行政院及所屬各機關出國報告
（出國類別：進修）
ASC-TRT-01-03-001

人為因素失事調查專業訓練報告

服務機關：行政院飛航安全委員會
出國人　職　　稱：飛航安全官
　　　　姓　　名：王興中
出國地區：澳洲坎培拉
出國期間：民國九十年二月廿三日至三月四日
報告日期：民國九十年三月八日

行政院及所屬各機關出國報告提要　　系統識別號
出國報告名稱：人為因素失事調查專業訓練報告
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出國計畫主辦機關：行政院飛航安全委員會
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出國類別：☐1 考察■2 進修☐3 研究☐4 實習☐5 其他

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報告日期：民國九十年三月八日

分類號/目

關鍵詞：人為因素(Human Factors)、CVR、AVR

內容摘要：

在各種不同的造成航空失事及意外事件的原因中，人為因素就佔了百分之六十左右，因此世界各航空失事調查及飛航安全推廣單位，皆將如何減少人為因素所導致的錯誤列為主要的重點工作。

此次的人為因素失事調查訓練的主要重點是希望受訓者在完成訓練後，皆能了解人類生理及心理上的極限，並了解這些限制對於飛行員在工作上的影響；在失事或意外事件發生後能夠有效的蒐集調查相關資料，分辨出人為因素對事件的影響，並加以分析原因，提出飛安改善建議。

本文電子檔已上傳至出國報告資訊網

行政院及所屬各機關出國報告審核表

出國報告名稱: 人為因素失事調查專業訓練報告
出國計畫主辦機關名稱: 行政院飛航安全委員會

出國人姓名：王興中
職稱：飛航安全官
服務單位:行政院飛航安全委員會

出國計畫主辦機關審核意見:

- □1.依限繳交出報告
- □2.格式完整
- □3.內容充實完備
- □4.建議具參考價值
- □5.送本機關參考或研辦
- □6.送上級機關參考
- □7.退回補正,原因:
  - □(1)不符原核定出國計畫
  - □(2)以外文撰寫或僅以所蒐集外文資料為內容
  - □(3)內容空洞簡略
  - □(4)未依行政院所屬各機關出國報告規格辦理
  - □(5)未於資訊網登錄提要資料及傳送出國報告電子檔
- □8.其他處理意見：

層轉機關審核意見:

- □同意主辦機關審核意見
  - □全部 □部份_________(填寫審核意見編號)
- □退回補正,原因:_________(填寫審核意見編號)
- □其他處理意見:

目錄

1. 行程說明

航空器飛航安全委員會人員赴澳洲坎培拉

澳洲運輸安全局人為因素失事調查專業訓練課程

月	日	起　　訖　　地　　點	行　　程　　紀　　要
2	23	台北－雪梨	搭機
2	24	雪梨－坎培拉	搭機
2	25	坎培拉	報到及準備
2	26-28	坎培拉	受訓
3	1-2	坎培拉	受訓
3	3	坎培拉－雪梨	受訓、搭機
3	4	雪梨－台北	搭機

2. 受訓課程表

Monday 26 February 2001

0845 – 0930　歡迎致詞
0930 – 1000　人為因素之演進
1020 – 1200　人類的認知、注意力及記憶力
1200 – 1430　人為錯誤
1430 – 1730　醫學生理因素的調查

Tuesday 27 February 2001

0845 – 0900　複習
0900 – 1010　人體工學介紹
1030 – 1100　決策下達
1100 – 1200　違規
1200 – 1300　語音分析
1400 – 1730　組員資源管理與溝通

Wednesday 28 February 2001

0845 – 0900　複習
0900 – 1000　自動化系統
1020 – 1300　疲倦度調查
1400 – 1510　面談理論
1530 – 1730　面談技巧練習

Thursday 1 March 2001

0845 – 0900　複習
0900 – 1100　管理與錯誤管理
1115 – 1230　Reason 模組理論介紹
1330 – 1510　Reason 模組運用
1530 – 1730　Reason 模組運用練習

Friday 2 March 2001

0845 – 0900　複習
0900 – 1100　失事調查及報告纂寫模擬
1100 – 1230　結訓考試
1330 – 1430　結訓儀式

3. 講師名單

Mr. Alan Hobbs	Australian Transport Safety Bureau
Dr Michael Walker	Australian Transport Safety Bureau
Captain Kit Filor	Australian Transport Safety Bureau
Mr. Richard Batt	Australian Transport Safety Bureau
Professor Drew Dawson	Center for Sleep Research
Dr Jeff Brock	Aviation Medicine Consultant
Dr Graham Edkins	Qantas Airways Ltd
Professor Ian Glendon	Griffith University

4. 受訓人員名單

Mike Squires	Australian Transport Safety Bureau (Marine)
Jenny Hill	Australian Transport Safety Bureau
Toni Lockyer	Qantas Airways Ltd
Andrew Poulsen	Qantas Airways Ltd
Todd Mickleson	Qantas Airways Ltd
Eric Oass	Qantas Airways Ltd
Jerry Reilly	Qantas Airways Ltd
Phil Naughton	Eastern Australia Airlines
Ian Warburton	ADF – Directorate of Flying Safety
Peter Willison	Cathay Pacific
Ian Brown	Kendell Airlines
Susan Brookes	Flight Attendants Association of Aust. (AN Rep.)
Carol Lockett	Flight Attendants Association of Aust. (QF Rep.)
Steve Pawson	New Zealand CAA
Susanah Davey	National Jet Systems
Thomas Wang	Taiwan Aviation Safety Council
David Edwards	National Rail
Alan Dockery	Department of Infrastructure, VIC (Rail)
Tricia Brett	Department of Infrastructure, VIC (Rail)
Adrian Ponton	Freight Australia (Rail)
Ian Dunstan	Transport WA (Rail)
Brian Busch	ARTC (Rail)
Phillip Barker	Queensland Rail
Steve Barron	Marine Board of Victoria
Arthur Diack	Maritime Division, Qld Transport
John Fewings	Transport WA (Marine)
Tim King	ASP Ship Management

5. 課程重點討論

5.1 人為因素

1. Chapanis 將人為因素定義為

   Human Factors is a body of knowledge about human abilities, human limitations, and other human characteristics that are relevant to the design of tools, machines, systems, tasks and environments.

2. 當事件發生時，並不單單代表某一人發生了問題，而應整體檢討工作者所工作的環境及組織是否導致事件的發生。

5.2 人類的認知、注意力及記憶力

1. 人類在一定時間內所能處理的資訊有一定的限制，因此當人類需要同時處理大量資料時，必須將注意力集中在比較重要的事情上，因而忽略了某些事務。

2. 人類的記憶力分為短期記意力及長期記意力，短期記憶力的容量通常為五至九個項目(7±2)，長期記憶力沒有容量的限制，但必須經過某種過程後，資料才能存入長期記憶中。

5.3 人為錯誤

1. 當一個人犯錯時，他往往會原因歸咎於外在環境對他的影響，但是當別人犯錯時，人們往往會將責任歸咎於犯錯的人，這種差異稱之為〝Attribution Bias〞。

2. 人為錯誤可大致分為三大類：1.技巧上的錯誤、2.規則上的錯誤，及 3.

知識上的錯誤。

5.4 醫學生理

1. 飛行員應瞭解人類對於飛行的生理反應及限制，以及高空缺氧、溫度、重力極限、視覺限制等對於飛行員的影響。
2. 在飛行環境中，會對飛行員造成影響的因素包括：溫度、濕度、大氣壓力、氧氣、天氣、地形、時間、光線、時區、幅射、煙霧、風沙等。
3. 從事失事調查時，應就操作者的病歷背景、社交生活、工作生活、財務狀況、心理狀況等方面作通盤檢討。
4. 失事調查時，應注意那些人死亡，那些人生還，並找出造成死亡及生還的原因。

5.5 違規

1. 不安全的行為（unsafe act）通常被定義為違反組織所訂的安全程序或規則，但較嚴謹的定義應為〝Observable behaviors that increase the risk of an accident to a level above that which is acceptable or necessary to complete an operation〞-Mike Walker
2. 不安全的行為可歸類為三種：1.錯誤、2.違規、3.誤導。
3. 違規的定義是〝刻意的去犯錯〞才叫違規。
4. 在失事調查中，違規不常常是造成事件的主要原因，但是許多的失事事件中，都會有違規的情形發生，雖然違規往往不是失事事件中最後發生的不安全行為，但的確會降低整體工作環境的安全係數。

5.6 語音分析

1. 語音分析在失事調查中是一門新發展的調查技術，主要的資料來源為VCR、AVR（air to ground, air to air, ground to ground）等。
2. 由語音記錄中可得到的資料為所遭遇的問題，事情發生的時間順序、不安全的行為、技術上的錯誤，及通話者的個性、心理狀況、工作負荷、壓力狀況等。

5.7 自動化系統

1. 自動化系統是用來幫助飛行員接收和處理資料的，但是隨著新的系統的引進，同時也帶來了新的問題。
2. 由於自動化系統處理資料的方式，往往讓使用者不知道它正在做什麼？不知道它為什麼那麼做？不知道它接下來要做什麼？

5.8 疲倦度

1. 缺少睡眠是造成疲倦的原因。
2. 研究結果顯示，疲倦對於生理的影響程度的酒精對生理的影響非常類似，當一個人連續工作 18-20 個小時的大夜班後，眼、手協調的程度相當於一個人血液中含有 0.05%的酒精濃度，在連續工作 23 小時後，眼、手協調程度相於血液酒精濃度 0.1%。

