White Paper on Public Safety(I) - Sleepy Drivers

公眾安全白皮書(I) – 疲勞駕駛

This white paper elaborates on how sleep research can be methodological and instrumental to measure the societal impact of sleepy and drowsy drivers.

本白皮書旨在闡明睡眠研究與相應發展出測量疲勞駕駛的方法、儀器與客觀參數，及其對社會的影響

I. Analyzing on Sleepiness at the Wheel 駕車疲勞分析

1. Sleep and wake cycle and factors affecting sleepiness of drivers. (睡眠生理時鐘與影響駕駛人駕車嗜睡的因素)

The body clock, physically located in the brain, is responsible for 24-hour rhythms, known as circadian rhythms, which control several functions including sleep and wakefulness. The circadian rhythm in sleepiness peaks in the early hours of the morning is 2-6 am, with another rise mid-afternoon (2-4 pm).

人體生物鐘主要由人類的大腦來負責調控，在生理上負責24小時的節律，稱為晝夜節律。晝夜節律控制多種功能，包括睡眠和清醒。而其中掌控的嗜睡高峰在凌晨(2-6時），用另一個高峰在午後（下午2-4時）。

Sleep pressure is the amount of fatigue that accumulates progressively throughout the day, due to daytime cerebral/mental activity mainly. as waking duration increases, sleep pressure increases, which progressively increases the feelings of daytime sleepiness. The sleep/wake cycle is thus a response to the dynamic balance between both regulatory mechanisms. On top of these integrated factors of influence, sleepiness can be influenced by a variety of external factors, which tend to add up exponentially.

睡眠壓力主要是經由白天腦/心理活動造成的疲勞全天逐步積累。當甦醒時間的增加，睡眠壓力增大，會逐漸增加白天嗜睡的感覺。人類的睡眠/醒的循環的反應是一種動態的平衡的機制，當多種外來的因素綜合的影響到這些平衡，就會引起嗜睡的反應。

When drivers are affected by sleepiness or fatigue, their performance can become seriously impaired, especially at attention and decision-making. they are prone to a loss of alertness, difficulty keeping their eyes in focus, loss of concentration and wandering thoughts, reduced awareness of the environment and memory lapses. individuals starts failing to check their rear view mirrors as frequently as they should, they present unconscious variations in speed, and erratic changing, drifting out of lanes. It is thus critical to identify the external factors influencing sleepiness to learn how to best manage them and reduce the likelihood of human error. A variety of strategies have been proposed to evaluate the risk of drowsy-driving accidents. Some methods are cheap and easy to perform on a wide number of subjects, like the **Epworth Sleepiness Scale （see below）**

當司機受到嗜睡或疲勞影響，他們的行為效能會變得嚴重受損，尤其是在注意力和決策上。這樣情況下，很容易喪失警覺性、很難保持他們的眼睛的焦距、喪失集中力、精神恍惚，以及對環境的認知降低和記憶能力下降。駕駛人開始減低檢查他們的後視鏡，以及不自覺的變化速度和駕駛路徑的飄忽不定，造成駕車偏離車道。找出影響嗜睡的外部因素，學習如何最好地管理它們，並減少人為錯誤的可能性會是關鍵。因此有很多種管理的策略來評估這些因為疲勞睏睡駕駛所造成的意外可能風險，而其中有些方法很常被使用且信效度也很高，例如：**Epworth 睏睡量表（請見下方說明)**

2. Measurement tools of daytime sleepiness 白天嗜睡之測量工具

- Objective methods 客觀的方法

- **The Multiple Sleep Latency Test (MSLT)** and **the Maintenance of Wakefulness Test (MWT)** are sensitive predictors of daytime sleepiness and driving performance. 多項式睡眠潛伏期檢查（MSLT）和清醒度維持測試（MWT）是日間嗜睡和駕駛性能的敏感度的預測。

  - **MSLT** –involves lying in a dark room where the participant is instructed to initiate sleep, 多項式睡眠潛伏期檢查– 受測者被要求躺在一個黑暗的房間被指示啟動睡眠

  - **MWT** –involves sitting on a comfortable chair in a semi-dark room where the participant is instructed to try to avoid falling asleep. 清醒度維持測試–受測者被要求躺在一個半黑暗的房間被指示不能睡著

The sooner participants enter sleep, the higher their objective sleepiness rating. Brain activity is recorded during the test. Both tests provide a very different environment to that of driving. Nonetheless, the MSLT and MWT have been found to correlate with subjective sleepiness measures, driving performance indicators, and have shown sensitivity to sleep deprivation.

