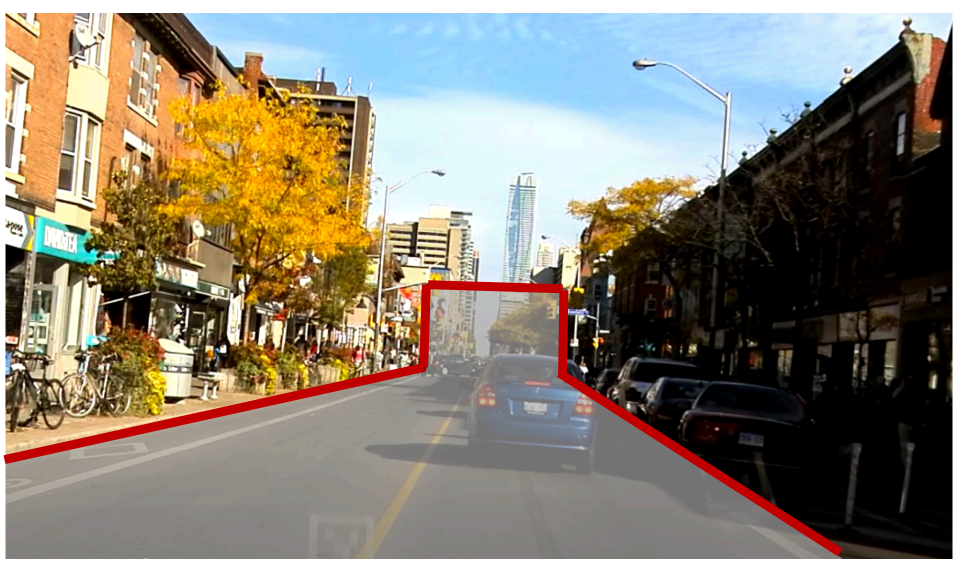

Figure 10: Bounded region considered "on-road" for glance analysis

Glances to the left window, right window, and rear-view mirror are subsets of off-road glances. We were interested in comparing the number of off-road glances of different durations, the proportion of off-road glances and the different allocation of off-road glances (e.g., to the right window) between the two task conditions. Because our interest was in the task of searching for parking *while driving*, glances during periods where drivers were slowing to a stop, stopped (generally at a red traffic signal or to allow pedestrians to cross the street, not because they were searching for a parking spot), or following a very slow-moving vehicle were not of interest. Drivers tended to scan the environment far more during these periods, greatly skewing results. Therefore, glances were filtered to include only those made while the vehicle was moving above 15 km/h. In addition, we conducted further analysis on glance frequencies utilizing specific thresholds for glance duration, in particular we analyzed the number of glances longer than 1.6s and the number of glances longer than 2s. Based on an on-road study using an eye-tracker, it was reported that drivers rarely glance off the road for longer than 1.6s (Sodhi et al., 2002); therefore, 1.6s was chosen as the first threshold for glance durations. In addition, it has been shown that glances off the forward roadway of over 2s double the risk of a crash (Klauer et al., 2006); thus, 2s was chosen as the second threshold. These two thresholds are used widely in the study of driver distraction, e.g. (Hallihan, Mayer, Caird, & Milloy, 2011; Horrey & Wickens, 2007; Reimer, Mehler, & Donmez, 2014; Sodhi et al., 2002). It should be noted that the study by Klauer et al. (2006) was a naturalistic one and utilized video recordings of the participants' face to assess gaze direction. Thus, their method is likely not as precise as our study's assessment of glance durations (hence the label "off the forward roadway" as opposed to "off-road"); however, the naturalistic nature of the study entails a higher level of ecological validity.

The number of off-road glances was modeled using a Poisson distribution in a generalized linear model, when appropriate, or a logit model when few glances were observed. The percent of off-road glances and average length of off-road glances were compared between task conditions using paired t-tests.

4.4 Questionnaires

Prior to driving the instrumented vehicle, participants completed surveys designed to gather information on their driving behaviour, driving experience, and attitudes toward driving. To investigate glance behaviour, the Susceptibility to Distracted Driving Questionnaire (SDDQ) was included in analysis as it is most relevant to visual allocation behaviour. The three subsections of the SDDQ, as defined in Feng et al. (2014), refer to “Distraction Engagement” (Question 1), “Attitudes and Beliefs about Voluntary Distraction” (Questions 2-5) and “Susceptibility to Involuntary Distraction” (Question 6). The SDDQ collects responses on a 5-point Likert scale: “Strongly disagree”/“Never”, “Disagree”/“Rarely”, “Neutral”/“Sometimes”, “Agree”/“Often”, and “Strongly agree”/“Very often”. For this survey, a response of “Strongly disagree”/“Never” receives a score of 1 and “Strongly agree”/“Very often” receives a score of 5; following this structure, averages of scores were calculated for each subsection for each participant. A response of “Never happens” was offered for some questions and resulted in that question being removed from the average. A higher score in the subsection “Distraction Engagement” means the participant reports engaging more often in distracting behaviours (e.g. using a mobile phone) while driving. In the second section (“Attitudes and Beliefs about Voluntary Distraction”), a higher score represents a more liberal attitude toward distracted driving behaviours held by others as believed by the participant or by the participant themselves. In the last section (“Susceptibility to Involuntary Distraction”), a higher score represents finding involuntary distracting activities, such as a ringing mobile phone, more distracting when driving. SDDQ scores were used to investigate relationships between subjective measures of driving behaviour and the objective changes observed in behaviour when drivers were searching for parking. SDDQ scores were included in a logit model predicting “high” or “low” frequency of off-road glances over 2s. Participant responses on the Driver Behaviour Questionnaire and the Arnett Inventory of Sensation Seeking are not reported in the thesis.

To study the effects of experience in driving and experience in driving downtown, responses to the screening survey questions “How often do you drive a vehicle?” and “How often do you drive in downtown Toronto?” in the screening questionnaire were used. Participants were organized into two groups, those who answered “Almost every day” or “A few days a week” (categorized as “Often”), and those who answered “A few days a month”, “A few days a year” or “Never” (categorized as “Not often”). After ensuring there was no correlation between responses to the two questions (Pearson chi-square test: $\chi^2(1, n = 26) = 2.10, p = .15$), the reported frequency of driving in downtown Toronto was used to predict and compare driving behaviour, physiology, and glance behaviour between drivers who drive downtown often and those who do not. Frequency of driving in downtown Toronto was explored both using t-tests for continuous variable outcomes (e.g. average speed, heart rate) or, when exploring the rate of off-road glances, by including this variable in linear models along with task condition as the other predictor.

4.5 Tools

Data sampled from physiological sensors and from the vehicle was analyzed over the periods of interest in MATLAB. A third-party MATLAB tool (HRVTool) was used to calculate heart rate (Vollmer, 2017). All t-tests were conducted in R. Statistical models of glance behaviour were built with SAS University Edition using the GENMOD and MIXED procedures.

5 Results

Both during data collection and during analysis, it was found that some participants were missing data measures. Unfortunately, this meant that not all participants had full sets of data. The table below (Table 1) summarizes the number of participants whose data was used for each measure, as well as their gender and age information.

Table 1: Number of participants used in analysis for each data measure

Measure	Number of participants	Age
NASA Task Load Index, SDDQ	14 males, 14 females	M = 41.9, SD = 5.7
Elapsed time, average speed over 15 km/h, standard deviation of speeds over 15 km/h	13 males, 13 females	M = 42.2, SD = 5.7
Average distance to left lane, lane position variability	12 males, 13 females	M = 42.5, SD = 5.7
Average GSR	12 males, 12 females	M = 42.4, SD = 5.9
Average heart rate	11 males, 12 females	M = 42.6, SD = 6.0
Number of off-road glances, glance duration, percentage of time looking off-road (all glance measures are only when driving over 15 km/h)	9 males, 7 females	M = 42.8, SD = 5.7

5.1 Subjective Workload (NASA TLX)

As stated earlier, after the first drive, drivers completed a pairwise comparison of six types of workload based on which they felt contributed more to their subjective workload during the entire drive. This produced weighting for each participant, 5 being the type of workload they felt most contributed to their drive and 0 being the least contributive. Figure 11 displays the average weight across participants for each type of workload.

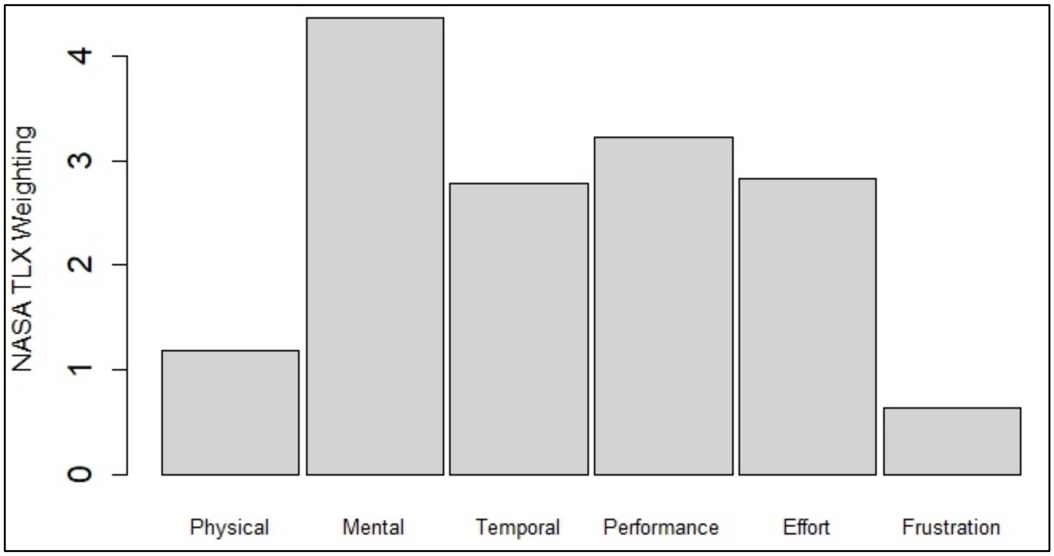

Figure 11: Average NASA TLX weightings by participants for different types of workload

Drivers rated, on a scale of 0 – 20, the amount of each type of workload (or demand) they felt after both experimental drives. These ratings were multiplied by the weights for each type calculated in the calibration and produced a total weighted average of workload for each experimental drive. The weighted average was significantly higher during the drive which included the parking-search task (M = 54.63, SD = 14.53) than in the baseline drive (M = 39.02, SD = 11.27); $t(27) = -5.36$, $p < .001$, Cohen's d = -1.01. The figure below (Figure 12) shows this comparison. All boxplots display the interquartile range of data points with the median indicated by the bold horizontal line and the mean indicated by a triangle.