5.9 面談

1. 在失事調查時，被面談者通常包括實際參與者、目擊證人、專家、失事

者的同事及親友。

2. 面談所能取得的資料可能會受到許多因素的影響，如事件發生時的天氣狀況、事情發生時間的長短、複雜程度等，另外被面談者在事件發生時所受的壓力、對事件熟悉的程度、所受的訓練背景、年紀、性別等，亦會對面談的結果造成影響。

5.10 Reason 模組

1. Reason 模組將失事的造成原因分為數個層面，包括個人的行為、環境的影響、組織的影響，及最後的防禦，而失事事件只有在每一個不同的層面皆在相同的位置上形成破洞時，才有可能發生。

5.11 組員資源管理與溝通

1. 組員資源管理(CRM)訓練原是美國德州大學奧斯汀分校的心理學教授 Helmreich 在 1980 年針對美國航空太空總署(NASA)所設計的訓練課程。隨後，該訓練課程被聯合航空應用於飛行組員的訓練，結果成效卓著。不僅明顯提昇了飛行組員的工作品質，亦有效的降低了飛安事故的發生比例。
2. John Allen 將組員資源管理訓練定義為: 利用所有可用的資源包括硬體、軟體及人員等所有資源，以獲得安全而有效率的航務操作。
3. CRM先被定義為Cockpit Resource Management，受訓對象為航空器的駕駛員。其乃根據傳統之管理觀念所發展出之理論，以心理學的方式為

根基並著重在個人風格與人際技巧的訓練，期望藉此改正不適任人員。

4. CRM繼被定義為Crew Resource Management，受訓對象為航空器的駕駛員、空服員、維修人員、簽派員、飛航管制員等等。主要著重在狀況警覺、領導、溝通技巧等特定的飛行概念，以單元的方式進行訓練決策與溝通技巧的教學。

5. CRM後被定義為Corporate Resource Management，即企業資源管理。其主要的改變係將管理階層亦納入CRM團隊的一部份。依據特定的組織需求訂定訓練內容，以支持理想的公司文化。此種由個人→群體→組織→企業的發展模式，強化整體環境之良性互動關係，落實飛安是航空體系共同的責任，而非單一歸咎於職場第一線人員的人為失誤，因而在新的管理模式中，係由「個人」人為失誤為主的觀點，轉變為潛伏的「組織行為（集體）」為主的失誤觀點。

6. 附錄

6.1 Attention

6.2 Memory

6.3 Human error and decision-making

6.4 Violations

6.5 Guidelines for Investigative interviewing

6.6 Fatigue Management in the New Millennium

6.7 Aviation Medicine

Attention

Alan Hobbs

The nature of attention

Attention is such a fundamental fact of life that we may not even be of what the limits to attention are. For example, what is occurring when you suddenly become aware of another conversation on the other side of the room, once you hear your name mentioned? How is it that people who live near a railway line may no longer hear the trains go by? What happens when a taxi driver must simultaneously drive in heavy traffic, enter information into the base computer, and deal with complaining passengers? And why is it that sometimes when we are concentrating on a television program, we do not hear other people talking to us?

Our senses have available to them a "booming buzzing confusion" of sensations. You are probably not aware of the feel of your feet in your shoes, or the sounds happening outside. Obviously, we must be able to focus in on what is important to us at the moment and screen out the irrelevant information. It is as though we have a flashlight beam, which we can shine on only one area at a time. The problem is that there will be times when there is too much important information coming in for us to cope with all at once, or we will miss information which is outside our attentional "beam of light". Or perhaps our attention will stray onto distracting information like financial concerns or physical discomfort.

It is generally agreed that there is a finite limit to the amount of information that can be processed at any time, and that we have a bottleneck in our information processing system, allowing only a limited amount of information to squeeze through to consciousness at a time. In this sense, our information processing system is sequential rather than parallel. When we feel that we are consciously attending to several things at a time, such as monitoring a radio and holding a conversation, we may in fact be rapidly switching our attention from one to the other.

Obviously, the limits of attention do not prevent us from doing more than one thing at once; we can drive a car and talk at the same time. But this is because well-learned skills like driving become increasingly automatic and hence demand less and less of our attention.

Responses to overload

One of the consequences of the limits on our attention is that individuals have a "red line" on their ability to process information. For example the Three Mile Island accident occurred when operators failed to diagnose the reason for loss of coolant from the reactor. This may be because more than 100 control panel alarms activated with no means of suppressing unimportant ones. Faced with an overload of information, a person can respond in a number of ways:

Load shedding is when a person ignores some of the information and concentrates on one or two aspects of the situation. Hopefully, the individual will shed the least important tasks. However, it is possible that the individual sheds vital information.

An extreme form of load shedding is *channelled* attention, in which the individual gives all of his or her attention to only one aspect of the situation.

Another coping mechanism for overload is *regression*. This is where an overloaded individual goes back to a previously well-learned pattern of behaviour.

The limits of attention do not just apply when someone is severely overloaded. Even a moderate mental workload can reduce an individual's capacity to deal with new information. NASA studies have shown that if a person attempts to perform a listening/ identification task at the same time as a visual tracking task, their eye movements can be reduced by up to sixty percent. A listening task will also cause an individual's peripheral vision to be less effective, almost as though they are wearing blinkers. Visual field narrowing, as this effect is known, has obvious implications for traffic scanning.

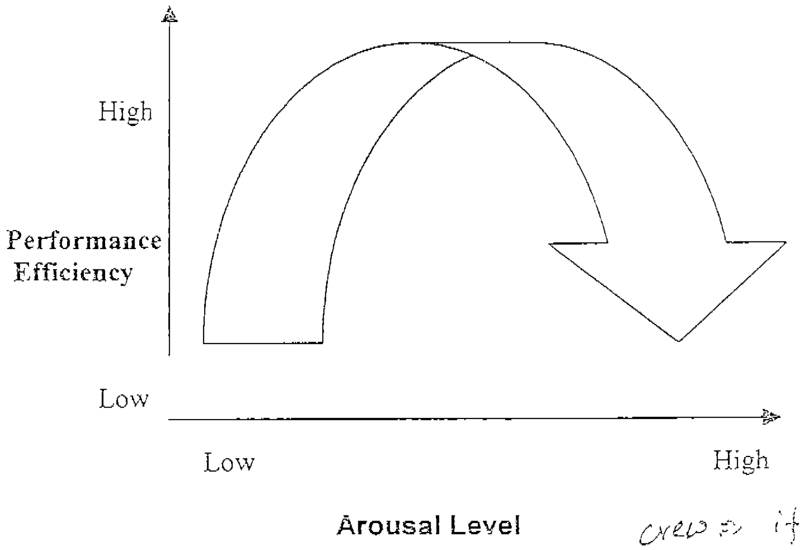
Stress and attention

The term "stress" encompasses a number of quite different human factors issues. While there is no universally accepted definition of what stress is, a reasonable working definition is that "stress is the body's response to stressors". It is important to distinguish the stress response from the stimulus or "stressor" which triggers it. There are environmental stressors such as noise and heat, task stressors such as demanding, time pressured tasks, and there are life event stressors such as financial uncertainty and domestic worries. Different stressors can lead to different stress problems.

Life event stress resulting from significant life events such as divorce, financial worries and the like can reduce general well being and increase the susceptibility to some illnesses. Personal worries can also make it more difficult to keep our attention on the task at hand. People who are experiencing significant life events may be distracted by intrusive thoughts, particularly when workload is low.

Task stress, or acute stress arises when the demands of the task approach or exceed the capabilities of the person. Many psychologists consider that the breadth of attention diminishes as task stress increases. The narrowing of attention with increasing stress has been advanced as an explanation for the familiar inverted U relation between arousal (stress) and task performance, originally proposed by Yerkes and Dodson in 1908. (See the figure below). According to the Yerkes-Dodson theory, performance is best when the person is moderately challenged by the task. Too little challenge, (resulting in boredom) or too much challenge, (resulting in panic) both result in poor performance. So a moderate level of task stress can be helpful. Some psychologists consider that this is because at moderate levels of task stress, performance improves as attention becomes focused on primary tasks and irrelevant stimuli are filtered out. As task stress increases however, attention narrows and task relevant stimuli are neglected. For example, aircraft pilots coping with an in-flight emergency have landed gear up and reported that they did not hear the gear warning horn, even though it was functioning. Passengers who have evacuated a crashed aircraft often report that everything was very silent. Perhaps this too, is a case of stress causing perceptual narrowing.

Yerkes-Dodson inverted U Curve: Performance versus Arousal



Vigilance

One final area where attention is important is *vigilance*. In WWII it was found that after about twenty minutes at their posts, radar operators became much more likely to completely miss obvious targets. Often somebody walking by would casually notice a radar paint that had been missed by the operator, even though he or she was intently concentrating on the screen. This problem, known as the *vigilance decrement*, applies to many monitoring tasks where "*hits*" are relatively rare. Aircraft inspection, the checking of medical X-rays and quality control inspection in factories are all areas where vigilance decrements may occur. Vigilance can be improved by increasing the conspicuousness of the signal and increasing the number of rest breaks or the variety of the work. Vigilance is also often better in a more social atmosphere, perhaps because it keeps people more alert.

Summary

To summarise the main points concerning attention: An individual's limited capabilities of information processing can be easily overloaded and can result in *load shedding*, *channelled* attention or *regression* to ingrained but inappropriate skills. The capacity to process information can be further reduced by stress, fatigue and lack of currency. Any conscious task (including daydreaming and worrying) can occupy attention and block out other information. Novel or difficult mental tasks can cause a narrowing of the visual field. However well-learned skill routines take up less mental capacity than routines that are less polished. Tasks requiring intense vigilance will suffer after approximately 20 minutes. Task stress can lead to a focusing of attention, causing us to filter out aspects of our surroundings that we would otherwise be aware of.