但由於MSLT和MWT的測試環境和方法都和駕駛環境相差很大，但儘管如此，這兩種測驗卻可以明確的指示出駕駛人的睡眠剝奪的敏感度、嗜睡程度、駕駛性能的指標。

- **Psychomotor vigilance Test – the measurement of the drivers' reaction time 測量駕駛人的反應時間(直接與疲勞睏睡程度成正比)**

  The test is often used to assess commercial driver sleepiness in the United States. The PVT is based on a simple task where the subject presses a button as soon as a stimulus -such as a light- appears. And the DUB Group in University of Washington had developed an APP, PVT-TOUCH, on android system for touchscreen devices. The stimulus will turn on randomly every few seconds for 5–10 minutes. The purpose

of the PVT is to measure sustained attention, and give a numerical measure of sleepiness by counting the number of lapses in attention of the tested subject.

此一測驗已被應用於美國的商業駕駛睏睡檢測上。而傳統的PVT測試是一個簡單的測試，在一個簡單的儀器中量的情況下請測試者按下按鈕，測試反應的時間，目前已經有美國華盛頓DUB團隊研發了一個可以安裝在Android系統上的軟體，可以方便安裝於觸控式螢幕的裝置上方便測量。測量的過程大約為5-10分鐘，測試的目的主要為測試注意力與反映出錯率並會給予一個綜合的睏倦數字。

- **Video recording of eye movements or body movements (head nod)**

  In recent years, new methods based on eyelid movement and eye-closure have been specifically developed to measure drowsiness while driving. An increase in eye blink duration is associated with an increase in sleepiness. Similarly, an increase in slow eye movements and eye blink frequency are also associated with increasing sleepiness. There are several technology used in detection of abnormal body movements, eyes movement and eyes blink frequency. Such as:

  - Machine Vision (Digital Video)
  - Infrared (IR) camera
  - Visible light camera
  - IR illumination and sensors
  - Laser Scanning
  - Motion detection (gyro sensor)

Most of commercial or developing fatigue-warning systems use video recording to determine the change of frequency of eyes movement and eyes blink. There are a few systems detect the driver' s body movement by gyro sensor fixed on the driver' s seat. The system detects the frequency of driver' s body movement. If the driver' s body movement becomes slow, it may mean driver is fall asleep. But this technology is not popular in the market.

- **Electroencephalography (EEG)**

Evaluate sleepiness without the need for participants to actually fall asleep to achieve a measurement.

The best-established technique to detect sleepiness is based on recording brain activity from an EEG, similar to that in a sleep laboratory experiment. EEG recordings are captured using one or several electrodes that detect local vigilance changes. The recorded EEG signal is analyzed for changes indicative of sleepiness (which it distinguishes from those indicative of distraction). However, to date, such a system is impractical as drivers are restricted and the complex electrode system may cause discomfort. Another obstacle is that other in-vehicle electronics can interfere with these EEG signals.

- **Subjective methods** 主觀的方法

  - **The Epworth Sleepiness Scale (ESS, 艾普沃斯睏睡量表)**

The Epworth Sleepiness Scale (ESS) is based on a subjective approach. It is one of the most commonly used methods for measuring sleepiness. And the scale intended to evaluate daytime sleepiness, measured using a short questionnaire. Subjects are asked to rate their likelihood of dozing off in different daily life situations. The higher the score, the higher the

individual’ s level of daytime sleepiness. While this test does not provide a diagnostic in itself, the ESS score can indicate the need to seek for expert medical advice.

Tests such as the ESS have the advantage of not influencing the behaviour of the driver –they do not constantly draw attention to his sleepiness. Thus the ESS has been extensively used as a research tool in studies of road crashes and driver impairment, however is less useful for the development of in-car sleepiness countermeasures.