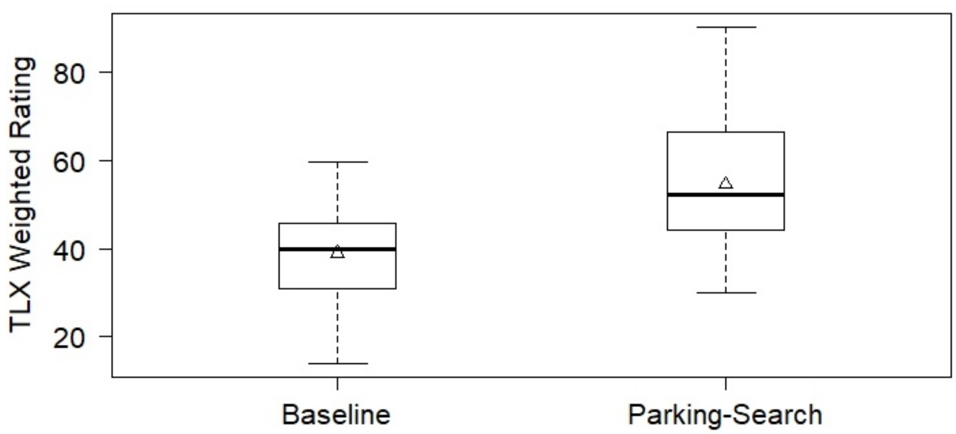

Figure 12: Weighted NASA TLX ratings by task condition

Figure 13 displays the raw (unadjusted by weighting) rating for each specific type of workload by task conditions.

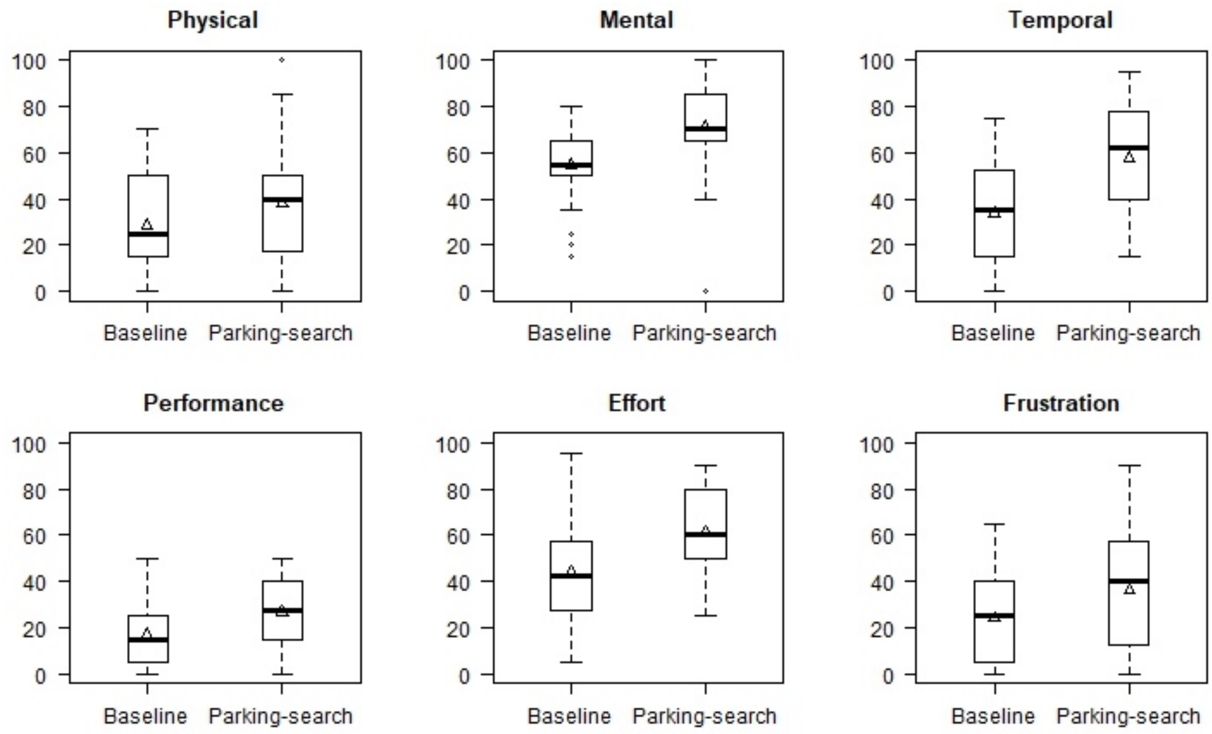

Figure 13: Ratings for specific types of workload by task condition

In the baseline condition, participants rated their experience of each type of workload in the following decreasing order of means: mental (54.63), effort (44.29), temporal (33.93), physical (24.75), frustration (24.11) and performance (17.14). In the parking-search condition, the order was the same, and the means were as follows: mental (71.07), effort (61.61), temporal (57.86), physical (38.04), frustration (36.07) and performance (26.61). The difference in means between parking-search and baseline routes were all significant: physical (9.28; t(27) = -2.6, p = .02, Cohen's d = -0.49), mental (16.44; t(27) = -3.7, p = .001, Cohen's d = -0.71), temporal (23.92; t(27) = -5.5, p < .001, Cohen's d = -1.03), performance (9.46; t(27) = -4.4, p < .001, Cohen's d = -0.83), effort (17.32; t(27) = -3.4, p = .002, Cohen's d = -0.64) and frustration (11.96; t(27) = -2.5, p = .02, Cohen's d = -0.48).

5.1.1 Frequency of Driving Downtown and NASA TLX

Significant differences were found in self-reported overall workload for both groups of participants: those who drive downtown frequently and those who do not. Participants who do not drive downtown often exhibited a 15.2 unit increase in overall weighted workload in the parking-search condition compared to the baseline; 95% CI = [7.09,23.4], $\chi^2(1, n = 42) = 13.45$;

$p < .001$. Those who drive downtown often reported an 11.7 unit increase; 95% CI = [5.34,18.00], $\chi^2(1, n = 42) = 13.07$; $p < .001$.

5.2 Vehicle Measures

Two participants out of the total 28 were removed in these results as their vehicle measures were not recorded. The total elapsed time driving the Bloor St. stretch was not expected to significantly differ between conditions, as the stretch contained 2 traffic signals and various traffic conditions that would affect this measure greatly. Indeed, the time elapsed while drivers drove the Bloor St. stretch did not differ significantly between conditions. It took participants an average of 77.22s to complete the stretch while searching for parking (SD = 25.17s) and 72.99s in the baseline condition (SD = 17.05s); $t(25) = -0.66$, $p = .51$. The average time participants drove over 15 km/h was 44.93s in the baseline condition and 50.14s (SD = 4.75s) when searching for parking. This difference was significant between task conditions; $t(15) = 2.58$, $p = .02$.

5.2.1 Speed

When considering only speeds above 15 km/h, the average speed was found to be significantly higher in the baseline condition (M = 28.77 km/h, SD = 4.01 km/h) than when drivers were searching for parking (M = 26.32 km/h, SD = 3.15 km/h); $t(25) = 2.34$, $p = .03$, Cohen's d = -0.46. The standard deviation (variability) of speeds above 15 km/h was also, on average, significantly higher in the baseline condition (M = 5.45 km/h, SD = 1.78 km/h) than in the parking-search condition (M = 4.40 km/h, SD = 0.99 km/h); $t(25) = 2.27$, $p = .03$, Cohen's d = -0.44. Figure 14 below contains boxplots showing differences in average speed and speed variability for the two conditions.

Figure 14: Average speed and variability of speed under the two task conditions

5.2.2 Lane Position

One participant with severely erratic lane position values was further removed from the following analysis, as their data was deemed to be incorrectly recorded. The average distance to the left lane significantly differed between conditions; drivers drove further from the left lane when searching for parking (M = 1.62 m, SD = 0.13 m) than in the baseline (M = 1.57 m, SD = 0.13 m); t(24) = -2.11, p = .045, Cohen' d = 0.42. The standard deviation of distance to the left lane (lane variability) did not differ significantly between when participants searched for parking (M = 0.33 m, SD = 0.09 m) compared to their baseline (M = 0.37 m, SD = 0.14 m); t(24) = 1.54, p = .14. The boxplots in Figure 15 show the differences between lane position and lane variability across the two task conditions.

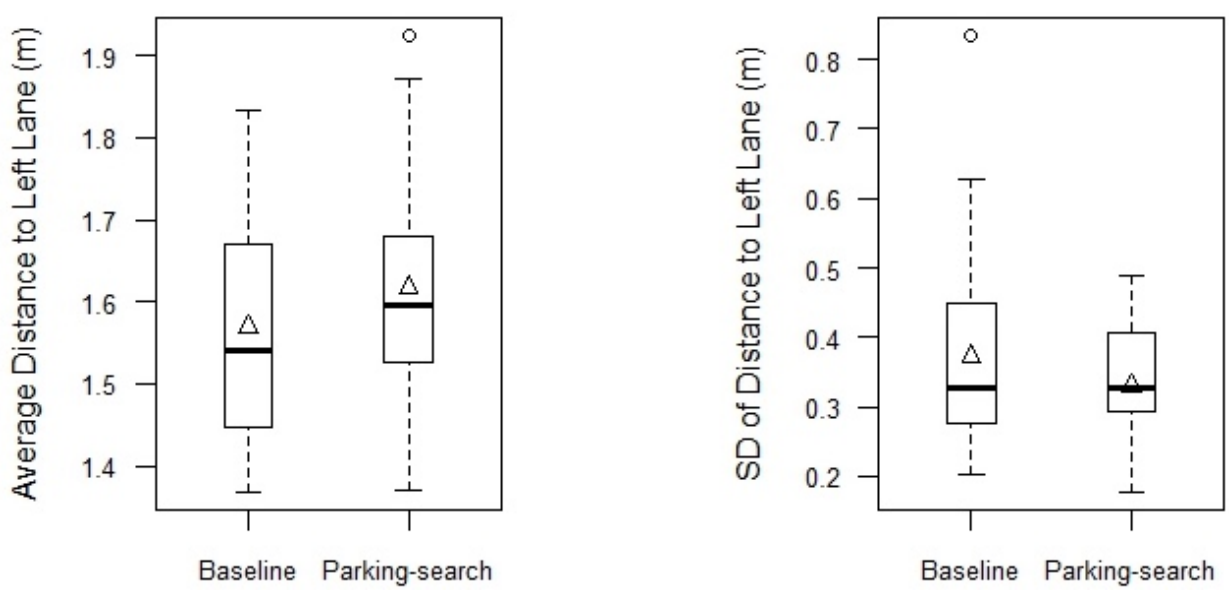

Figure 15: Lane position and lane variability under the two task conditions

5.2.3 Frequency of Driving Downtown and Vehicle Measures

Two participants did not answer the survey question about frequency of driving downtown and were excluded from analysis using this variable. There were no significant differences in vehicle measures found between task conditions in each downtown driving frequency group (e.g. there was no difference in average speed between the baseline and parking-search conditions for frequent downtown drivers). Thus, the findings reported in the earlier section were not observed when the sample was broken into two groups: those who drive frequently in downtown and those who do not. In addition, there were no differences observed between frequent and infrequent downtown drivers for vehicle measures recorded in the baseline drive. Similarly, no differences were found between frequent and infrequent downtown drivers for vehicle measures recorded in the parking-search drive. A larger sample size might be needed to assess these potential differences.

5.3 Physiological Measures

5.3.1 Galvanic Skin Response (GSR)

Four participants were removed from the original data set for GSR measures as their physiological signals were not recorded. Between task conditions, the average skin conductance did not differ significantly, with it being slightly higher in the baseline condition (M = 10.53 μS, SD = 6.89 μS) than when drivers searched for parking (M = 10.00 μS, SD = 6.45 μS); $t(23) = 1.51$, $p = .14$. A bA boxplot for this can be found in Figure 16 below.