Memory

Alan Hobbs

We often talk about memory as though there is only one sort of memory whereas in fact we have a number of memory systems, each adapted for a different purpose. We remember new telephone numbers just long enough to dial them. Other information must be remembered for years. If memory worked perfectly all the time we could ignore it as a safety issue. Our interest in memory stems from the problem of forgetting. Just as there are different types of memory, so there are different types of memory lapses. Such as forgetting a name but recognising it as soon as it is mentioned; filling the gaps in our memories with logical expectations; assuming that the information retrieved is correct when in fact it is the wrong information; blending memories together to come up with an answer that is half right; or even forgetting something entirely!

Sensory store

The first stage of information processing is the short-term sensory store. This store enables us to hold information momentarily before it is processed further. The two most important sensory stores are echoic memory and iconic memory. Echoic for sounds, and iconic for images.

Iconic memory

The sensory store retains a brief trace of the stimulus after the stimulus has disappeared. For example, children commonly write in the air with sparklers, making use of the momentary image left after the sparkler has moved on. You can time how long the iconic trace lasts by placing a light on a wheel at night and rotating the wheel. If you measure the speed of revolution of the wheel at the point where a continuous circle of light begins to break up, you have measured the duration of iconic memory. Information in iconic memory lasts for between .5 and one second. Iconic memory enables you to glance at an instrument and mentally scan it after your eyes have moved on.

Echoic memory

Echoic memory lasts a little longer than iconic memory, in some cases up to eight seconds. It enables us to hear a message and briefly put off listening to it until we have finished dealing with other information. For example, half of a radio message may have passed before you hear your name and realise that it relates to you. Echoic memory enables you to mentally "replay" the message and go back over the initial bit that you were not attending to.

Interference in Echoic memory

Like all forms of memory however, echoic memory can let us down. Each sound in a string of sounds can interfere with the preceding sounds. For this reason, the final word in a string of words has a better chance of being recalled than a word from the middle of the message. Unnecessary radio transmissions at the end of a message (such as "over") can potentially mask out part of the echoic trace of the preceding message.

Short term memory (STM)

Sensory memory lasts for a few seconds and decays very rapidly. But there is another form of temporary memory that is more durable and enables us to keep several bits of information in mind at once. This is working memory or short term memory.

When you look up a phone number and keep it in mind until you dial it, you are depending on short term memory. Mental arithmetic is another situation where we have to keep several items stored in memory until we have found the answer.
Short term memory is not necessarily limited by the time that items are stored, because by saying them over and over (rehearsing them) we can store something for a long time. Short term memory is limited by the number of items that can be held. A common way of checking the capacity of short term memory is *the digit span test.*

The digit span test was first conducted by Jacobs (1887). A sequence of numbers is read aloud in no particular order. After the sequence has been completed, the listeners are asked to write down as many as they can remember. In general, people can store between five and nine unrelated items in short term memory. The average is around seven, and the capacity of short term memory is sometimes called **"seven plus or minus two".** This limitation is tremendously important, particularly when receiving important information which is transitory (such as auditory information) which must be momentarily kept in memory before they are acted upon.

However, it is possible to increase the capacity of short term memory by chunking information together. Such as encoding a string of numbers as dates instead of single digits eg 1914 2000 1988. Or for example, the French chunk telephone numbers into three large numbers rather than six digits eg. ninety six, twenty seven, thirteen for 962713.

Short term memory seems to depend on verbal rehearsal, so if you are told to call on 123.9 just as you are about to do something else, you may repeat 123.9 to yourself under your breath. Without this sort of verbal repetition, short term memory decays rapidly. But verbal repetition has some important implications for short term recall.

First, similar sounding items are likely to get confused with each other. For example the letters t, p, v, and d, all sound similar and therefore may interact with each other and influence the way any of them are rehearsed and consequently remembered.

Furthermore, items of information containing common or redundant elements are also likely to be confused, for example, A123, A734, A391 are harder to remember than just 123, 734 and 391.

Having to talk or pay attention elsewhere will disrupt the short term store. For example the process of performing mental arithmetic will make it difficult to retain other information in short-term memory.

In addition, if items must be retained in short term memory, it is better if the information is distributed over time rather than received all at once. Finally, we should not forget that the capacity of short term memory decreases with age.

Long term memory

A small proportion of the information that passes through our short term memory finds its way into long term memory. Unlike short term memory, there is no limit to the amount of information we can store in long term memory.

There are two types of long term memory. Episodic and semantic.

Episodic

Episodic memory is the recall of specific events or episodes such as a particular voyage or a day's events. A limitation of episodic memory is that it is easily distorted after the event. For example accident investigators often find that the way they ask questions of a witness can easily change the witnesses' recall of events. In an interview, terms like **breeze**, may tend to encourage recall of the weather as milder than was experienced. Whereas the word **wind** may elicit recall of stronger weather conditions. Episodic memory for events in time is also notoriously unreliable. For example, witnesses sometimes recall an event that lasted thirty seconds as lasting for much longer or even reverse the order of events.

Semantic

Semantic memory is where we store our abstract knowledge of meanings, relations and the mental frameworks we use to understand the world. Semantic memory appears to be a permanent record. Once you have learned about meteorology or how turbine engines function, that knowledge is there for good. This is not to say that information is always easy to retrieve!

Semantic memory relies heavily on associations between memories, or memory cues for retrieval. This is why when we lose our car keys, it helps to go back to where we last had them- the sights, smell and sounds of the place will help us get access to the information in our memory. This principle has wider applications than just looking for keys. In general, the more associations a memory has, the easier it will be to recall. Another result of this is that it will be easiest to recall information in the same environment in which it was learned. Information learned in a classroom will be recalled most easily onshore and things learned on the ship will be best recalled in that environment. A bad memory is often a sign of poor organisation and a failure to link the information to existing knowledge. It is a general principle that the more mental work we do at the time of encoding in memory, the better our memory will be. For example, you will remember more of this course if you have actively thought how the principles apply to your own company than if you have simply listened attentively. What we are talking about here is essentially learning. It is sometimes assumed that people learn better under stress. Although everyone is different, in general stress hampers learning.

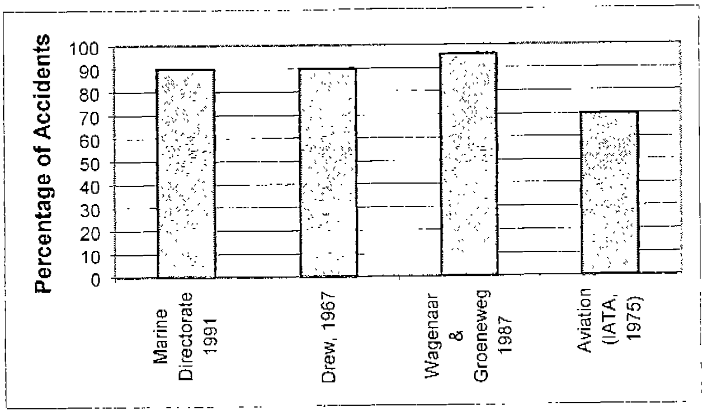
Human error and decision-making

Alan Hobbs

The role of unsafe acts in accidents

It is commonly claimed that between seventy and ninety-five percent of industrial and transport accidents involve human factors, see figure 1. Some authorities, however, claim that ultimately, all accidents involve human factors somewhere in the causal chain.

Figure 1: Contribution of Human Factors to Accidents



The human element in accidents takes a wide variety of forms, including perceptual errors, memory lapses, mistaken decisions and intentional rule violations.

Attribution bias

If we strip away the context in which these unsafe acts occur, we are left with human actions which may appear inexplicable or even bizarre. Yet investigators must take care to avoid focusing on unsafe acts in isolation. In doing so, we *personalise* accidents and run the risk of attributing them to the particular characteristics of the individuals involved.

Investigators need to be aware of a powerful phenomenon known as 'attribution bias'. This is the tendency of people to attribute their own mistakes to the environment or situation, but to attribute the misfortunes of others to internal inadequacies. In general, the more similar another person is to us, the more we will be prepared to consider the context in which their behaviour occurred. This is not to say that individuals are not responsible for their actions, but rather that as investigators, we need to consider the context in which human actions occur, not merely the actions themselves.

The skill rule knowledge distinction

The activities of an individual can basically be divided up into three types of actions. Knowledge based actions, rule based actions and skilled behaviour.

Skill based behaviour
Unlike knowledge based and rule based actions, skill-based behaviour is unconscious, rapid, seemingly effortless and most importantly it is automatic. Proficient drivers control their vehicle without having to consciously dwell on every movement of the steering wheel. Drivers can change gear, steer and work the accelerator without giving it a moments thought because these skilled actions have become automatic. We each have an astounding repertoire of skill routines which we can consciously initiate and then leave to run their course. The automatic nature of skill frees us to think about other things, but the cost of this automaticity is that we monitor what we are doing less. Another problem is that skilled operators are generally unaware of the automatic procedures they are following and may be unable to explain how the skill is performed.

Rule based behaviour
We use rules constantly in everyday life, without necessarily being aware of them. These rules are often procedures we have learned through trial and error and then apply to situations in an "if..then.." manner. For example, if the dipstick on you car indicated that the engine oil is low, then you would top up the oil. Although it is a conscious process, it does not require you to go back to first principles in the way that knowledge based behaviour does. People constantly apply rules, many of them formally laid down procedures.

Knowledge based behaviour
Knowledge based behaviour is required when there is no pre-packaged solution to a situation. The individual must think out a response using his experience or knowledge. Knowledge based behaviour tends to be slow and very demanding of mental resources. In effect, knowledge based behaviour is about thinking or decision making, often in unfamiliar situations.