問卷內容：

說明：

在您目前或最近過去下列的狀況，什麼樣的情境與情況下你會打瞌睡或者睡著的情況，發生的頻率最高？即便是下列所列的情況是您最近沒有做或者經歷的，也請您試著回想或者設想一下該情境是否會影響你使你有打瞌睡的可能，設想在該情況下選擇適當的反應與相對的嗜睡程度，並在該程度下打勾。

調查評估：

狀態	打瞌睡的可能性			
	從來沒有	輕微的小睡	中度機會的打瞌睡	幾乎每次都會打瞌睡
1. 靜坐閱讀書報時	– –	– –	– –	– –
2. 觀看電視節目時	– –	– –	– –	– –
3. 靜坐於未有活動的公共場合時(如	– –	– –	– –	– –

一個會議場所或劇院)				
4. 當你是一位乘客，靜坐於連續開了一個小時的車子時	_ _	_ _	_ _	_ _
5. 當環境許可時，下午躺下來休息	_ _	_ _	_ _	_ _
6. 靜坐與別人交談時	_ _	_ _	_ _	_ _
7. 午餐後安靜坐著時(未曾喝酒)	_ _	_ _	_ _	_ _
8. 乘坐車子(開車時)停頓幾分鐘時。	_ _	_ _	_ _	_ _

➢ Stanford Sleepiness Scale (SSS, 史丹佛嗜睡量表)

The Stanford Sleepiness Scale (SSS) was first presented in 1972 by Hoddes. It is a quick and easy way to assess how alert you are feeling. The questionnaire is a self-rating scale that is used to quantify progressive steps in sleepiness at a certain point in time. Discover your own pattern of alertness by recording your "degree of sleepiness" at different times throughout the day.

The Stanford Sleepiness Scale is a totally subjective rating subjects where give evaluating how they feel – from 1 to 7. 1 means totally alert (vigilant) and 7 means really struggling to stay awake and dream-like thoughts are occurring. It could help to understand the person' s circadian rhythms by tracking a person' s sleepiness and wakefulness throughout the day. Understanding of personal circadian rhythms could help the employers manage the worker fatigue. It may allow shift workers to work during hours in which they are least sleepy/most alert.

Degree of Sleepiness	Scale Rating
Feeling active, vital, alert, or wide awake	1
Functioning at high levels, but not fully alert	2
Awake, but relaxed; responsive but not fully alert	3
Somewhat foggy, let down	4
Foggy; losing interest in remaining awake; slowed down	5
Sleepy, woozy, fighting sleep; prefer to lie down	6
No longer fighting sleep, sleep onset soon; having dream-like thoughts	7
Asleep	X

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
7am							
8am							
9am							
10am							
11am							
12pm							
1pm							
2pm							
3pm							
4pm							
5pm							
6pm							
7pm							
8pm							
9pm							
10pm							
11pm							
12am							

中文：

嗜睡狀態	等級
覺得很有勁、生龍活虎、而且清醒	1
活動力雖然未達巔峰,但仍保持高水準,能集中注意力	2
放鬆、仍然維持醒著,但無法完全警覺,有點遲鈍	3
已經有點模糊,精神不振	4
意識模糊,開始覺得無法專心,難以保持清醒	5
嗜睡、頭昏眼花、想躺下來	6
完全不能保持清醒,隨時可以睡著,有如夢似幻之思考	7

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
7 AM							
8 AM							
9 AM							
10AM							
11AM							
12AM							
1 PM							
2 PM							
3 PM							
4 PM							
5 PM							
6 PM							
7 PM							

8 PM							
9 PM							
10PM							
11PM							
12PM							

依照上述評量之評分，從早上7點記錄至晚上12點的自我困睡的感覺，並記錄一周的時間，以了解接受測驗者的一週困睡程度與生理週期，方便疲勞控制與管理。

- **Driving fatigue questionnaire (designed)**

A short questionnaire according to the research of Nelson B. Powell et al published on *SLEEP, Vol. 30, No. 3, 2007*. The questionnaire was designed to understand the driver' s behavior and experience of driving fatigue. And this questionnaire is also designed to understand driver lifestyle concerned with driving fatigue.