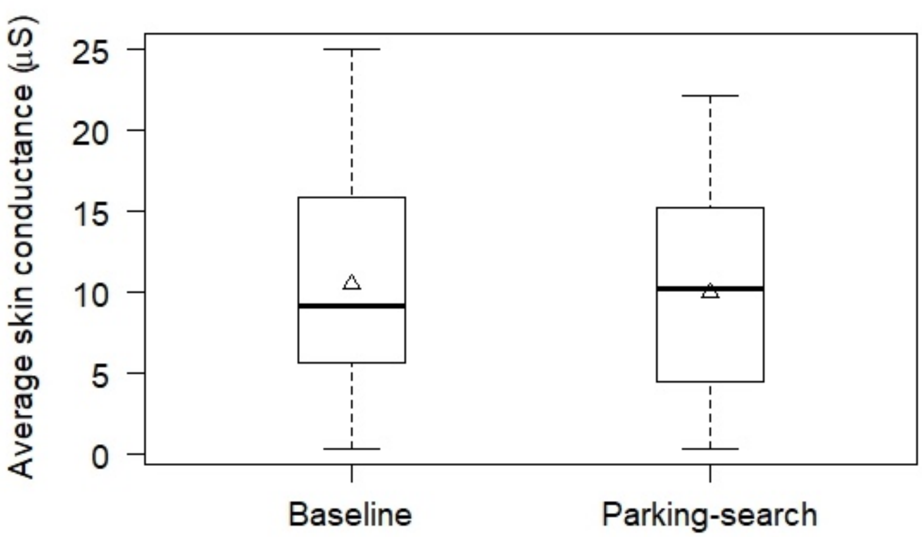

Figure 16: Average skin conductance under the two task conditions

5.3.2 Heart Rate

One participant was removed from the analysis of ECG data as the sensor malfunctioned. The difference in average heart rate was only marginally significant, with participants exhibiting a slight increase when searching for parking (M = 78.99 bpm, SD = 12.34 beats/minute (bpm)) over the baseline (M = 77.89 bpm, SD = 12.55 bpm); t(22) = -1.76, p = .09. A boxplot of this measure is displayed in Figure 17 below.

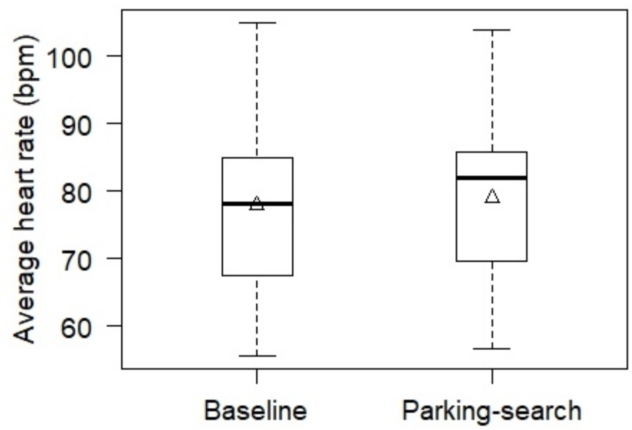

Figure 17: Average heart rate under the two task conditions

5.3.3 Frequency of Driving Downtown and Physiology

Two participants did not answer the survey question about frequency of driving downtown and were excluded from analysis using this variable. As physiology is person-specific, no comparison was performed between participants in physiological measures. For drivers that drive downtown often, no significant difference was found in their average HR or average GSR between task conditions. However, for drivers that do not drive downtown often, two physiological measures exhibited significant differences. Infrequent downtown drivers had heart rates when searching for parking (M = 77.12 bpm, SD = 12.64 bpm) compared to the baseline (M = 75.24 bpm, SD = 11.20); t(10) = 2.63, p = .03, Cohen's d = 0.79. The difference in average skin conductance was significant and was higher in the baseline condition (M = 10.79, SD = 8.29) than when searching for parking (M = 9.92, SD = 7.57); t(11) = -2.15, p = .054.

5.3.4 Physiological Measures during Turns

Physiological measures of participants were extracted when participants drove under the two task conditions and during turns: baseline, parking-search, and turning at intersections. A three-factor repeated measures analysis of variance was conducted to compare average heart rate and average GSR between task conditions. The comparison of task conditions yielded an F-value of $F(2,62) = 0.04$, $p = .97$ for average heart rate and $F(2,67) = 0.02$, $p = .98$ for average GSR. None was significant. Boxplots of these measures under each condition are displayed in Figures 18 and 19 below.

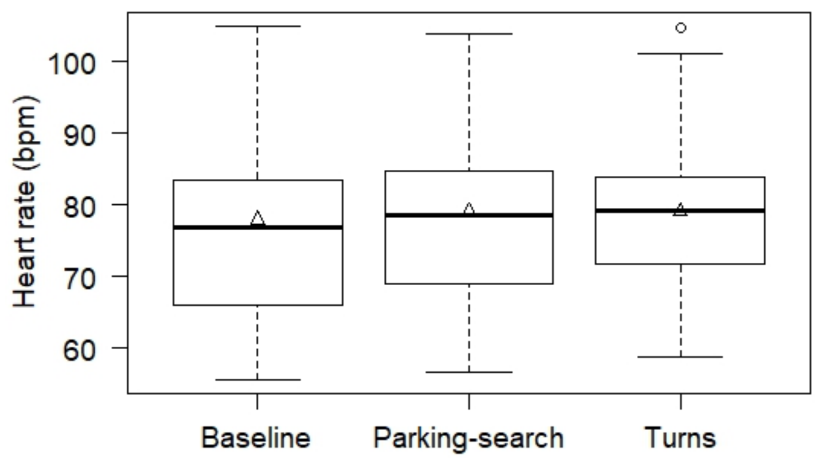

Figure 18: Average heart rate in the two task conditions and during turns

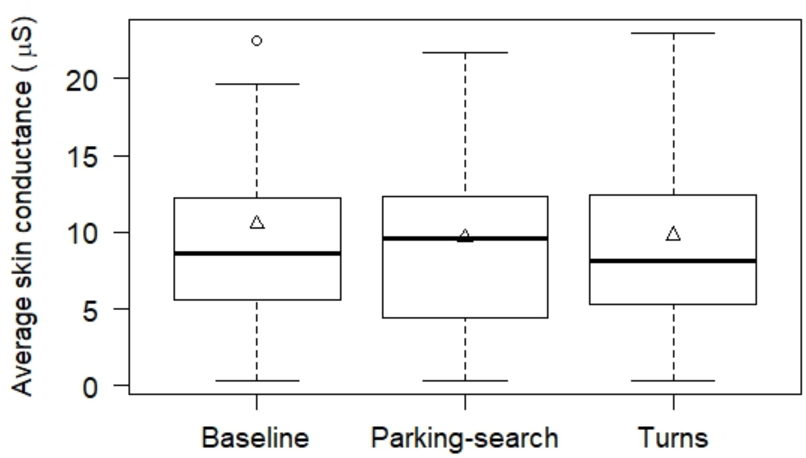

Figure 19: Average GSR in the two task conditions and during turns

5.4 Glance Behaviour

The percent duration of looking off-road (when driving over 15 km/h) was compared between task conditions using a paired t-test; the result was significant ($t(15) = 2.80$, $p = .01$, Cohen's $d = 0.70$). Participants allocated more percentage of time to looking off-road when searching for parking ($M = 53\%$, $SD = 17\%$) than in the baseline condition ($M = 39\%$, $SD = 15\%$) (Figure 20).

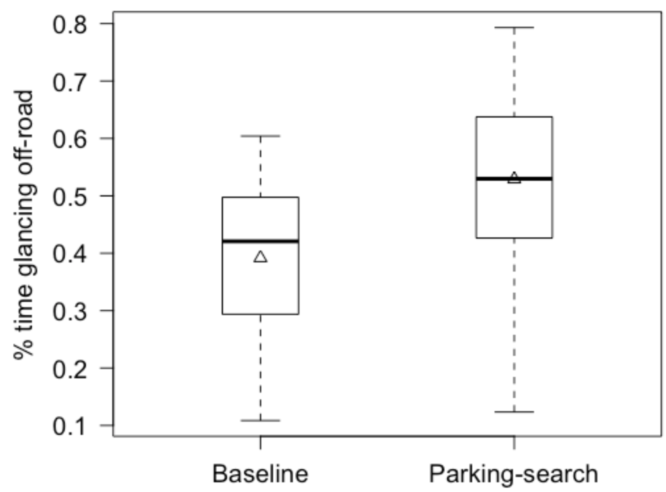

Figure 20: Percentage of time glancing off-road by task condition

A paired t-test revealed that a significant difference between the average duration of off-road glances between task conditions. Participants exhibited longer off-road glances while searching for parking (M = 1.1 sec, SD = 0.4 sec) than in the baseline (M = 0.7 sec, SD = 0.2 sec); $t(15) = 3.5$, $p = .003$, Cohen's $d = 0.87$ (Figure 21).

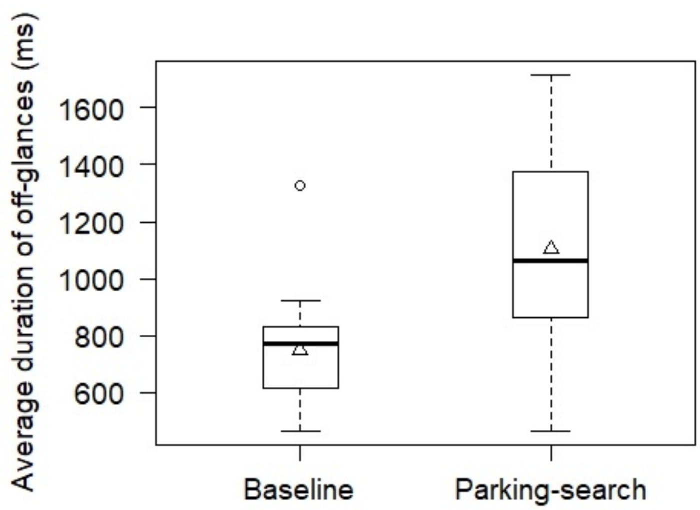

Figure 21: Average duration of off-road glances by task condition

The total number of off-road glances, the number of off-road glances under 1.6s, and the number of glances over 2s were modelled using a Poisson distribution in a generalized linear model, with task condition (baseline or parking-search) as the predictor variable. All Poisson models predicting the number of glances were offset by elapsed time driving over 15 km/h. Thus, the models predicted rate of glances. Off-road glances between 1.6s and 2s were analyzed by a logit function using the binomial distribution due to the low number of occurrences. These glances were categorized into "Higher" (more than 2) and "Lower" (2 or fewer). Thus, the model predicted the likelihood of a driver exhibiting more than 2 (higher) off-road glances between 1.6s and 2s.

The rate of off-road glances was not significantly predicted by task condition. However, the rate off-road glances under 1.6s, the likelihood of higher off-road glances between 1.6s and 2s, and the rate of off-road glances over 2s were all significantly predicted by task condition. The rate of off-road glances under 1.6s was 1.28 times higher in the baseline condition compared to the parking-search condition; 95% CI = [1.09,1.47], $\chi^2(1, n = 32) = 10.72$; $p < .001$. However, the rate of off-road glances over 2s was 3.35 times higher in the parking-search condition than in the baseline; 95% CI = [1.81,6.20], $\chi^2(1, n = 32) = 14.74$, $p < .001$. These measures can be seen in Figure 22 below. As for glances between 1.6s and 2s, participants were more likely to exhibit more than 2 of these glances in the parking-search condition compared to the baseline; OR=6.49, 95% CI = [1.35, 31.17], $\chi^2(1, n = 32) = 5.45$, $p = .02$.