Errors

One of the most useful aspects of the Skill-Rule-Knowledge distinction is that it helps to explain why errors occur and to predict the types of errors that will occur under various circumstances. Each of the three types of behaviour is characterised by particular error forms.

Skill based errors
Skill based errors are sometimes referred to as 'automatic' or absent-minded errors. They occur in familiar situations where the person has automatic skill based routines which control their actions. One of the most common skill errors is sometimes called "environmental capture" or habit intrusion. This occurs when a person is performing a well-learned action in familiar surroundings, but their routine action is no longer appropriate because the environment has changed. If they then fail to make an appropriate attentional check, they may inadvertently carry out the well-learned action without modifying it to the new or unusual circumstances. A common example is filling in a cheque in January and writing in the previous year. This sort of error is seen in aviation when a pilot who is flying an aircraft which has the flap and gear selectors reversed, inadvertently retracts the landing gear rather than the flaps after landing. This general problem, known as 'negative transfer' occurs when

a skill learned in one situation interferes with performance in another situation.

Another common skill error is the "Omission following an interruption". If a familiar routine is interrupted, it may never be completed, or may be picked up again at the wrong stage. One of the most dangerous manifestations of this in aviation is the interrupted checklist.

Rule based errors

While skill based errors are errors of action *execution*, rule based errors occur at the stage of action *planning*. Unlike skill based errors, the actions involved in a rule based error are intended, although misguided. Rule based errors generally occur in situations where the person has the expertise to deal with the task but where this expertise is wrongly applied. One of the most common rule based errors is where a person makes an assumption about the task they are performing, without checking that assumption. For example, an electrician may assume that the power supply has been disconnected because it usually has been in the past. A further common rule based error is where a rule or procedure which works in most situations is applied to a situation where it is not appropriate. For example, a mechanic who is accustomed to inflating tyres to 40 psi may apply this 'rule' to a new type of tyre which requires a different pressure.

A particular type of rule based error relevant to automated systems is the 'mode error'. When a system can be operated in more than one mode, sooner or later a person will attempt to perform a function without first confirming that the system is in the appropriate mode. An everyday example of a mode error is using an automated photocopier to make a single copy of a page, immediately after a previous user has set the machine to perform complex functions such as sorting and stapling.

Knowledge based errors

Knowledge based thinking involves evaluating an unfamiliar or unusual situation and deciding on a course of action. Essentially, knowledge based thinking can be equated with decision making. The history of accidents and disasters is frequently the history of wrong decisions. The charge of the Light Brigade, the sinking of the Titanic and the Challenger space shuttle accident are each examples of tragedies which resulted in part from poor decisions. More often than not the people who made these decisions were properly trained and had the necessary information available to them, but for some reason arrived at a poor decision.

Ideally, operational personnel would make decisions by following a carefully reasoned process involving considering all the options and weighing up the risks of various courses of action. In reality however, things are not that simple.

Sometimes we do not consider all of the alternatives or we take mental short cuts to arrive at a solution. Or under the pressure of having too little time and too much to do, thinking becomes 'short circuited' and we end up deciding on an unsuitable course of action. Emotional factors also exert a powerful influence on decisions, and despite the most thorough training, no one is immune to such pressures. Some major decision making problems are dealt with in the next sections.

Case study: Operational decision making
Ed is flying his Lama at a mining project in the mountains and decides out of the blue he's had enough of a tree branch that has fallen across one side of his helipad at the rain gauging station. He thinks, 'The heck with this, I'll just break off the branches with my skids. I've done it a few times before and everything worked OK. Besides, if I don't do it myself it'll never get done'.

He hooks the toe of his skid under the branch and pulls power—craaaak, the branch snaps off and he pushes it clear with his skid. He turns to his passenger with a wide grin and chuckles 'You're flying with the Master today, Pal!'

After his successful first go, he attacks the remaining branch. He again hooks it over the toe of the skid and begins to pull pitch. The branch, however, does not break. He thinks, 'The darn thing won't snap! I've got plenty of cyclic and power left—I'll just pull more power. Damned if I'll let a stupid old branch beat me! Besides if I start to list too far, I'll just back off. What could go wrong?'

He pulls more power and almost instantly the Lama rolls over on its right side on top of the branch he was trying to break off. It didn't break, but the Lama did.

Fortunately, neither Ed nor the passenger was injured. Ed cancelled his SAR and informed the client there would be no more flying that day.
—Pacific Helicopters (Goroka) Judgement Training Manual

False hypothesis
Psychologists sometimes refer to the 'strength' of an idea, meaning the degree to which an idea, once formed, can become firmly entrenched, even when information is available that would contradict it. A pilot who is concerned about fuel quantity, for example, might make a rough calculation and conclude that they have sufficient fuel, but before there is a chance to make proper fuel calculations, the pilot is distracted by the radio and questions from passengers. In the meantime, the comforting idea about fuel has become an unshakeable conviction.

In ambiguous situations, we tend to be uncomfortable with uncertainty and have a strong tendency to latch onto an explanation or idea. Common scenarios or ideas are likely to become 'default' assumptions. This is particularly the case when workload is high or the person is distracted. The strongest false hypotheses are those which provide comfort and reassurance when we are worried about something—the fuel state or the weather, for example.

Case study: False Hypothesis
An accident on the Farmsum, 14 December 1982, illustrates the problem of false hypothesis. Ballast water was in hold 4, hold 5 was meant to be empty, whilst four men were cleaning hold 6. A large amount of water was being lost from hold 4. When water was unable to be pumped from hold 6, the first mate discovered that the sluice valve in hold 4 was stuck open. The first mate assumed that this accounted for the inability to pump water out of hold 6 and the loss of water from hold 4 (a false hypothesis). However, water from hold 4 was actually leaking into hold 5 instead. 3,300 tons of water was missing from hold 4, the first mate

failed to notice that this had been replenished by 6,600 tons of water. This replenishment of hold 4 actually filled both hold four and hold 5. The wall between hold 5 and hold 6 was not designed to withstand the pressure. This caused the wall between hold 5 and hold 6 to collapse. Six thousand tons of water flooded into hold 6 and three men were drowned.

Confirmation bias

One of the reasons why false hypotheses can persist is the tendency known as 'confirmation bias'. Once we have a theory to explain an otherwise ambiguous situation, we tend to search for information which will confirm what we suspect. People however, rarely attempt to prove themselves *wrong* and in fact, often disregard information which would contradict their ideas. For example, lost pilots will sometimes try to guess where they are, and then look for ground features that are consistent with that idea, ignoring those which are inconsistent. Confirmation bias can also interfere with troubleshooting of mechanical faults, where unexpected information can be ignored or disregarded.

Case study: Bell 206B Fuel Exhaustion on Passenger Charter Flight

After consultation with his passengers regarding the expected duration of the return survey flight, the pilot decided that he needed only one 200-L drum to refuel. Just short of the destination, he advised the passengers that he would have to land due to low fuel state. During the descent, the engine stopped due to fuel exhaustion, and the helicopter was substantially damaged in the resulting heavy landing on a dirt road, in fading light.

The pilot was unfamiliar with the fuel system installed in the aircraft. The duration of the return flight was increased by a requirement to complete an extra task. However, when the pilot became aware that insufficient fuel remained to complete the flight with the required reserves, he decided to continue the flight to the planned destination. The landing was only attempted when the pilot became concerned that all the fuel would be exhausted before arrival at the destination.

Risky shift

A surprising finding about risk-taking is that people in a group (even just two people) will sometimes accept a higher level of risk than each would accept on their own. This phenomenon, known as 'risky shift', seems to be a particular problem for younger pilots who may not have the experience or confidence to know when exciting flying becomes dangerous flying. Two careful pilots put together in the one aircraft do not always constitute a careful team, particularly if there are no formal procedures to guide them.

There is some dispute about why this effect occurs, but it might be that when there is someone else to share the responsibility, people feel less individually responsible. We look to the other person to see if they look worried, while at the same time they are looking at us. This is sometimes called *diffusion of responsibility*. Of course, it doesn't just affect pilots. Diffusion of responsibility occurs in all walks of life (including management) particularly in situations where no one is in charge or where there are no procedures to deal with a situation.

The following accident case study is consistent with the problem of risky shift:

Case study: Bell 47G Loss of Control on Ferry Flight

A group of pilots had travelled from a property strip to a nearby dam in order to complete training exercises on a float-equipped Bell 47 helicopter. The helicopter was not fitted with floats but had been used to ferry some of the pilots to the area. At the conclusion of the training operation, the pilot arranged to ferry the helicopter back to the property strip.

After takeoff, a practice autorotation was conducted over the dam and was followed by some unauthorised low flying in the vicinity. On arrival at the strip, low-level runs were performed with torque turns at each end. Control of the aircraft was lost during the third of these turns and the aircraft struck the ground in a steep nose-down attitude. Fire broke out on impact and engulfed the wreckage. The subsequent investigation did not reveal any evidence of a pre-impact defect or malfunction of the aircraft which might have contributed to the accident. Several of the pilots who observed the flight reported that the final manoeuvres performed were outside the normal operating parameters of the helicopter, and were conducted at an unsafe height above the ground. However, it was not possible to determine which of the pilots was flying the aircraft at the time of the accident.

Choosing between losses

Imagine a casino where they offered you the choice of either losing 10 dollars, or tossing a coin and losing one hundred dollars if it came up heads but nothing if it came up tails. In this unlikely situation, many people, being optimists, would choose to try their luck and risk the $100, rather than cutting their losses and accepting the smaller penalty. It is as though people when making a decision, sometimes consider only the *odds*, but do not weight their judgement by considering the relative seriousness of the *outcomes*.