Questionnaire 問卷:

1. Please select that which is closest to describing your work schedule. I always work a daytime shift.

   ☐ I always work an evening shift

   ☐ I always work a nighttime shift

   ☐ My shift is irregular but it includes some nighttime or evening work I am not currently employed

2. How many hours (to the nearest hour) of sleep do you get:

A) On an average night when you work the next day_____hours of sleep (leave blank if you are not working) B) On an average night when you are not working the next day_____hours of sleep

3. Do you have any of the following sleep abnormalities?

A) Insomnia

- ☐ No
- ☐ Yes
- ☐ Do not know what insomnia is

B) Sleep Apnea No

- ☐ Yes
- ☐ Do not know what sleep apnea is

C) Narcolepsy

- ☐ No
- ☐ Yes
- ☐ Do not know what narcolepsy is

4. About how many alcoholic drinks do you have in anaverage week?

- ☐ None
- ☐ 1-3
- ☐ 4-6
- ☐ 7-9 (i.e. 1-1.5 per day)

- ☐ 10-13 (i.e. 1.5-2 per day)
- ☐ 14-20 (i.e. 2-3 per day)
- ☐ 21 or more (i.e., at least 3 per day)

5. Have you driven a motor vehicle for a total of at least 1000 miles during the last 3 years?

- ☐ No
- ☐ Yes

If you do drive a motor vehicle, please answer the following questions

6. How many miles a year do you drive?

- ☐ less than 5000
- ☐ 5,000-10,000
- ☐ 10,000-15,000
- ☐ 15,000-25,000
- ☐ 25,000-40,000
- ☐ greater than 40,000

7. What percentage of your driving is between midnight and 6AM?

- ☐ 0-15%
- ☐ 16-25%
- ☐ 26-40%
- ☐ 41-60%

- ☐ more than 60%

8. Do you drive professionally?

   - ☐ No
   - ☐ Yes

9. How many motor vehicle accidents have you had during the last 3 years?

   - ☐ None
   - ☐ 1
   - ☐ 2
   - ☐ 3
   - ☐ 4 or more

10. Were any of these accidents associated with being sleepy?

    - ☐ No
    - ☐ Yes

11. Have you experienced a near miss accident due to driving sleepy in the past 3 years?

    - ☐ No
    - ☐ once
    - ☐ 2-3 times
    - ☐ 4 or more times

12. How sleepy or unusually tired were you feeling at the time of the most recent accident that was not caused by a distraction?

- ☐ Fully awake and refreshed
- ☐ Slightly tired, but not enough to affect my driving.
- ☐ Tired enough that it might have been a partial cause of the accident
- ☐ Very tired. This probably contributed to the accident.
- ☐ Exhausted. I either fell asleep at the wheel or am otherwise certain that being tired was the cause of the accident.
- ☐ Do not recall

13. Do you wear seatbelts when you drive?

- ☐ Always (100% of the time)
- ☐ Most of the time (75-95% of the time) More than 50% of the time
- ☐ Less than 50% of the time
- ☐ Seldom (less that 25% of the time)
- ☐ Never

問卷（中文）：

說明：

以下為調查您個人的工作與您睡眠習慣的時程調查，以及關於您過去近3年間駕車經驗的平均水平問卷，請儘量依照調查問題完成工作與睡眠習慣之調查，並協助了解您駕駛習慣，以了解駕車習慣與疲勞的關聯性。

調查問題：

1. 請選擇下列何者較符合您的工作時程的敘述：

   ☐ 我的工作時程是白天班（約AM9:00~PM6:00）

   ☐ 我的工作時程是在傍晚班（約PM3:00~12:00）

   ☐ 我的工作時程是在大夜班（約在PM）

2. 你通常睡幾個小時？（依你最近的平均經驗）

   A. 當您隔天需要工作時您平均晚上會睡_____小時 （若您沒有工作請空白）

   B. 當您隔天不工作時您平均晚上會睡_____小時

3. 請問您有下列任何不正常的睡眠問題嗎？

   A. 失眠

      ☐ 有

      ☐ 沒有

      ☐ 不知道麼是失眠（或者不清楚您有沒有）

   B. 睡眠呼吸中止症

      ☐ 有

      ☐ 沒有

      ☐ 不知道麼是“睡眠呼吸中止症”