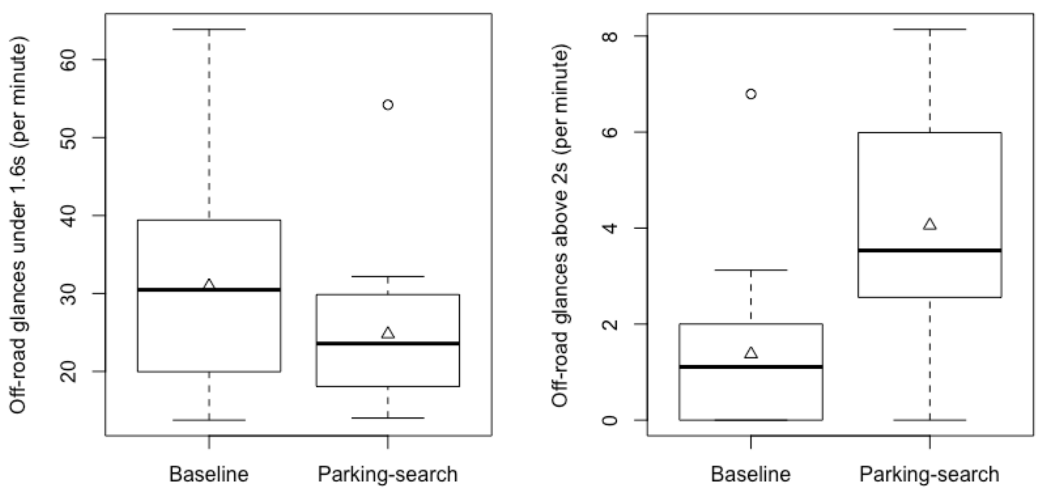

Figure 22: Rate of glances under 1.6s (left) and over 2s (right) by both task condition

A paired t-test was conducted to investigate whether drivers were slowing down during long off-road glances. Only the parking-search drive was used for this test as drivers exhibited very few glances over 2s in the baseline condition. The average speed over 15 km/h during off-road glances over 2s (in the parking-search condition) was compared to the overall average speed over 15 km/h in the parking-search condition. There was no significant difference found between the overall average speed (M = 25.90 km/h, SD = 3.35 km/h) and average speed during the long (>2s) off-road glances (M = 24.89 km/h, SD = 2.86 km/h); $t(15) = 0.29$, $p = .78$.

Finally, very few rear-view mirror, left window, and right window glances were observed, thus no statistical analysis was carried out for these measures. A summary of the total number of glances observed in each condition (for 16 participants) is given in Table 2.

Table 2: Number of left/right window and rear-view mirror glances observed across participants whose eye tracking data was recorded (n=16)

	Baseline	Parking-Search
Right window	1	3
Left window	9	7
Rear-view mirror	2	3

5.4.1 Frequency of Driving Downtown and Glance Behaviour

The response to a survey question which asked how frequently participants drive in downtown Toronto was included in models of off-road glance rates as a predictor variable along with task condition and their interaction. Two participants did not answer the survey question about frequency of driving downtown and were excluded from analysis using this variable. Glances between 1.6s and 2s, and glances over 2s were combined into one variable describing total glances over 1.6s as there were not enough glances in each category (of driving frequency) to conduct the analysis.

When predicting total number of off-road glances, the effect of task condition, downtown driving frequency, and the interaction were not significant. However, participants that do not drive downtown often, exhibited 1.3 times the rate of off-road glances under 1.6s in the baseline, compared to when they were searching for parking; 95% CI = [1.07,1.60], $\chi^2(1, n = 28) = 6.83$, $p = .01$. For participants who drive downtown often, the rate of off-road glances under 1.6s was not significantly different between the baseline and the parking-search task. For glances over 1.6s, the interaction between frequency of driving in downtown and the task condition was significant; $\chi^2(1, n = 28) = 3.68$, $p = .05$. Participants that do not drive downtown often, exhibited about 1/3rd (x 0.33) the rate of off-road glances above 1.6s in the baseline, compared to when they were searching for parking; 95% CI = [0.21,0.54], $\chi^2(1, n = 28) = 20.19$, $p < .001$. Participants who drive downtown often had a larger decline with about 1/7th (x 0.14) the rate of off-road glances above 1.6s in the baseline, compared to when they were searching for parking; 95% CI = [0.07,0.30], $\chi^2(1, n = 28) = 27.73$, $p < .001$. For a given familiarity driving downtown, contrast estimates examining the difference in off-road glances above 1.6s between task conditions were not significant.

5.4.2 The Relation of Long Off-road Glances to SDDQ

Scores from three subsections of the Susceptibility to Distracted Driving Questionnaire (SDDQ) (Engagement in Distraction While Driving, Attitudes and Beliefs about Voluntary Distraction and Susceptibility to Involuntary Distraction) were included in a logit model predicting “High” (2 or more) or “Low” (less than 2) numbers of off-road glances over 2s. The threshold values were chosen so that data was equally distributed among each category. Only glances above 2s were included in this analysis as these have been suggested to increase crash risk (Klauer et al., 2006). One variable showed a significant effect: SDDQ – Susceptibility to Involuntary Distraction (Estimate = -1.56, 95% CI = [-2.6073, -0.5115], χ^2 (1, n = 32) = 8.51, p = .004). The interaction of this section of the SDDQ with task condition did not prove significant when included in the model.

When considering only glance behaviour during the parking-search task (as otherwise there were not enough long off-road glances exhibited), an independent t-test revealed a significant difference in SDDQ score in the Susceptibility to Involuntary Distraction section between participants who exhibited more than 2 long off-road glances and under 2 long off-road glances; t(9.8) = -3.0, p = .01 (Figure 23). A higher SDDQ score in this section means that participants reported that they find activities such as their phone ringing, listening to music and speaking with passengers more distracting while they are driving. No other SDDQ sections resulted in significant differences between high and low long off-road glance frequency groups.

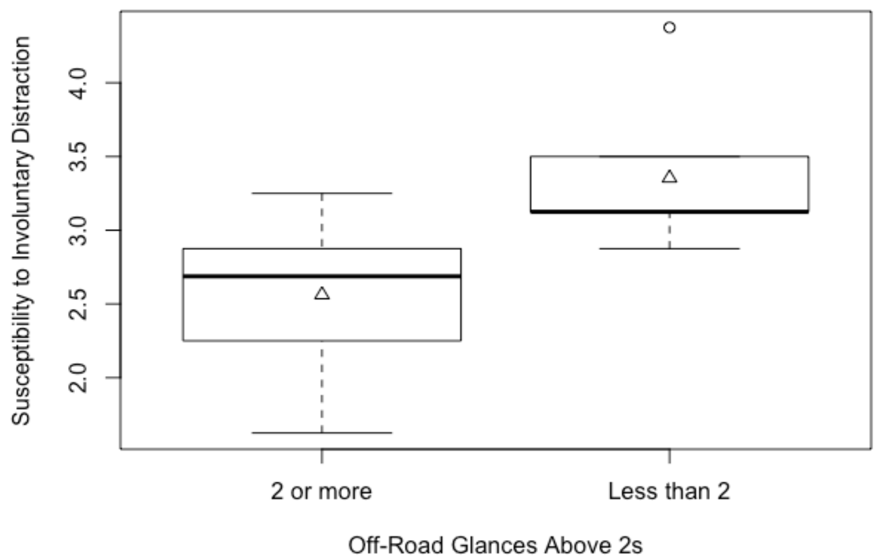

Figure 23: Differences in SDDQ scores for the “involuntary distraction” section between participants who exhibited 2 or more off-road glances above 2s and those who exhibited less than 2

6 Discussion

It is important to study the effects of driving tasks which are common, and often necessary, but may impose demands on drivers that can lead to unsafe driving behaviour. Searching for parking is one such task which remains under-researched in regard to human factors and traffic safety, despite its prevalence as an activity on urban roads. This study is the first known experiment that attempts to quantify the effects searching for parking has on drivers. Advanced technology (such as the instrumented vehicle and head-mounted eye tracker) was used in data collection, allowing for reliable and precise data collection.

Participants self-reported a clear increase in workload between driving under the baseline condition and driving when periodically searching for parking. Participants who do not drive in downtown Toronto often reported a higher difference in workload between task conditions than those who do drive in downtown often, however both increases are considered large effects according to Cohen (1988). Of the individual types of demand explored in NASA TLX, participants found mental demand to be the highest in both conditions, followed by effort and temporal demand. From a descriptive statistical perspective, the largest average difference in demand reported was in temporal demand, which indicates that drivers did feel time pressure when searching for parking even though there was no deadline to reach a destination; it seems, then, that the rate at which they performed the task was at least partially imposed on them by external pressures. Nevertheless, participants drove slower on average when searching for parking. Given that the variability of speed was higher in the baseline condition, it appears that drivers are lowering their speed overall when tasked with searching for parking, and not slowing down periodically as one may suppose. Lowering speed is often seen as a compensatory strategy that has been observed when drivers experience high visual workload (Engström et al., 2005). The lower speed variability may also be a statistical artifact of the generally lower speeds exhibited when searching for parking.

The Edquist et al. (2012) simulator study found that drivers drove further from the curb when parking bays were 90% occupied compared to when no street parking bays were present or if they were empty; it was suggested that this may be dangerous as vehicles were positioned closer to oncoming traffic. Our study found that when tasked with searching for parking on the same street as the baseline (with occupied parking bays), drivers drove closer to the curb. Drivers may have purposefully kept themselves farther from oncoming traffic while they engaged in a potentially distracting task. However, it is also possible that they drifted nearer to the parking bays as they visually inspected them for vacancy, or to better read parking signs with small letter sizing. It was observed that participants received many of their cues about the legality of parking spaces by the presence of other parked cars, rather than first reading the parking signage thoroughly. Further research is needed to comment on the role reading signs plays in the search for parking. No increase in lane keeping variability was observed, despite the hypothesis that it would increase under heightened visual load as reported in another study (Engström et al., 2005). The lack of significance in our study may be due to the generally low speeds of the driving area which allowed participants to maintain their course with minimal deviation; it is suggested that further research be done in an area where speeds average above 40 km/h. A lack of statistical power may also explain these and other nonsignificant findings.

Physiological signals (heart rate and galvanic skin response (GSR)) were expected to reflect an increase in workload. However, average heart rate showed only a slight increase approaching significance when drivers were searching for parking, and average GSR did not show any significant difference between task conditions. The lack of significance may again be due to a lack of power resulting from our limited sample size or from the variability introduced from the driving environment encompassing uncontrolled factors (e.g. pedestrians jay-walking, traffic signal status, behaviour of other traffic) that may have impacted the driver's physiological state more than the searching for parking task. Interestingly, there was an increase in heart rate for drivers unfamiliar with driving downtown when searching for parking compared to baseline. This increase is in line with the hypothesis that infrequent downtown drivers would experience heightened effects of the parking search task. However, average GSR significantly increased when searching for parking for this group, which is the opposite of the expected response with increased stress and workload. It is believed that the GSR sensors used in the study are unreliable due to the noise in the signal brought on by the vibrations in the vehicle and the movement of the participant; a less sensitive placement than the bottom of the foot may have achieved more reliable results. In general, in a real-life scenario, the pressure of having to park the car after the parking search is expected to contribute to the workload of the driver and impact their physiological signals further than observed in this experiment. Initial analysis of data from this experiment included measures of heart rate variability (HRV) – another often-used measure to assess driver workload (Mehler et al., 2009) – but no significant effects were found. It was determined that we did not have the recommended 5-minute minimum of baseline signal to properly assess any change in HRV between task conditions (Shaffer & Ginsberg, 2017).