Operational personnel are often faced with dilemmas like this where they have to choose between two unpleasant options, one of which is inconvenient, the other potentially disastrous. We sometimes see accidents where a pilot under pressure chooses to take a gamble that the serious outcome won't happen, rather than taking the safe but inconvenient option.

For example, in the heat of the moment, a pilot faced with deteriorating weather may decide to press on rather than turn back, preferring possible disaster to certain inconvenience.

One solution is to ensure that operational personnel have a plan about how they will deal with various situations *before* they encounter them. That way, they can reduce the need for impromptu risk assessments in situations where their judgement may be clouded.

There is a risk that when a person is under-loaded or not sufficiently challenged by the task at hand, they may make the task more challenging to maintain their alertness. So even apparently simple tasks can become potentially hazardous.

Frustration

There is a clear link between frustration and aggression. It seems to be hard-wired into people that if a situation keeps frustrating us, we may move into 'aggressive mode', giving us access to extra reserves of strength and motivation. Thousands of years ago, the frustration - aggression link probably helped our ancestors fight wild animals, catch food and solve many other stone-age problems. Unfortunately, the world in which we live requires careful action more often than brute force, but we still carry within us this primitive problem-solving system.

For example, a helicopter pilot faced with everyday frustrations such as a faulty headset or long-term unserviceabilities, may begin to handle the aircraft more roughly than normal or may begin to act impulsively.

The pilot in the following example let frustrations get the better of him.

Case study: Frustration and aggression
I had just brought a mob of cattle to the yards and I noticed that the stockmen were sitting under a tree having smoko. The cattle were starting to wander back into the scrub, this [..annoyed me..] because it had taken a lot of trouble to get the animals there, so I hovered near the stockmen and used the shotgun to blast the billy off the fire.

De-identified pilot report

Lessons in judgement may come with years of experience, but may also come at great cost. Traditionally, the training of pilots has emphasised the knowledge, rules, procedures and handling skills which must be acquired to operate an aircraft. But the skills required in making sound judgements have largely been left for pilots to pick up along the way. There is a growing acceptance that good judgement can be developed, and many companies now invest the time and money to train their personnel in decision-making skills. This training can also help managers to identify the part *they* play in influencing the decision making of operational personnel.

Conclusion

Accidents can be complex events originating deep within an organisation and while it is important to understand the unsafe acts which may have contributed to an accident, it is crucial that these actions are seen in the organisational context in which they occur. Errors are not only 'causes' of accidents, they are in themselves *consequences* of organisational circumstances.

One further important step is to acknowledge that human error is an unavoidable reality. As a result, systems and procedures must be designed to anticipate unsafe acts and prevent them from contributing to major problems.

Violations

Mike Walker

1. Definitions

Unsafe acts are often considered to simply be deviations from an organisation's safety procedures or rules. However, procedures are not always well designed. A breach of procedures may not be unsafe, and an unsafe behaviour may not breach the organisation's standards. Consequently, a more appropriate definition is as follows:

- **Unsafe acts**: observable behaviours that increase the risk of an accident to a level above that which is acceptable or necessary to complete an operation/task.

There are three main types of unsafe acts:

- **Errors**: those occasions in which an individual's planned sequence of mental or physical activities fails to achieve his/hers intended outcomes (Reason, 1990, p.9).
- **Violations**: deliberate deviations from an organisation's safety procedures drawn up for the safe or efficient operation and maintenance of plant or equipment (Health and Safety Executive, 1995, p.3). (The term 'procedures' also includes rules, instructions and regulations in this context.)
- **Misguided acts:** those occasions in which the individual's behaviour is unsafe, but it is not the result of an error and it is not a deliberate breach of any procedures. For example, no relevant procedures may exist, the individual may have complied with poorly designed procedures, or the individual may not have been aware of the relevant procedures.

A key aspect of the definition of violations is the word 'deliberate'. A breach of safety procedures may be accidental or unintentional (i.e. an error). Alternatively, the individual may not have been aware of the relevant procedures (i.e. a form of misguided act).

Even though violations are deliberate breaches, it should be noted that many of them are conducted with good intentions (i.e. to assist the organisation to meet its objectives) (Mason, 1997). (See also section 3).

2. Importance of Violations

The following can be stated about violations (as well as errors) and their association with accidents:

- Violations are generally quite rare in terms of the proportion of times they are conducted per the proportion of times the task is conducted. However, for some tasks, the proportion is quite high. Overall, the presence of violations in a work environment can often be quite common (in terms of the number of violations per shift).
    - Klinect et al (1999) observed flight crew behaviour on 314 flight sectors (three different airlines). They observed a total of 578 unsafe acts, 54% of which were violations. Most of these were not 'consequential' (i.e. they did not present subsequent problems for the crew).
    - A large number of studies have reported observing employee behaviour in manufacturing and maintenance plants, and noting that compliance with safety procedures was generally 50 to 90% (Walker, 1995).

- Accidents are extremely rare events.

- Most violations do not result in an accident.

- Many accidents involve violations in their development. This is a widely agreed statement. However, there has been little research which has examined the involvement of violations (using the definition in section 1) in accidents.
    - Feyer and Williamson (1991) founded that misguided acts (termed 'work practice' factors) were involved in the causation of 42% of occupational safety accidents in Australia, and a prime cause of 34% of accidents. Other unsafe acts (errors and violations) were probably or possibly involved in 70% and a prime cause of 51% of accidents.
    - A Boeing analysis of (high-capacity) aircraft accidents from 1982-91 found that the 'elimination of procedural errors' is the leading strategy for reducing the probability of future accidents. It is not clear to what extent the procedural deviations were errors or violations.
    - Parket et al. (1995) conducted a survey of over 1,600 drivers in the UK. They identified three main types of unsafe acts: lapses, more serious errors, and violations. Accident liability was correlated with the drivers' tendency to commit violations, although the correlation was small.

Violations are not usually the last event in an accident sequence. However, they tend to increase the risk of subsequent errors as they make the environment less understood and less error-tolerant, (Hudson, 2000; Lawton, 1998).

Hudson (2000) argues that violations are a significant safety issue as they undermine a basic assumption of a safety management system—procedures will be followed. Some violations can also be difficult to detect as employees hide them (as they obviously want to minimise the likelihood of any disciplinary action).

Violations are also important because of what they say about an organisation. The extent of violations, and they way they are treated by employees and managers, provide a good insight into the overall safety culture in an organisations.

3. Types of Violations

Based on Lawton's (1998) research into the safety behaviour of railway shunters in Manchester, and discussions by Reason (1990) and Mason (1997), the following five types of violations can be distinguished:

- **routine**
  - normal way of operating for employees in that work environment
  - commonly associated with a lack of enforcement or other negative consequences
  - skill-based or rule-based behaviour (i.e. usually automatic)
  - very low perception of risk
  - example: exceeding duty times

- **situational**
  - initiated due to the nature of a specific situation in which the procedure is difficult to comply with (or violating is much easier than complying)
  - if the situation keeps repeating, may lead to routine violations
  - usually rule-based behaviour
  - low to moderate perception of risk
  - example: lockout procedures

- **exceptional**
  - rare, occurring in only extreme situations (usually emergencies)
  - usually high degree of risk (as the situation is new)
  - usually knowledge-based behaviour
  - moderate perception of risk
  - example: Chernobyl (operators overrode automatic shutdown)

- **optimising**
  - created by a motive to improve a work situation
  - motives may include need for excitement (in boring task), desire to impress others, inquisitiveness
  - usually rule-based behaviour
  - low perception of risk

    - examples: USAF B-52, 24 June 1994

- **sabotage**
    - intent is to violate and create damage
    - difficult to predict, but very rare
    - most likely knowledge-based processing (but reactive acts of aggression may be more automatic in nature)
    - high perception of risk
    - examples: FedEx DC-10, 7 April 1994; Silk Air B737, 19 December 1997 (no cause agreed)

Sabotage is generally quite different and easy to distinguish from the other types. Routine violations are relatively easy to distinguish from situational, exceptional, and optimising violations. However, it is not always easy to distinguish between the other three types.

4. Reasons for Violations

Violations can occur due to a wide variety of reasons. Some of these reasons are the same as for errors, but many are also different. Examples of frequently-encountered reasons are listed below. See also Maurino et al. (1995) and Mason, (1997).

- Less cognitive workload/effort.
- Less physical workload/effort.
- Saves time.
- More comfortable.
- Financial gain (i.e. bonus schemes).
- Demonstrates skill, enhances self-esteem.
- Peer pressure (e.g. to conform, achieve bonuses).
- Role modelling (e.g. supervisors, experienced personnel or opinion leaders demonstrating bad habits).
- Impractical procedures/schedules.
- Pressure (real or perceived) to get the job done.
- Lack of supervision/monitoring.
- Managers/supervisors condoning behaviour ('silent applause').
- Ineffective/inconsistent disciplinary procedures.
- Lack of positive rewards for working safely.
- Poor perception of benefits of violating.
- Poor perception of risks violating.
- Individual characteristics (e.g. age, personality, gender). Young males more likely to commit violations (driving). Unstable extroverts more likely to commit violations, particularly under stress (Lawton and Parker, 1998).

Three aspects of these 'reasons' warrant further discussion.

Firstly, many of the important reasons are actually 'consequences' of a behaviour. The behaviour analysis (or operant conditioning) approach in psychology states that the more favourable the consequences are, the more likely the behaviour will be used in similar situations in the future. The less favourable the consequences, the less likely that behaviour will be repeated. There are three dimensions of consequences that determine their strength: value (positive is better than negative), immediacy (immediate is better than a long time away), and frequency (always better than rarely). When attempting to understand the reasons for a violation, it is worth comparing the consequences (for the individual) of complying with the procedures versus violating the procedure.