C. 嗜睡症

☐ 有

☐ 沒有

☐ 不知道麼是“嗜睡症”

4. 請問您每週大約喝多少杯（瓶、罐）酒精性飲料？

☐ 1-3

☐ 4-6

☐ 7-9 (每天1-1.5)

☐ 10-13 (每天1.5-2)

☐ 14-20 (每天2-3)

☐ 21 or more (每天至少3)

5. 您是否有駕車的習慣？

☐ 是

☐ 否

若您回答“是”請麻煩協助完成下列幾項問題：

6. 您過去三年總共駕車的里程數是否超過 1600 公里（Km，1000 英里 miles）

參考：南北中山高速公路約長 373 公里，長度約是 2 趟來回

☐ 是

☐ 否

7. 您平均一年的駕車里程數為多少？

☐ 低於 8,000 公里

- ☐ 8,000~16,000 公里
- ☐ 16,000~24,000 公里
- ☐ 24,000~40,000 公里
- ☐ 40,000~64,000 公里
- ☐ 超過 64,000 公里

8. 您的駕駛經驗有多少比例是在半夜到早上(0-6AM)？

- ☐ 0-15%
- ☐ 16-25%
- ☐ 26-40%
- ☐ 41-60%
- ☐ 大於 60%

9. 您覺得您是個專業的駕駛人嗎？

- ☐ 是
- ☐ 否

10. 您最近 3 年內有多少次有過駕車擦撞、車禍、與駕車意外的經驗？

- ☐ 沒有 （回答“沒有”請直接填寫第 9 題）
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4 或者 4 次以上

11. 所發生的駕車擦撞、車禍、與駕車意外經驗，有沒有與駕車時疲勞想睡有關？

- ☐ 沒有
- ☐ 有

12. 在您最近不是因為分心所以起的駕車擦撞、車禍、與駕車意外經驗，您感覺到

有多想睡或者不尋常的疲憊？

- ☐ 感覺很清醒
- ☐ 輕微的疲憊感，但不影響我開車
- ☐ 感覺到疲憊，應該是造成我駕車意外的部分原因
- ☐ 非常疲憊，應該是造成我駕車意外的原因
- ☐ 精疲力竭，我甚至睡著的，並且完全確定是造成駕車意外的原因
- ☐ 不記得了

13. 最近 3 年內在您的駕駛經驗中，有幾次是因為駕車疲勞或想睡覺，險些發生駕車意外？

- ☐ 沒有
- ☐ 1 次
- ☐ 2~3 次
- ☐ 4 次或者以上

II. Technology to fight fatigue at the wheel 現行技術應用於對抗駕車疲勞之方法

No matter what kind of systems for detection of fatigue of driver in vehicle systems is set up for prevention driver from impairing. The system may be designed to monitor diver' s bio-signal or behavior or detected and calculated vehicle direction. After system computing, the system would provide alerts or set up security automatisms if a driver seems impaired.

不論哪一種偵測駕駛疲勞的系統都是為了預防駕駛者因為疲勞受到損害，這些系統大致上都是利用偵測駕駛人的生物訊號或者駕駛人的行為，或者利用計算行車的路徑方性，並經由這些偵測與計算當發現有危及駕駛人的安全時會再進一步的自動地做出安全的機制來保護駕駛人安全。

1. Systems monitoring the vehicle 車輛監測系統

As technology advances, more and more functions have been added to automobiles to assist drivers in controlling their vehicles. Such as pre-crash systems, advanced automatic collision notification, automotive night vision with pedestrian detection, lane departure systems, vehicle tracking systems, adaptive cruise control, adaptive headlamps, etc. These systems are designed to monitor the vehicle but not directly detect the driver. So the system could not respond and warn when the driver already have felt sleepy at the first minute.