Significant differences were not found for the average heart rate or average GSR when the baseline and parking search task conditions (on the Bloor St. stretch) were compared to the four turns executed by the participant. While possible that the effect of turning on physiology is smaller than the effect of searching for parking, it is also possible that that the baseline condition itself was relatively stressful and therefore did not differ highly from turning maneuvers. In addition, while it is well-documented that intersection maneuvers occur under an increased visual workload (Bao & Boyle, 2009; Harbluk et al., 2007; Werneke & Vollrath, 2012), there was little research found that examined how physiological measures are affected during turns. These results serve as a small contribution to an area of driving research that requires further investigation.

Analysis of off-road glances produced some interesting results. Firstly, participants exhibited fewer off-road glances under 1.6s but more glances over 1.6s when searching for parking compared to the baseline. This suggests that drivers adjust their visual scanning behaviour when searching for parking by lessening the number of short glances they perform to allow more long off-road glances. Long off-road glances can reduce the driver's ability to respond to unexpected events on the road (Liang et al., 2012). Drivers exhibiting more frequent long off-road glances may contribute to a more dangerous driving environment. Even though participants were found to decrease the number of short off-road glances when searching for parking, the total percentage of off-road glance duration, was still higher in this condition compared to the baseline.

There was no difference in the rate of off-road glances between those participants who drive in downtown often and those who do not. However, those who do not drive downtown often performed significantly higher rates of glances under 1.6s under the baseline condition than when searching for parking, whereas there was no significant effect for those who drive downtown frequently. It appears that infrequent downtown drivers reallocated their attention by exhibiting fewer short glances when searching for parking, but frequent downtown drivers did not significantly alter their number of short glances. For glances over 1.6s, both frequent downtown drivers and infrequent downtown drivers performed significantly more glances when searching for parking. However, this effect was greater for drivers who do not drive downtown often. Frequent downtown drivers may exhibit less long glances off-road when searching for parking because it takes less time for them to confirm an available space. Overall, more samples of drivers who drive frequently in downtown Toronto are needed to better comment on the effect of familiarity driving downtown has on glances.

Participant's self-reported susceptibility to involuntary distraction (as assessed using the Susceptibility to Distracted Driving Questionnaire (SDDQ)) was a significant predictor of off-road glances over 2s in both task conditions. Those who self-reported to being more susceptible may have been more aware of their susceptibility to involuntary distractions, and thus may have consciously scanned the roadway more frequently. It is important to note that not all off-road glances are equivalent. Glances made far ahead of the vehicle (Figure 24, point B) still allow the driver to maintain the environment ahead in their field of view, while fixations made on points closer to the vehicle with a higher angular velocity (Figure 24, point A) have a reduced portion of the road ahead held in their view.

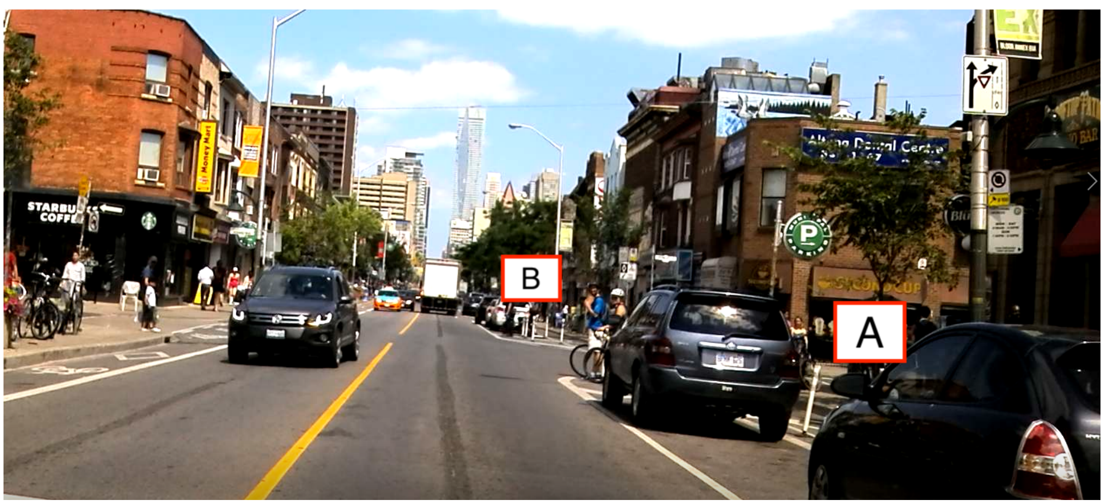

Figure 24: Fixation on point B allows more of the road ahead to be maintained in the driver's vision than fixation on point A

Further analysis on the angular velocity of fixation points is needed to further comment about how unsafe some of the long off-road glances observed in this study are. Some off-road glances are necessary to ensure a safe environment, such as glances to a pedestrian about to cross the street. Again, more research is needed to determine whether the off-road glances we observed affect the driver's ability to notice and react to unexpected events in the road ahead. In the

Edquist et al. (2012) simulator study, they concluded that even though participants reduced their speed, it was not sufficient in allowing drivers to maintain safe hazard response times. Here, we cannot make such a statement without further exploration.

Our findings provide evidence that searching for parking imposes demands on the driver that affect driver physiology, visual attention allocation, and driving behaviour. The parking-search task designed for this experiment was a simplified version of the search for parking drivers normally experience. Participants did not have to navigate or find their way to a destination, they did not have any time pressures enforced on them (e.g. reaching a destination on time), and they were only required to search for parking that was in the same direction they were going as well as on the same street. Given the simplification of the parking-search task in this experiment, it is expected that drivers in a similarly complex environment are affected even more so in natural conditions. Drivers exhibited some compensatory behaviours which are conducive to a safer driving environment, such as reduced speed. They also exhibited behaviours which can be considered unsafe, such as increased off-road glances over 2s. More research is needed to determine which behavioural changes have a greater effect on the overall safety of the driver and road environment, and what these effects are. This work serves as an important initial step in an ongoing investigation of how searching for parking affects drivers and the road environment. In addition, given there is now evidence that searching for parking does affect drivers, we can say that measures such as changes in road design or parking search assistance via mobile applications may pose additional benefits to drivers beyond reducing traffic congestion and parking payment efficiency.

6.1 Limitations

This study was conducted in an instrumented vehicle in a real-world environment, which provided a greater level of ecological validity than a simulator study and provided the ability to collect more precise data than a naturalistic study through an eye-tracker. However, there were also some resultant experimental limitations. First, the study was conducted with two researchers present in the car in addition to the participant at all times. The participants were aware that they were under direct observation and this awareness may have affected their driving performance and physiological response, though comparisons were made to a baseline during which participants were also under observation to mitigate this potential effect. The instrumented vehicle itself may also have affected participants due to the visible presence of equipment and the general adaptation required when using another vehicle than their own. The sample size was limited due to the challenges of finding and scheduling participants qualified to take part in an on-road study during specific hours, and the further loss of data due to equipment malfunctions amplified the limitation of a small sample size. Additional samples would also bring further clarity to the small and medium effect sizes of some of the significant statistical test results. It should be noted that with each additional statistical test reported, there is an increased possibility of encountering Type I error. Adjustments to significance levels may be made by the reader to reduce the chance of reporting inflated results.

Participants in this study were all experienced drivers within a low crash-risk age group (Cooper, 1990; McGwin, Jr & Brown, 1999), which means they may represent drivers that exhibit the lowest frequency of unsafe behaviours and are best equipped to drive under additional workload. Further research is needed to determine how searching for parking affects young, old, and new drivers differently from this sample. In addition, the experimental region of most of the analysis (the Bloor St. stretch) is a highly trafficked area with two traffic signals where vehicles rarely reach the speed limit of 50 km/h. This limits the speeds which our participants could choose to drive, as well as the pressures they were under from surrounding vehicles. In addition, due to issues with equipment, headway distance (to the lead vehicle) and brake pressure could not be recorded, both of which would have been useful measures of driving performance. In general, we were unable to control many factors such as the availability of parking and the behaviour of surrounding traffic, which might have affected participants differently between conditions. Also, the posted parking restrictions in the area do not vary, and drivers may not have needed to look at them more than once. In future studies, it is suggested that there be consequences of incorrectly identifying legal parking spaces, to incentivize participants to truly consider whether they can park there or not. Not having to park would have affected the degree to which participants seriously assessed parking spaces and thus how well the experimental task mimicked a true parking search. In addition, we compared drivers who reported that they drive in downtown Toronto frequently against those that reported that they do not, but did not consider drivers who may drive in another similar urban region as downtown Toronto, but not in Toronto. Future analyses should also consider how urban and suburban/rural drivers may differ.

Finally, the Bloor St. stretch is relatively short, which limited the opportunity to examine heart rate variability (another common measure of workload in driving research) as over 5-minutes of signal is often the recommended minimum for baselines (Shaffer & Ginsberg, 2017). The region also had clearly marked parking bays which our limited sample drove only twice; further studies should utilize a larger sample with more experimental regions (and a variety of parking restrictions, signage and existence of parking bays) for stronger and broader conclusions about the effects of parking search.

6.2 Future Work

In addition to the Bloor St. stretch analyzed in this thesis, the conducted experiment produced data of participants driving a variety of roads with several types of posted parking restrictions and different driving conditions (e.g. one-way). Further analysis of this data will be performed to compare changes in driving behaviour on different types of roads. In addition, we would like to investigate the influence of parking signs where they are more complicated and relevant, such as in regions where posted signage contains many restrictions and where there are multiple different types of parking signs along the route. It is also highly relevant to analyze the visual angle of off-road glances, which would be an important inclusion in future studies. The effects of time pressure, wayfinding and the added stress of parking the car were not imposed on participants in this study but are expected to increase workload on the driver and should be further investigated. It is believed that the most accurate depiction of the effects of the parking search on the driver would be observed in a naturalistic setting.

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Appendices

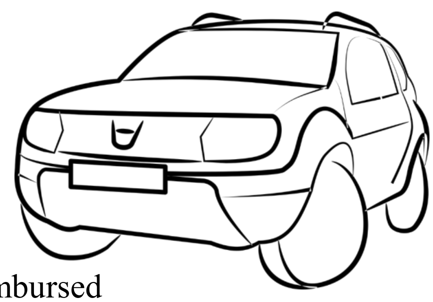
Appendix A: Recruitment Poster

Mechanical & Industrial Engineering
UNIVERSITY OF TORONTO

Drivers Needed for On-Road Study

For an Instrumented Vehicle Study on Driving Behaviour
July – September 2017

The Human Factors and Applied Statistics Lab invites you to participate in an on-road driving experiment studying driving behaviour.