Secondly, one consequence that is often (incorrectly) considered to have a large impact on employee behaviour is the risk of an accident. However:

- The accuracy of an individual's risk perception is often poor.
- When dealing with familiar tasks in familiar environments, it appears that an individual operates with a 'zero' level of risk perception (Summala, 1988). That is, the individual does not believe there is any chance of an accident occurring by doing the task that way (using violations).
- As a result, an individual's behaviour is more concerned with satisfying other demands or desires (e.g. getting the task done, impressing others, not getting punished).
- Risk compensation does occur. That is, if a change is made to the task or environment, people will adjust their behaviour to operate at a similar perceived level of overall comfort (e.g. improve the quality of a road and people will drive faster—unless there are other reasons not to).

Thirdly, it is often claimed that a primary reason for violations is due to inappropriate attitudes of employees. It is also often stated that to change behaviour, you need to change attitudes. Attitudes are complex sets of beliefs and feelings an individual has about another individual, object or task. The main problems with attitude change are that attitudes are complex and often well established. The approach of trying to change safety behaviour (or other types of behaviour) by directly focussing on attitudes (e.g. via education campaigns) has rarely been shown to lead to significant or lasting changes in behaviour. In contrast, changing the consequences of behaviour has been shown to be much more effective (McAfee and Winn, 1989; Walker, 1995). It also leads indirectly to changes in attitudes.

5. Dealing with Violations

Know the reasons first.

To address violations, the first step is to understand the specific reasons that are leading to the violations of concern. As noted in section 4, there are a wide variety of potential reasons. A different pattern of reasons will require different solutions. This analysis will generally involve reviewing incident reports, obtaining information from relevant personnel (via interviews or surveys), and observing behaviour.

A wide variety of solutions can be employed, depending on the circumstances. The Health and Safety Executive (1995) has detailed the following types of interventions:

- Rules and procedures: correct aims and objectives (to ensure relevance, practicality and no ambiguity)
- Rules and procedures: correct application and presentation (to ensure easy to understand and ownership)
- Training: rules and procedures (to ensure are known)
- Training: hazard awareness and risk perception (to ensure understand the hazards and risks)
- Safety commitment: the workforce (to ensure involvement and ownership in the safety management process, good role models)
- Safety commitment: management (by appropriate interest/involvement in safety management activities)
- Supervision: monitoring and detection (to ensure problems are identified)
- Supervision: style (to ensure good role models, consistent and effective recognition and enforcement)
- Plant and equipment: design and modification
- Job design (to ensure more interest/involvement/satisfaction in the job)
- Working conditions (to ensure noise, lighting, and other physical environmental factors are conducive to effective work habits)
- Logistic support (to ensure appropriate equipment/materials/resources are available)

When considering what types of interventions to employ, some basic principles should also be considered:

- The most effective solutions when generally be those which redesign the task/environment/procedure to: (a) avoid the need for the problematic procedure to be used; (b) make it easier to comply with the procedure (e.g. more comfortable, less time, less effort), or (c) make it harder to violate the procedure.
- If the task/environment/procedure cannot be redesigned, then interventions involving the measurement of compliance and providing regular performance feedback (as well as appropriate praise/disciplinary action) should be considered. However:
  - Disciplinary action is difficult to implement satisfactorily (i.e. consistently and fairly), and often leads to negative employee attitudes about other issues. It should only be employed along with the provision of positive rewards for compliance (e.g. praise, recognition).
  - Use of monetary rewards/bonuses for safe behaviour is also difficult to implement satisfactorily. They generally have no lasting effective on behaviour.
- Training and education interventions are always necessary, but rarely sufficient for increasing compliance with procedures.

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Guidelines for Investigative Interviewing

Mike Walker

Overview

1. Interviewing is a critically important skill for all types of accident/incident investigators, although the extent to which it is important for a particular investigation will vary.

2. Good interviewing skills are required to help overcome the many limitations in a witness's perception, retention and recall of events. These limitations include:

   - Perception of an event can be affected by environmental factors, such as lighting and visibility, duration of the event (longer is better), complexity (simpler is better), and familiarity (more familiar helps with complex events).

   - Witnesses experiencing stress or fear will tend to narrow their attentional focus. They will generally remember more details about what they were focussing on, but less detail about peripheral events. Children will generally recall less detail and are more suggestible than adults, but will be less likely to rationalise events. Elderly people will generally perform less well due to the increased limitations of their information processing system. A witness will generally perceive and recall more easily those aspects of an event which they can relate to previous knowledge or training. However, expectations and biases can easily affect perceptions. Participants actively involved in an event will often have an inaccurate recall of the exact decisions and actions used during the performance of familiar tasks.

   - Retention of perceptions fades with time. It is also greatly affected by post-event information, such as media reports or the nature of an interviewer's questions. It can be affected by the perception of similar events or performance of similar tasks after the incident, as details relevant to the incident tend to merge with these other events. Motivation can also play a significant role. Some people will want to forget, others will want to receive attention by reporting more than they actually witnessed.

- The actual retrieval of event memories is also subject to many limitations, and memory retrieval is an effortful process. Question wording, distractions and motivation can all be important factors. Reinstating the event context and using multiple retrieval attempts will generally assist.

3. Most investigators receive little training in the use of investigative interviewing techniques. Many experienced investigators believe that well-proven interviewing guidelines are 'common sense', but research and anecdotal evidence suggests they are not commonly used. Many experienced investigators also believe they use good interviewing techniques, but research and anecdotal evidence suggests that this is often not true.

4. There are many different types of interviews which may be conducted during an investigation. An interviewee or witness may be acting in one or more of the following roles:

   a. Eyewitness (EW).
   b. Participant (PW) in the event, usually an operational person such as a pilot, air traffic controller, or LAME.
   c. Expert on a relevant operational matter.
   d. Organisational member.
   e. Friend / relative.

5. The following guidelines focus on EW and PW interviews. Many of the principles are also relevant for other types of interviews. The guidelines are divided into the following interview stages:

   a. Preparation.
   b. Introduction.
   c. General account of event.
   d. Detailed account of event.
   e. Background issues (PW only).
   f. Review.
   g. Evaluation and follow-up.

6. These guidelines are based on many documents and research articles. The major influence is the 'cognitive interviewing' method developed by Fisher and Geiselman, and adapted by the British police, for interviewing EWs of criminal events. The method uses principles of cognition and communication to help witnesses improve their recall of events. The guidelines also incorporate aspects of the critical decision method developed by Klein. This method uses cognitive probes to determine a PW's bases for situation assessment and decision-making.

7. The guidelines are quite detailed. However, they are all based around a limited number of general principles such as:

- Develop and maintain good rapport.
- Maximise concentration (by minimising distractions, active listening, motivation).
- Let the witness do the talking (by minimising interruptions, using open questions).
- Recreate the event context (by appropriate use of instructions, questions, and cues).
- Promote extensive and detailed responses.
- Use multiple retrieval attempts.
- Divide the interview into a number of key topics (after the general account stage).
- Minimise your own workload (by team resource management, good note-taking techniques, acting naturally where appropriate).

A. Preparation

1. Obtain background information.

- Obtain information about the event. (This will assist in understanding and clarifying the information obtained from the witness.)

- If possible, visit the scene or familiarise yourself with relevant equipment.

- Obtain information about the witness. Consider issues such as age, cultural background, educational background, disabilities, involvement in the accident / incident, and relationship to others who were involved.

- Determine if the witness has been interviewed about the event, and by whom. If possible, obtain and review the interview notes or tapes. (This information can help you appreciate the witness's motivation to talk or not talk about the event, and the extent that the witness's recollection may be contaminated. If the witness has already been interviewed, you will need to motivate the witness more by using more active listening, stressing the importance of your interview, and instructing the witness to recall the original event - not just their earlier statements.)

- For a PW, also consider work experience, as well as incident / violation history.

- During the interview, act as if you have started with little information about the event and the witness. (This will lead to more open questions and more active listening.)

2. Determine aims (what).

- Determine the types of information you want from the witness. For an EW it will usually be what the witness saw or heard. For a PW it will also include decisions and actions, contributing factors and other background information.

- Be prepared for anything.

3. Determine location (where).

- Ensure the location will not be intimidating to the witness, will be comfortable for the witness and yourself, and distractions can be minimised.

- If possible, conduct the interview near the scene of the event or a very similar scene so that it can be used as a prompt to aid recall. Be aware that in rare cases a physical recreation of the context may be stressful for a witness.

4. **Determine time** (when).

- The interview should be conducted as soon as possible after the event. Witness's often need to talk, and you should be one of the first to listen. However, consider the witness's condition. It may be necessary to conduct a brief interview initially, and obtain more details at a later point in time.

- If there will be a significant delay before the interview, consider asking the witness to write down some key details about the event. For a PW this may include aspects of their 72 hour history.

- Allow plenty of time for the interview so that it can be comprehensive and not hurried.

5. **Determine who will be involved.**

- Whenever possible, interview each witness individually. Determine if the witness would like a friend or representative to be present.

- Whenever possible, have two interviewers. It is best if you have different yet relevant backgrounds or experience. (Two interviewers assist with note-taking and ensuring all relevant questions will be asked. More than two interviewers can be intimidating for a witness, particular without a representative.)

6. **Determine the interview plan** (how).

- Ensure that the interviewers' roles are clearly defined. For example, identify who will be asking most of the questions and who will be taking most of the notes.

- Ensure that the general format or interview procedure is clearly understood by all interviewers. This can be particularly relevant for joint investigations.

7. **Obtain relevant materials and equipment.**

- Ensure that all relevant materials and equipment are present, such as paper, pens, and refreshments.