隨著科技的進步，汽車上加入越來越多的科技來輔助汽車自動控制。其中包括：防碰撞系統、先進的自動碰撞通知、汽車夜視行人通知、車道偏離系統、車輛跟蹤系統、主動車距控制巡航系統、自動適應前燈系統等。而這些系統通常都是設計於監控車子本身而非駕駛，因此通常無法在駕駛員發生睏睡的第一時間由系統偵測到給予警告。

- Autonomous cruise control (ACC) 主動車距控制巡航系統

  Autonomous cruise control (ACC) is an optional cruise system based on information detected by on-board sensors. These sensors, either radar or laser-based, inform the vehicle to slow down when approaching another vehicle ahead, and to accelerate again to a pre-set speed when traffic allows. Single radar systems are the most common. Many luxury, mid-size and small cars in Europe are now fitted with an adaptive cruise control (ACC) system. Now more and more general car building this system.

  ACC是一種選用的訊息傳送車用偵測器配備，而這些偵測器大多為雷達形式或者鐳射形式，其主要的功能在於讓傳統的定速巡航系統不僅僅只是擁有定速行駛的功能而已，而是能夠進一步主動辨識前方車輛的速度來調整自己的速度，並且在適度的距離範圍之內，讓雙方的車速達到同步的水準，一旦等到前方車輛加速前進或是離開原有的車道時，ACC便會自動將車輛的速度回升到原本的設定範圍。目前單一雷達形式的ACC系統較常見。在歐洲許多高級中小型房車都會建議選配有ACC系統，也越來越多一般房車會配備此系統。

- Pre-crash system (Collision avoidance system) 防撞系統

  A pre-crash system is an automobile safety system designed to reduce the severity of an accident. It uses radar and sometimes laser and camera sensors to detect an imminent crash. Once the detection is done, these systems either provide a warning to the driver when there is an imminent collision or take action autonomously without any driver input (by braking or steering or both). There are two crash-avoidance features provide the biggest benefits: (a) autonomous braking that would brake on its own, if the driver does not, to avoid a forward collision, and (b) adaptive headlights that would shift the headlights in the direction the driver steers. In an important 2012 study by the nonprofit research

organization Insurance Institute for Highway Safety, researchers examined how particular features of crash-avoidance systems affected the number of claims under various forms of insurance coverage. Unexpectedly, they found lane departure systems to be not helpful, and perhaps harmful, at the circa 2012 stage of development.

(http://www.iihs.org/iihs/news/desktopnews/crash-avoidance-features-reduce-crashes-insurance-claims-study-shows-autonomous-braking-and-adaptive-headlights-yield-biggest-benefits)

- Lane departure warning systems 車道偏移系統

In road-transport terminology, a lane departure warning system is a mechanism designed to warn a driver when the vehicle begins to move out of its lane (unless a turn signal is on in that direction) on freeways and arterial roads. These systems are designed to minimize accidents by addressing the main causes of collisions: driver error, distractions and drowsiness. There are two main types of systems: (a) Systems which warn the driver (lane departure warning, LDW) if the vehicle is leaving its lane (visual, audible, and/or vibration warnings); (b) Systems which warn the driver and, if no action is taken, automatically take steps to ensure the vehicle stays in its lane (lane keeping system, LKS). Lane warning/keeping systems (LDW/LKS) are based on 3 kinds of sensor: (a) Video sensors in the visual domain (mounted behind the windshield, typically integrated beside the rear mirror); (b) Laser sensors (mounted on the front of the vehicle); (c) Infrared sensors (mounted either behind the windshield or under the vehicle). Lane Departure Warning Systems and Lane Keeping Systems rely on visible lane markings. They typically cannot decipher faded, missing, or incorrect lane markings. Markings covered in snow or old lane markings left visible can hinder the ability of the system.

2. Drivers' sleepiness detection-based systems 駕駛人嗜睡偵測系統

- Camera-based systems
  - ✧ **Machine Vision (Digital Video)**
  - ✧ **Infrared (IR) camera**
  - ✧ **Visible light camera**

- Detection of driver head or body movement by "Capacitive Foils"
- Steering wheel grip and other driving inputs
- EEG (Electroencephalography)