Location: University of Toronto
St. George Campus
(Downtown)

Duration: Approximately 3 hours

Compensation: $15 per hour + parking reimbursed

- **Must have had a valid G driver's license (or equivalent) for at least 3 years**
- **Must drive at least once per week**
- **Ages 35 - 54**

To apply, fill out our short questionnaire:
http://ca.surveygizmo.com/s3/50001961/Parking-Study-Screening-Survey

For more information, please contact:
uoftparkingstudy@gmail.com
(647) 573 6294

Appendix B: Informed Consent Form

Participant Consent Form

Title of Study: Effects of Searching for On-Street Parking on Driver Behaviour, Physiology and Attention Allocation

Investigators: Canmanie Teresa Ponnambalam (647-573-6294; canmanie@mie.utoronto.ca)
Prof. Birsen Donmez (416-978-7399; donmez@mie.utoronto.ca)

You are being asked to take part in a research study. Before agreeing to participate in this study, it is important that you read and understand the following explanation of the proposed study procedures. The following information describes the purpose, procedures, benefits, discomforts, risks and precautions associated with this study. To decide whether you wish to participate or withdraw in this research study, you should understand enough about its risks and benefits to be able to make an informed decision. This is known as the informed consent process. Please ask the investigator to explain any words you don't understand before signing this consent form. Make sure all your questions have been answered to your satisfaction before signing this document.

Purpose

This study **funded by NSERC Strategic Partnership Grant** aims to understand the demands drivers experience in urban driving:

1. Fill out a series of questionnaires
2. Wear measurement devices (physiological sensors) on your body
3. Drive on urban streets while following turn-by-turn directions given by the researcher

Procedure

There are five parts to this study:

1) Informed Consent: You have been asked to read this document. Please feel free to ask the researcher any questions you may have.

2) Surveys and Training: If you agree to participate, you will be asked to fill out surveys related to your driving habits, behaviour, and personality. A photocopy will be made of your driver license for insurance purposes. Then, the researcher will describe the experiment in more detail in a training session.

3) Initial Setup of Sensors and Familiarization Drive: The researcher will familiarize you with the features of the instrumented vehicle. You will be guided through a preset route by the researcher in the passenger seat. We will answer any questions about the system during and after this familiarization drive. After this drive, the researcher will fasten physiological sensors (a list is provided on the next page) to your body and secure the eye-tracking device.

4) Baseline and 5) Parking Drive: You will then be asked to drive two preset routes. These drives will take approximately 15 minutes each. You will be guided through the routes by turn-by-turn instructions given by the researcher in the passenger seat. On one of the drives, you will be asked intermittently to identify vacant street parking spaces but you will not be asked to actually park. At the end of each drive, you will be asked to complete a perceived effort survey. Sensors and cameras will record your behaviour.

The experiment is expected to last up to three hours, including filling out questionnaires and surveys.

Risks
We want to make you aware of two possible risks:

1. The first potential risk is that of a collision. The risk to the driver is minimal because all driving for the experiment will be done on streets with speed limits of 50 km/h or less. In case of an emergency, the vehicle is equipped with a secondary brake that can be depressed from the passenger seat. During the experiment, you will be closely monitored for any signs of discomfort and you are asked to notify the experimenter if they begin to feel uncomfortable in the driving environment. The experimenter will stop the experiment if you drive in a dangerous or reckless manner. A first aid kit will be carried in the vehicle at all times. In case of collision, you will be covered by University of Toronto insurance. You will not be asked to violate any laws, and you should not. You will be held responsible for any tickets issued for illegal actions while the vehicle is under your control.

2. You will be wearing the following instruments which may cause some discomfort.
    a. Electrocardiography (ECG) device that measures heart rate
    b. Skin conductance sensor (GSR) that measures sweat
    c. Eye tracking headset that measures where you are looking

    Some of these instruments have electrodes that are 2.5 cm radius and are attached to the skin through an adhesive surface. Adhesives are safe for skin contact, and adhesive residue is removable by wiping with paper towel, or washing with soap and water if necessary. You will be provided with paper towel to clean your skin. Disposable adhesive pads will be used during the experiment.

Benefits
There are several benefits to conducting this study. The most important benefit is your contribution to research in traffic safety, which will guide the development of methods to enhance traffic safety. You will also gain experience with academic research and be able to use and test out a state of the art instrumented vehicle.

Compensation
The experiment is expected to last for approximately three hours. You will be receiving payment at the rate of $15/hr. Hence, the expected total compensation is $45 ($15/hr x 3hr). You may withdraw at any time. If a withdrawal should occur, you will be compensated on a pro-rated basis at $15 per hour for your involvement to that point. Compensation will be pro-rated to the next half-hour increment. If you have any parking costs associated with your participation in the experiment, they will be reimbursed.

Confidentiality
All information obtained during the study will be held in strict confidence. You will be identified with a study number only, and this study number will only be identifiable by researchers working on this project. No names or identifying information will be used in any publication or presentation. No information identifying you will be transferred outside the research facilities in this study. The photocopy of your driver license will be stored separately from your experimental records for the sole purpose of keeping a record for the vehicle's insurance company.

The research study you are participating in may be reviewed for quality assurance to make sure that the required laws and guidelines are followed. If chosen, (a) representative(s) of the Human Research Ethics Program (HREP) may access study-related data and/or consent materials as part of the review. All information accessed by the HREP will be upheld to the same level of confidentiality that has been stated by the research team.

Please be advised that we make video recordings of experimental trials. The recordings will be stored securely in digital format. The videos will only be seen by the investigator, as well as the co-investigator's and faculty supervisor's research assistants and research collaborators. Faces will be blurred in all photographs used in publications. Please indicate below if you give us permission to show videos of your face in in public presentations:

( ) I consent to having my video used for public presentations
( ) I DO NOT consent to having my video used for public presentations

Participation
Your participation is voluntary, and you may refuse to participate, may withdraw at any time, and may decline to answer any question or participate in any parts of the procedures/tasks – all without negative consequences. If you choose to withdraw at any point during the experiment, your data will be deleted and the experimenter will drive you back to the experiment origin. Only your name will be kept on record for your participation in this experiment.

If you choose to participate in this study, the responses you have already given to the screening questionnaire, including your age, sex, and driving frequency may be used in data analysis.

Location
The classroom portion of the experiment will be conducted in the Human Factors and Applied Statistics Lab, located at Rosebrugh Building (RS), 164 College Street, Toronto, ON M5S 3G8. The on-road portion of the experiment will take place within downtown Toronto.

Questions
You can contact the Office of Research Ethics at ethics.review@utoronto.ca, or 416-946-3273, if you have questions about your rights as a participant. If you have any general questions about this study, please call Canmanie T. Ponnambalam at (647) 573-6294 or email canmanie@mie.utoronto.ca.

Results
To request a copy of the published results of this study, please email canmanie@mie.utoronto.ca with subject line "Research Results". A link to the published results of this study will also be made available at https://hfast.mie.utoronto.ca/ under "Publications".

Consent
I have had the opportunity to discuss this study and my questions have been answered to my satisfaction. I consent to take part in the study with the understanding I may withdraw at any time. I have received a signed copy of this consent form. I voluntarily consent to participate in this study

______________________	______________________	______________________
Participant's Name (please print)	Signature	Date

I confirm that I have explained the nature and purpose of the study to the participant named above. I have answered all questions.

______________________	______________________	______________________
Investigator's Name	Signature	Date

Appendix C: Screening Survey

University of Toronto Driving Study Screening Survey

Do you want to start the survey now?
*

- Yes
- No

Personal Information

1. What is your first name? *

2. What is your last name? *

3. What is you E-mail address? *

4. What is you phone number? *

5. What is your preferred method of contact? *

- Phone
- E-mail

6. In what year were you born? (YYYY) *

7. What is your sex? *

- Male
- Female
- Other

8. Do you currently hold a valid government issued driver's license? *

- Yes
- No

Driving routine

9. What is your current driver's license? *

- Full license (e.g. G license in Ontario)
- Learner's license (e.g G1 and G2 license in Ontario)
- Other(please specify)

10. How often do you drive a car or other motor vehicle? *

- Almost every day
- A few days a week
- A few days a month
- A few days a year or less
- Never

11. How often do you drive in Downtown Toronto?

- Almost every day
- A few days a week
- A few days a month
- A few days a year
- Never

12. Over last year, approximately how many kilometres did you drive? *

- Under 5,000 km
- Between 5,000 km and 15,000 km
- Between 15,001 km and 25,000 km
- Between 25,001 km and 35,000 km
- Between 35,001 km and 45,000 km
- Over 45,000
- None
- I don't know.

13. Are you required to wear corrective lenses of any kind while you drive? *

- Yes
- No

14. Would you be able to wear contact lenses during the experiment? *

- Yes
- No

15. When did you obtain your FULL driver's license? (G license in Ontario) *

�

Driving Behaviour

16. On a scale of 1 to 10, with 1 being very unsafe and 10 being very safe, how safe a driver do you think you are? *

1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○

17. In the past five years, how many times have you been stopped by a police officer and received a **warning** (but no citation or ticket) for a moving violation (i.e. speeding, running a red light, running a stop sign, failing to yield, reckless driving, etc.)? Enter 0 if none. *

18. In the past five years, how many times have you been stopped by a police officer and received a **citation or ticket** for a moving violation? Enter 0 if none. *

19. In the past five years, how many times have you been in a **vehicle crash** where you were the driver of one of the vehicles involved? Enter 0 if none. *

Personal Well-being

20. How would you describe your **physical** well-being (in the past month)? *

- Excellent
- Good
- Average
- Fair
- Poor

21. Compared with others your age, how would you rate your overall **vision**? (If you wear glasses or contacts, rate your corrected vision when you are wearing them.) *

- Excellent
- Good
- Average
- Fair
- Poor

22. Compared with others your age, how would you rate your overall **hearing**? *

- ○ Excellent
- ○ Good
- ○ Average
- ○ Fair
- ○ Poor

23. Compared with others your age, how would you rate your overall **memory**? *

- ○ Excellent
- ○ Good
- ○ Average
- ○ Fair
- ○ Poor

Almost done!

24. If you are interested in participating in other current or future research (beyond this study) at the Human Factors and Applied Statistics Lab, please indicate below. *

- ○ I am interested in participating in future research; please contact me when opportunities become available.
- ○ Do not contact me about future studies.

25. Where did you hear about our study?

- A friend
- Facebook
- Craigslist
- Kijiji
- Poster
- Indeed
- Other - Write In (Required)

Thank you!

We will contact you within 48 hours to let you know if you qualify for the study or not.

Appendix D: Susceptibility to Distracted Driving Questionnaire

1. When driving, I:	Never	Rarely	Sometimes	Often	Very Often
a. have phone conversations.					
b. manually interact with a phone (e.g., sending text messages).					
c. adjust the settings of in-vehicle technology (e.g., radio channel or song selection).					
d. read roadside advertisements.					
e. continually check roadside accident scenes if there are any.					
f. chat with passengers if you have them.					
g. daydream.					

2. I think, it is alright for me to drive and	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. have phone conversations.					
b. manually interact with a phone (e.g., sending text messages).					
c. adjust the settings of in-vehicle technology (e.g., radio channel or song selection).					
d. read roadside advertisements.					
e. continually check roadside accident scenes.					
f. chat with passengers.					