- Consider whether to have additional prompts or tools available: models, maps, charts, checklists, photographs of the scene, and relevant equipment.

- Tape recorders: Opinion is divided about the use of tape recorders for BASI interviews, and it is generally up to the investigator. They make note-taking easier, but their presence will affect the willingness of some people to talk, particularly if they are a PW. They can also be a distraction at critical times. If you are doing many EW interviews by yourself in one day, then a tape recorder may well be useful. If you are in any doubt, do not use a tape recorder.

B. Introduction

1. Ensure positive greeting.

- Determine the witness's preferred name, and use it.

- Smile, but ensure the greeting is appropriate for the circumstances.

- Use some minimal physical contact, such as shaking hands or touching the witness's shoulder. Take care not to be too familiar.

- Make sure everyone is introduced to each other.

2. Develop rapport.

- Treat the witness as an individual with a unique set of needs. Show an interest in them and their circumstances. Ensure they are comfortable and relaxed.

- View the event from the witness's perspective. Treat their story as truthful.

- Ask how they are feeling. Examine any injuries; inquire about discomfort.

- Maintain eye contact. Sit facing the witness, and lean forward to indicate interest.

- Present yourself positively. Be open, honest and interested. Be a genuine, identifiable person - not just a representative of an official organisation. Introduce some personal information about yourself to establish a common link. Do not use the same standard questions or statements in all interviews.

3. Explain interview process.

- Clarify whether the witness has been interviewed about the event already, and by whom. Determine how much they have discussed the event and with whom.

- Explain the reason for your interview, and the types of information you are seeking. Emphasise the importance of the interview.

- Explain the role of BASI, and how and why it does investigations. Emphasise the focus on safety enhancement rather than the allocation of blame.

- Explain the interview method. Discuss the need for taking notes, and the legal status of investigators' notes. Ask permission before using a tape recorder.

- Explain the witness's rights and obligations. Clarify whether the witness would like a friend or representative to be present. Ensure that person knows their role, rights and obligations.
- Tell the witness that they can ask questions at any time.

- Tell the witness how long the interview may take. Ensure that they have no pressing work or domestic tasks which may be affected.

4. **State expectations of the witness.**

- Clearly explain that the witness is required to:

  a. Do most of the talking. (The witness has all the information - they should be doing most of the talking.)
  b. Tell things in their own words and at their own pace.
  c. Give as much detail as possible and not edit things out, even if they are trivial or conflict with things they said earlier.
  d. Not guess, fabricate or make up answers.
  e. (Probably) go over things more than once.
  f. (Probably) use considerable effort and concentration.

5. **Assess the witness.**

- Evaluate the witness's skills, interests, and language ability. (Use this information to ensure you ask witness-compatible questions.)

- Determine if the witness has any specific concerns. (These issues need to be dealt with promptly or else they will interfere with the witness's effort.)

- Determine the witness's level of anxiety. If they appear to be quite anxious, use simple factual questions at the start of the interview. In rare cases it may be worthwhile using deep breathing exercises.

6. **Consider specific witness needs** (if required).

- Intoxicated: Provide as much structure as possible to your questioning.

- English as a second language: Use short sentences and a simple vocabulary. Speak more slowly and distinctly, but not any louder.

- Children: Spend more time developing rapport. Use short sentences and a simple vocabulary. Ask the child to use models rather than words to demonstrate what happened. Get the child to describe a game or play event, and use this description as a basis for later questioning.

C. General account of event

1. Recreate general context.

- Specifically request the witness to recreate the context of the event. Ask them to mentally relive the time and place of the event. Alternatively, ask selected questions to recreate the context. Useful examples may include:

  - What time was it?
  - Where were you?
  - What was the weather like?
  - How were you feeling?
  - What were you doing?
  - Were you alone?

- Sometimes it is useful to provide more concrete cues prior to starting with the description - such as tapes, photographs, or documents. Such cues are often not needed in the general account stage, except perhaps for PWs who have performed a task automatically.

- Allow the person time to recreate the context before questioning them. Keep quiet during this period.

- For certain traumatic events, it is wise to warn the witness that they may experience some fear or anxiety about 'reliving' the incident. Explain that this is normal, but the fear should not be as severe as the original event. Explain that they can control their level of fear now, and have a break anytime they wish. In extreme cases, ask them to perceive the event as occurring to someone else.

2. Request general description.

- It is usually best to use a simple request such as: "Tell me in your own words whatever you can remember about the event from the time that .... Tell me everything you can in as much detail as possible." Alternatively, ask the witness to recall what happened as though it was happening now. Ask them to imagine they are watching a video of the incident, and to describe what is happening in the video.

- Restate any of the expectations as required.

- Ask the witness to draw a map of the location and / or event sequence if it will assist.

3. **Active listening.**

- Do not interrupt.

- Use long pauses after the witness stops talking.

- Give feedback to indicate that you are listening and understanding - such as a nod, 'uh huh', 'okay'.

- Maintain eye contact. If the witness is concentrating intensely, look at the lower part of their face. Lean forward to indicate interest.

- Keep note-taking to a minimum during the general account phase - restrict it to main points and queries.

- Do not act surprised by anything the witness says. Avoid giving direct, qualitative feedback to anything the witness says. (You need to avoid reinforcing the witness for recalling items, or they may fabricate answers.)

4. **Control the witness's behaviour** (if required).

- Witness has high anxiety level: Deal with this issue straight away. Switch to simple factual questions; get the witness a drink; take a short break; save the most stressful issues to later in the interview. In some circumstances it may be worthwhile to use deep breathing exercises.

- Witness speaking too fast, soft, or incoherently: Model the desired behaviour. Alternatively, specifically request the witness to change.

- Witness having trouble concentrating: Minimise distractions; take a short break; switch to simple factual questions.

- Witness unable to follow instructions: Take a break; consider suspending the interview.

5. **Identify 'items' for detailed questioning.**

- Develop a written list of the specific **events** and **objects** which require a more detailed description. Order these events and items logically. If the witness is having difficulty concentrating, deal with the most important items first.

- For a PW, also identify the key **actions** and **decisions** which you want further details on.

- In some circumstances, it can be useful to develop an incident **timeline** (i.e., a listing of relevant events in chronological order) in consultation with a PW before proceeding to the next stage.

D. Detailed account of event

1. **Recreate specific context.** (see stage C)

- Explain the need for more details.

- Use the witness's own words to recreate the context. If necessary, use prompts such as photographs, maps, equipment, audio tapes.

- Ask the witness to concentrate, and close their eyes or look at a blank wall. Allow the person time to recreate the context before questioning them. Keep quiet during this period.

2. **Request item description.** (see stage C)

- Use a simple, open request such as "Tell me all you can remember about ...".

- Restate any expectations as required.

3. **Probe the item.**

- a. Question ordering:

    - Start with open questions before closed questions.
    - Use phrases such as "describe everything you can about .."; "what was the most distinctive feature you can remember about ...".
    - Order questions chronologically or in another logical order.
    - If the witness is not familiar with the item they are describing, guide them to the most important features.

- b. Question format:

    - Ensure all questions are neutral.
        - Use the noun form of an article ("what was the length of") rather than an adjective ("how long").
        - Use the indefinite form of an article ("a collision") rather than the definite form ("the collision"), unless the fact has been established.
        - Ask about a general dimension ("what colour was ...") rather than try to confirm or disconfirm a specific trait ("was the item red").

    - Ensure all questions are simple. Use short sentences; avoid negatives; ask questions one at a time; avoid jargon and long words.
    - Phrase questions positively - "do you remember .." rather than "you wouldn't remember whether ...".
    - Use the witness's words where possible.
    - Use witness-compatible questions (i.e., do not use terms which the witness is unfamiliar with).

- c. Speech: Speak slowly and distinctly; use a moderate tone of voice; speak softly if the witness is concentrating intensely.

- d. Determine witness limitations: Time under observation; distance from event; visibility and obstructions; how often seen similar events.

- e. Use special techniques. Where required:

    - Convert subjective descriptions to objective descriptions.
    - Encourage relative judgements over absolute judgements.
    - Ask the witness to use models, or draw items on paper.
    - Ask the witness to use other senses.
    - Ask the witness to use other perspectives.
    - Ask for general impressions about the item.
    - Multiple retrieval attempts: Use different words; motivate the witness.
    - For PWs - get them to sit / stand in the same operational environment.

4. **Use decision probes** (for PW).

- Simply ask the witness why they performed a certain action or made a certain decision. Also ask what factors may have affected their actions or decisions.

- For a richer understanding of a PW's decision processes, various "cognitive probes" can be useful. The following are some examples to consider:

    - What was your situation assessment at the time?
    - Was this easy or difficult to obtain? Why?
    - Imagine that you were asked to describe the situation to another operator (e.g., pilot, controller) at that point in time. How would you summarise the situation?
    - What critical cues did you use to make this assessment?
    - Were you reminded of any previous experiences at the time?
    - Did you search for any additional information? What?
    - What were your main goals at the time? Why?
    - What strategy did you select to achieve these goals?
    - Did you consider alternatives? What? Why did you reject them?
    - What 'tricks' / 'rules of thumb' did you use to make your decision?
    - What specific training or experience was helpful in making this decision?
    - What did you think was going to happen if you did not take any action? As a result of your action?
    - What else was going on which was requiring your attention or distracting you?
    - If you could make the decision again, what would you do differently?
    - What training, knowledge, or information could have helped you when making this decision?

5. **Active listening.** (see stage C)

- In particular, do not interrupt and do use long pauses.
- Take detailed notes.

6. **Control the witness's behaviour.** (see stage C)

- It may be necessary to keep motivating the witness to try and recall aspects of the event. Restating the importance of the witness's recall may assist, as well as taking breaks and active listening.