3. I believe I can drive well even when I:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. have phone conversations.					
b. manually interact with a phone (e.g., sending text messages).					
c. adjust the settings of in-vehicle technology (e.g., radio channel or song selection).					
d. read roadside advertisements.					
e. continually check roadside accident scenes.					
f. chat with passengers.					

4. Most drivers around me drive and:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. have phone conversations.					
b. manually interact with phones.					
c. adjust the settings of in-vehicle technology (e.g., radio channel or song selection).					
d. read roadside advertisements.					
e. continually check roadside accident scenes if there are any.					
f. chat with passengers if there are any.					

5. Most people who are important to me think, it is alright for me to drive and:	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
a. have phone conversations.					
b. manually interact with phones.					
c. adjust the settings of in-vehicle technology (e.g., radio channel or song selection).					
d. read roadside advertisements.					
e. continually check roadside accident scenes.					
f. chat with passengers.					

6. While driving, I find it distracting when	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Never happens
a. my phone is ringing.						
b. I receive an alert from my phone (e.g., incoming text message).						
c. I am listening to music.						
d. I am listening to talk radio.						
e. there are roadside advertisements.						
f. there are roadside accident scenes.						
g. a passenger speaks to me.						
h. daydreaming.						

Appendix E: Driving Behaviour Questionnaire

Nobody is perfect. Even the best drivers make mistakes, do foolish things, or bend the rules at some time or another. For each item below you are asked to indicate HOW OFTEN, if at all, this kind of thing has happened to you. Base your judgments on what you remember of your driving. Please indicate your judgments by circling ONE of the numbers next to each item. Remember we do not expect exact answers, merely your best guess; so please do not spend too much time on any one item.

How often do you do each of the following?	Never	Hardly ever	Occasionally	Quite often	Frequently	Nearly all the time
a. Try to pass another car that is signaling a left turn.	○	○	○	○	○	○
b. Select the wrong turn lane when approaching an intersection.	○	○	○	○	○	○
c. Fail to 'Stop' or 'Yield' at a sign, almost hitting a car that has the right of way.	○	○	○	○	○	○
d. Misread signs and miss your exit.	○	○	○	○	○	○
e. Fail to notice pedestrians crossing when turning onto a side street.	○	○	○	○	○	○
f. Drive very close to a car in front of you as a signal that they should go faster or get out of the way.	○	○	○	○	○	○
g. Forget where you parked your car in a parking lot.	○	○	○	○	○	○
h. When preparing to turn from a side road onto a main road, you pay too much attention to the traffic on the main road so that you nearly hit the car in front of you.	○	○	○	○	○	○
i. When you back up, you hit something that you did not observe before but was there.	○	○	○	○	○	○
j. Pass through an intersection even though you know that the traffic light has turned yellow and may go red.	○	○	○	○	○	○
k. When making a turn, you almost hit a cyclist or pedestrian who has come up on your right side.	○	○	○	○	○	○
l. Ignore speed limits late at night or very early in the morning.	○	○	○	○	○	○
m. Forget that your lights are on high beam until another driver flashes his headlights at you.	○	○	○	○	○	○
n. Fail to check your rear-view mirror before pulling out and changing lanes.	○	○	○	○	○	○

How often do you do each of the following?	Never	Hardly ever	Occasionally	Quite often	Frequently	Nearly all the time
o. Have a strong dislike of a particular type of driver, and indicate your dislike by any means that you can.	○	○	○	○	○	○
p. Become impatient with a slow driver in the left lane and pass on the right.	○	○	○	○	○	○
q. Underestimate the speed of an oncoming vehicle when passing.	○	○	○	○	○	○
r. Switch on one thing, for example, the headlights, when you meant to switch on something else, for example, the windshield wipers.	○	○	○	○	○	○
s. Brake too quickly on a slippery road, or turn your steering wheel in the wrong direction while skidding.	○	○	○	○	○	○
t. You intend to drive to destination A, but you ‘wake up’ to find yourself on the road to destination B, perhaps because B is your more usual destination.	○	○	○	○	○	○
u. Drive even though you realize that your blood alcohol may be over the legal limit.	○	○	○	○	○	○
v. Get involved in spontaneous, or spur-of-the moment, races with other drivers.	○	○	○	○	○	○
w. Realize that you cannot clearly remember the road you were just driving on.	○	○	○	○	○	○
x. You get angry at the behavior of another driver and you chase that driver so that you can give him/her a piece of your mind.	○	○	○	○	○	○

Appendix F: Arnett Inventory of Sensation Seeking

For each item, indicate how well it describes you.	Very well	Somewhat	Not very well	Not at all
I can see how it would be interesting to marry someone from a foreign country.				
When the water is very cold, I prefer not to swim even if it is a hot day.				
If I have to wait in a long line, I am usually patient about it.				
When I listen to music, I like to be loud.				
When taking a trip, I think it is best to make as few plans as possible and just take it as it comes.				
I stayed away from movies that are said to be frightening or highly suspenseful.				
I think it's fun and exciting to perform or speak before a group.				
If I were to go to an amusement park, I would prefer to ride the rollercoaster or other fast rides.				
I would like to travel to places that are strange and far away.				
I would never like to gamble with money, even if I could afford it.				
I would have enjoyed being one of the first explorers of an unknown land.				
I like a movie where there are a lot of explosions and car chases.				
I don't like extremely hot and spicy foods.				
In general, I work better when I'm under pressure.				
I often like to have the radio or TV on while I'm doing something else, such as reading or cleaning up.				
It would be interesting to see a car accident happen.				
I think it's best to order something familiar when eating in a restaurant.				
I like the feeling or standing next to the edge on a high place and looking down.				
If it were possible to visit another planet or the moon for free, I would be among the first in line to sign up.				
I can see how it must be exciting to be in a battle during a war.				

Appendix G: Supplemental Information Questionnaire

1) How safe a driver do you consider yourself?

Very unsafe ( ) 1 ( ) 2 ( ) 3 ( ) 4 ( ) 5 ( ) 6 ( ) 7 ( ) 8 ( ) 9 ( ) 10 Very safe

2) For how many years have you been driving?

____

3) In the past five years, how many times have you been stopped by a police officer and received a WARNING (but no citation or ticket) for a moving violation (i.e. speeding, running a red light, running a stop sign, failing to yield, reckless driving, etc.)?
Enter a number (0 for none)*

____

4) In the past five years, how many times have you been stopped by a police officer and received a CITATION OR TICKET for a moving violation?
Enter a number (0 for none)*

____

5) In the past five years, how many times have you been in a VEHICLE CRASH where you were the driver of one of the vehicles involved?
Enter a number (0 for none)*

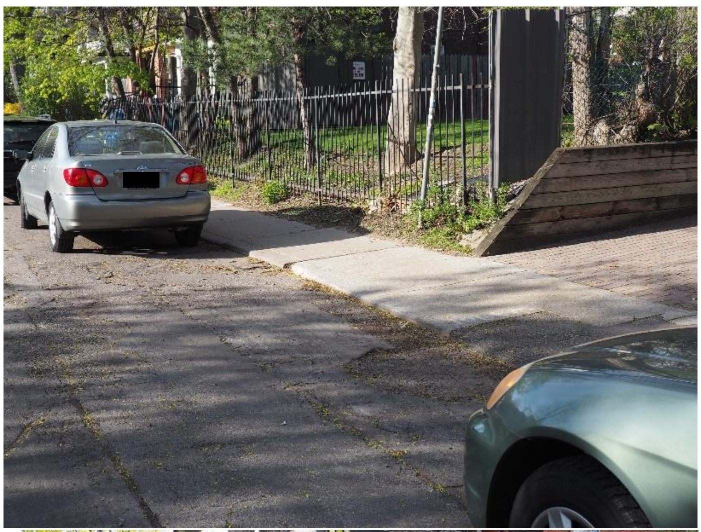
____

Appendix H: Parking Sign Instructions Booklet

The purpose of this exercise is to familiarize yourself with the parking rules, regulations, and signs that you may encounter during the study. We have provided some pictures of unique parking signs along with their meaning. We will go through each scenario to ensure that you have a basic understanding of the parking rules. At the end, there will be a short quiz to ensure that you are comfortable with these parking rules. The results of the quiz will not impact your ability to participate in this study. Feel free to seek clarification for any of the pictures, definitions, or questions.

Important Parking Rules and Conventions in Toronto

- If it is outside of the times that are specified on the parking sign, parking is allowed for a maximum time of 3 hours
- The arrows on the bottom of parking signs indicate which side of the post the restrictions apply to

	Do not obstruct a driveway.
	Do not park within 3 metres of a fire hydrant.

You cannot stop on the left side of the post. Stopping may result in an $150 fine.

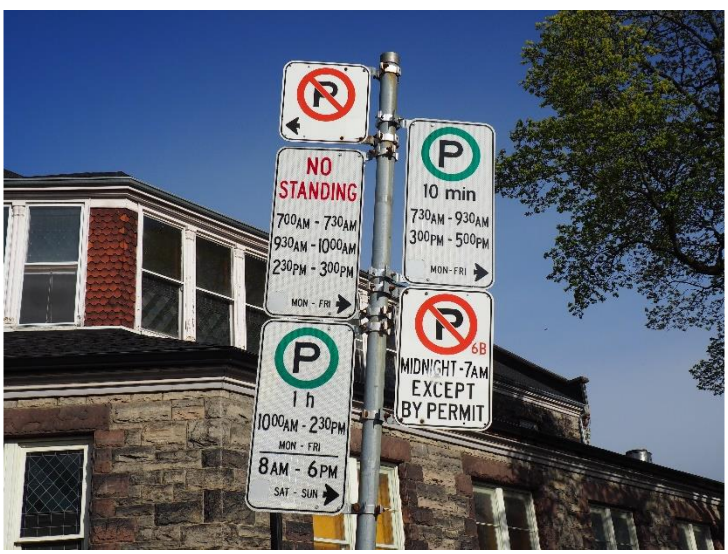
You may park to the right of the post. You must pay for a ticket from Monday to Saturday between 8:00am - 9:00pm and on Sunday between 1:00pm - 9:00pm. At all other times, you may park on the right side of the post without payment.

No parking within 15 metres of the corner on either side of the post.

You may park on the left side of the post from Monday to 10:00am on Sunday by permit only. After 10:00am on Sunday, you may park on the left side of the post without a permit until 12:00am on Monday.

You may park on the right side of the post between 10:00am - 10:00pm for maximum 1 hour. You may not park on the right side of the post between 10:00pm - 10:00am from Monday to Saturday and on Sunday between 12:01am - 10:00am, except by permit.

No parking on this side of the street between 12:00am – 7:00am, except by permit. From December 1 to March 31 and from the 16^{th} to the end of each month between April 1 to November 30, there is no parking on both sides of the post. From the 1^{st} to 15^{th} of each month between April 1 to November 30, you may park between 8:00am – 6:00pm for maximum 1 hour and between 6:00pm – 12:00am.



There is no standing on the right side of the post between 7:00am - 7:30am, 9:30am - 10:00am, and 2:30pm – 3:00pm, from Monday to Friday. You may park on the right side of the post between 7:30am – 9:30am and 3:00pm – 5:00pm for maximum 10 minutes, and between 10:00am – 2:30pm for maximum 1 hour, from Monday to Friday. You may park on the right side of the post between 8:00am – 6:00pm from Saturday to Sunday for maximum 1 hour. You may park on the right side of the post between 5:00pm – 12:00am from Monday to Friday and between 6:00pm – 12:00am from Saturday to Sunday. You cannot park on this side of the street between 12:00am – 7:00am, except by permit.
You cannot park on the left side of the post.

Appendix I: Parking Sign Quiz

Parking Sign Quiz

We are going to test your knowledge on the signs we just introduced. Your performance on this test is not recorded and does not affect your ability to participate in this study but allows us to correct or reinforce your interpretations of the signs. While you do this quiz, imagine you do not have a parking permit and are looking for either free or paid parking.

Quiz starts from below.

1. Participant ID:

While you are answering this question, please consider parking signs above

2. What time are you allowed to park on the left side of the post? *

- 10:00am
- Never
- 10:00pm
- 12:00pm

While you are answering this question, please consider the parking signs above

3. What time are you allowed to park on the left side of the post? *

- 6:00pm on Friday
- 9:30am on Friday
- 7:15am on Friday
- 2:30pm on Friday

While you are answering this question, please consider the parking signs above

4. What time are you allowed to park on the left side of the post? *

- Never
- 12:01am on Sunday
- 12:00pm on Sunday
- 7:00am on Sunday

While you are answering this question, please consider the parking signs above

5. What time are you allowed to park without a permit on the right side of the post?
*

- 12:00am on Sunday
- 7:00am on Sunday
- 9:00am on Sunday
- After 10:00am on Sunday

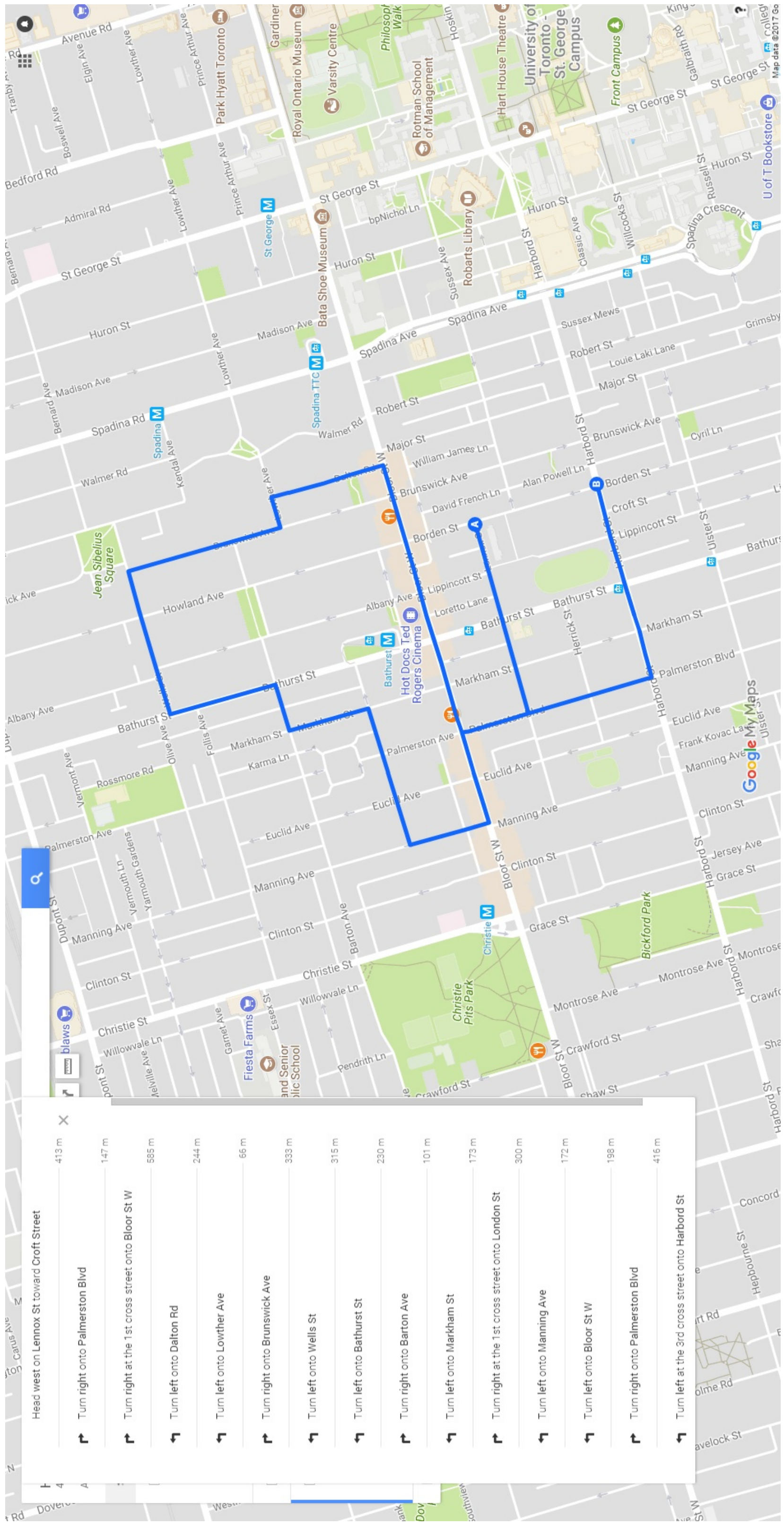
While you are answering this question, please consider the parking signs above

6. When are you allowed to park on the left side of the post on June 15^{th}? *

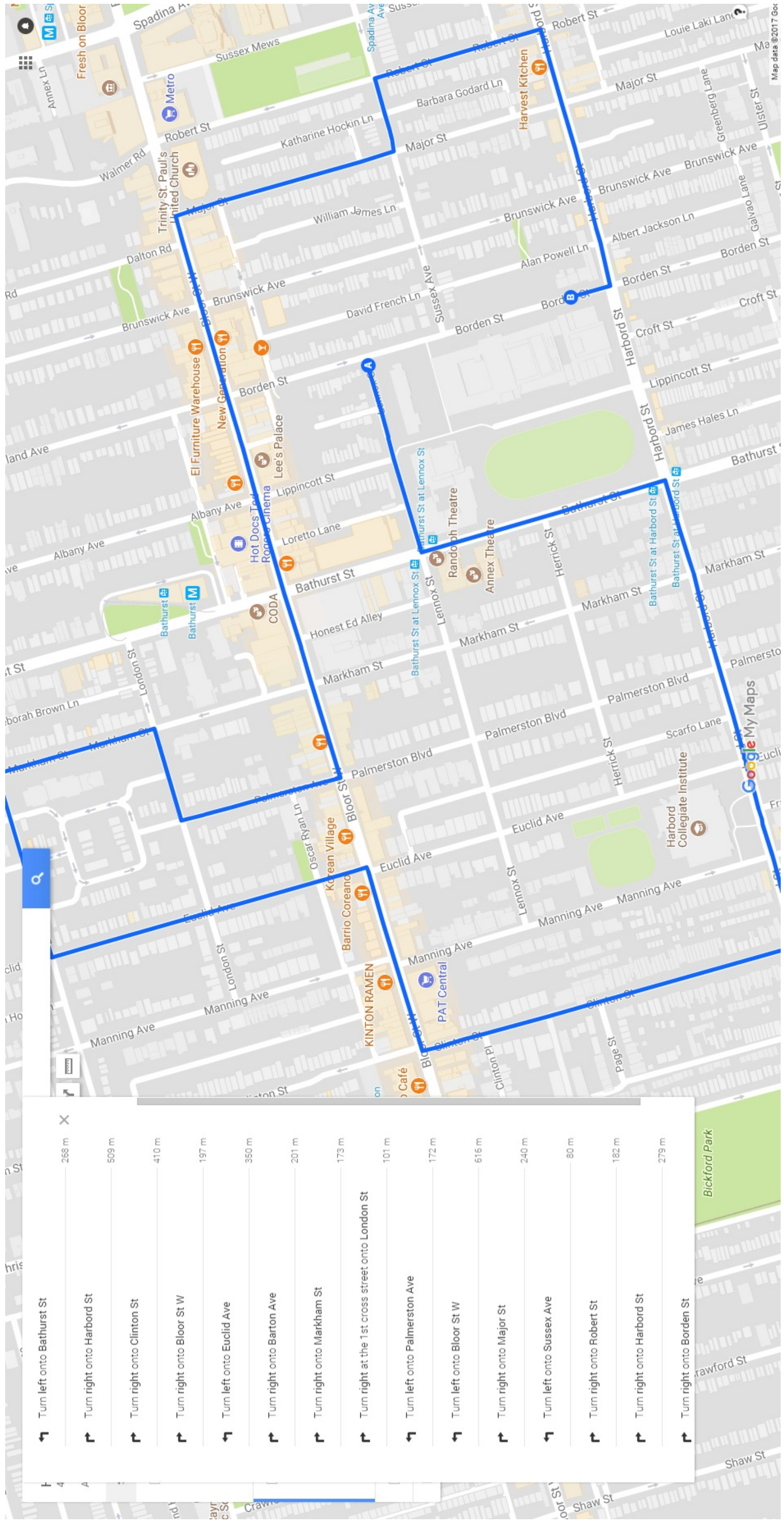
- After 6:00pm
- Before 8:00am
- Never
- 8:00am – 6:00pm

Appendix J: Map of Route A and Route B

Route A



Route B



Turn left onto Bathurst St
268 m
Turn right onto Harbord St
509 m
Turn right onto Clinton St
410 m
Turn right onto Bloor St W
197 m
Turn left onto Euclid Ave
350 m
Turn right onto Barton Ave
201 m
Turn right onto Markham St
173 m
Turn right at the 1st cross street onto London St
101 m
Turn left onto Palmerston Ave
172 m
Turn left onto Bloor St W
616 m
Turn right onto Major St
240 m
Turn left onto Sussex Ave
80 m
Turn right onto Robert St
182 m
Turn right onto Harbord St
279 m
Turn right onto Borden St
Google My Maps

Appendix K: NASA Task Load Index

RATING SCALE DEFINITIONS

Title	Endpoints	Descriptions
MENTAL DEMAND	*Low/High*	How much mental and perceptual activity was required (e.g., thinking, deciding, calculating, remembering, looking, searching, etc.)? Was the task easy or demanding, simple or complex, exacting or forgiving?
PHYSICAL DEMAND	*Low/High*	How much physical activity was required (e.g., pushing, pulling, turning, controlling, activating, etc.)? Was the task easy or demanding, slow or brisk, slack or strenuous, restful or laborious?
TEMPORAL DEMAND	*Low/High*	How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred? Was the pace slow and leisurely or rapid and frantic?
EFFORT	*Low/High*	How hard did you have to work (mentally and physically) to accomplish your level of performance?
PERFORMANCE	*good/poor*	How successful do you think you were in accomplishing the goals of the task set by the experimenter (or yourself)? How satisfied were you with your performance in accomplishing these goals?
FRUSTRATION LEVEL	*Low/High*	How insecure, discouraged, irritated, stressed and annoyed versus secure, gratified, content, relaxed and complacent did you feel during the task?

MENTAL DEMAND

Low High

PHYSICAL DEMAND

Low High

TEMPORAL DEMAND

Low High

PERFORMANCE

Good Poor

EFFORT

Low High

FRUSTRATION

Low High