7. **Summarise.**

- Restate the witness's recollection of an item in detail and using their own words where possible. Check that your notes and comprehension are correct.
- Exhaust each topic before moving onto the next.

8. **Link.**

- Move onto the next item by linking it with the previous item. Restate part of the witness's recollection as a means of recreating the context. For example: "Okay, so you saw the aircraft start to dive. Tell me as much as you can remember from the time it started to dive until when it hit the ground."

E. **Background issues (for PW interviews)**

1. **Situational factors.**

- Ask questions to determine the general condition, adequacy or unusual aspects of relevant factors such as the following:

  - Equipment, including displays and controls.
  - Materials, charts, maps.
  - Procedures and instructions.
  - Visibility conditions and other environmental factors.
  - Weather.
  - Communications.
  - Relationships / coordination with other personnel.

2. **72 hour / 7 day history.**

- Consider the PW's sleep hours and work hours in the previous few days.

- Also consider preoccupations, significant events, health, drug / alcohol use.

3. **Medical / physiological factors.**

- Consider the PW's recent history of physiological problems, work schedules, drug use, illness or fatigue symptoms, injuries.

- Consider any relevant performance limitations or characteristics of the PW, such as vision, hearing, strength, reaction time, memory and concentration.

4. **Operational experience.**

- Consider the PW's overall experience, experience on the relevant task or equipment, and experience of the event situation. Also consider incident / violation history.

- Consider asking questions to help determine the level of the PW's operational skills and knowledge.

5. **Organisational issues.**

- Consider the PW's opinions / evaluations / perceptions of the task, job, co-workers, supervisor, subordinates, organisational polices and practices, and the organisation itself. Ask the witness to comment on what are the best ways to stop this type of event from occurring again, and what are the main problems with the safety system.

- Organisational issues are often best handled in a follow-up interview.

F. **Review**

1. **Ensure all items covered.**

- Refer to your original plan, your list of written items from the General Account Stage, and any other queries you have written down. Ensure all these issues have been addressed.

2. **Conduct overall review.**

- Briefly summarise your understanding of the witness's recollections and thoughts, using the witness's words as much as possible. Speak slowly and clearly.

3. **Clarify discrepancies** (if required).

- Identify if there has been any witness discrepancies within the interview, or between the witness and other information sources. (It is usually best to deal with conflicts later in the interview. Minor discrepancies can be dealt with during the summarise step of the Detailed Account stage.)

- Present the discrepancy as a problem solving exercise which you want the witness to contribute to.

4. **Obtain background information.**

- Obtain relevant factual details such as name, contact details, position, experience that you have not already obtained. Do not ask for irrelevant personal information.

- While obtaining this type of information, it helps to dismiss it as an official requirement (this will make the witness feel more comfortable with revealing any personal details).

5. **Finalise the interview.**

- Determine if the witness was happy with the interview and the way it was conducted.

- Ask the witness if they have any questions about anything else.

- Give the witness your contact details, and encourage them to contact you if they think of any new information.

- Thank the witness for their assistance.

- Create a positive, lasting impression.

G. Evaluation/follow-up

1. Write up your interview notes.

- Write up your notes as soon as possible.

- If there are more than one set of notes, compare them and resolve discrepancies before finalising. Use the recommendations in the BASI Policy and Procedures Manual as a guide for the format for the notes, or discuss formats with other investigators.

2. Evaluate the information obtained.

- Evaluate the comprehensiveness of the information obtained.

- Evaluate the validity of the information obtained. Compare the event information obtained from the witness with that obtained from other sources. Compare the influence of contributing factors obtained from the witness with that based on human factors research.

- Think of any other questions you would like to have asked.

3. Evaluate the quality of the interview.

- Obtain feedback from another interviewer, or review the tape recording.

- Consider what you did well, what you could have done better, what areas can you develop, and how can you acquire these skills.

4. Contact the witness again.

- A few days after the interview, contact the witness to see if they have remembered any other details. Ask any new questions which have come to mind. A telephone interview is often sufficient for this follow-up.

INVESTIGATIVE INTERVIEWING CHECKLIST

Date: **Time:**
Incident / Accident:

Step	OK?	Comments
A. Preparation		
1. Background information. 2. Aims 3. Location 4. Time. 5. Who. 6. Plan. 7. Materials / equipment.		
B. Introduction	OK?	Comments
1. Positive greeting. 2. Develop rapport. 3. Explain interview. 4. State expectations. 5. Assess witness. 6. Special needs.		
C. General Account	OK?	Comments
1. Recreate context. 2. Request description. 3. Active listening. 4. Control witness behaviour. 5. Identify items.		
D. Detailed Account.	OK?	Comments
1. Recreate context. 2. Request description 3. Probe item. a. Question ordering. b. Question format. c. Speech style. d. Witness limitations. e. Special techniques. 4. Decision probes (PW only). 5. Active listening. 6. Control witness behaviour. 7. Summarise. 8. Link.		

E. Background Issues	OK?	Comments
1. Situational factors. 2. 72 hours. 3. Medical / physiological factors. 4. Operational experience. 5. Organisational issues.		

F. Review.	OK?	Comments
1. All items covered. 2. Conduct overall review. 3. Clarify discrepancies. 4. Obtain personal information. 5. Finalise interview.		

G. Evaluation / Follow-up.	OK?	Comments
1. Write notes. 2. Evaluate information. 3. Evaluate interview. 4. Contact witness again.		

General comments:

Witness details:

Interviewers:

Others present:

Notes / recording details:

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Fatigue Management in the New Millennium

Drew Dawson

It is our opinion that the major causes of fatigue are loss of sleep due to changing economic and social patterns over the last few decades. In general, many workers are now required to work longer, more flexible hours at reduced staffing levels. This, in conjunction with increasing task demands and social pressures have resulted in significant reductions in the quality and duration of sleep.

The effects of increased levels of fatigue on human performance and the community are profound. Research by our group and others has demonstrated that fatigue-related impairment is not dissimilar to the effects of moderate alcohol intoxication. In humans, fatigue delays response and reaction times, negatively impacts on logical reasoning and decision making and impairs hand-eye co-ordination – all critical safety issues in the transport industry. A significant body of research has concluded that fatigue is rapidly emerging as one of the greatest single safety issue now facing the community.
Like alcohol intoxication, fatigue-related impairment is a major source of accidents and injuries and represents a significant social cost to the community. Recent estimates suggest that fatigue-related accidents and injuries, lost production and indirect subsidies cost the Australian community over 1 billion dollars annually.

The lessons learned from industry-based collaborations suggest that responsible management requires fatigue to be 'risk-managed' as an Occupational Health and Safety issue rather than as an industrial issue. Moreover, fatigue management should be viewed as a shared responsibility. Employers have a 'duty-of-care' to provide work schedules that are consistent with a safe system of work. That is, to permit an adequate amount of time for an employee to sleep, rest and recover as well as fulfil their social and domestic responsibilities between subsequent shifts. Conversely, employees have a 'duty-of-care' to use their time away from work in a safe and responsible manner. That is, to ensure that they obtain sufficient sleep and recovery in order to complete their subsequent work duties in a safe and responsible manner.

In this paper, a series of recommendations has been outlined. These create a policy framework through which the Government, employers and employees and the community could rationally determine the economic, social and environmental cost benefit associated with workplace fatigue.

1. Causes of, and contributing factors to, fatigue

Significant industrial and cultural changes have occurred within many industries in recent years. These changes include, but are not limited to:

- Pressure to enhance capital utilisation
- Heightened competition within and between companies
- Increasing financial expectations of employees
- Management pressure to decrease employee numbers
- *Perceived value* of long hours of work and flexibility by employers

One of the main outcomes of these changes is that workers now work longer, more flexible hours, which often includes more shiftwork. There is little doubt that the productivity benefits that can flow from flexible rosters systems are desirable. Nevertheless, it is likely that employers and employees with little knowledge of the financial, biological and psycho-social impacts of shiftwork and fatigue could negotiate work systems that significantly compromise potential benefits.

Determining all of the factors that cause, and contribute to, fatigue has proved difficult. Furthermore, determining the relative importance for all of these factors under different conditions has been problematic. In part, this is because few shift systems have been evaluated either 'post-implementation' or in the laboratory. Furthermore, the results from one roster assessment cannot necessarily be generalised to other rosters.
At the most basic level, fatigue can be viewed as the consequence of inadequate restorative sleep. There are many factors that reduce sleep opportunity including:

- Longer hours: not surprisingly, when people work for more than 40 hours per week there is increasing competition between sleep and other activities of daily living.

- Night work: as the amount of night work increases, so does the amount of sleep that must be attempted at biologically inappropriate times. Sleeping 'out of synch' with the body's biological clock results in reduced duration and quality of sleep. This in turn reduces the restorative value of sleep obtained.

- Changing psycho-social expectations: For example, the increasing number of two income families means that both partners have less time available for family and social commitments. This can lead to a 'social debt' that can compete with the need for sleep.

Thus, the sleep deprivation and fatigue experienced by an individual may be largely dependent on the interaction between the roster and the individual worker's social and domestic circumstances. Many 'deregulated' work schedules, particularly those that incorporate long blocks of night work, significantly reduce the opportunity for sleep and recovery between shifts. The research data indicates that shift workers obtain significantly less sleep than those who are not shift workers. Moreover, the quality of that sleep is also significantly reduced. Sleep loss during night work is typically 1-3 hours per day. Furthermore, sleep deprivation can accumulate across a block of shifts, which leads to higher fatigue.

In addition to work-related causes of fatigue, non-work-related factors can also contribute to fatigue. Non-work factors such as sleep disorders, individual differences in coping strategies and psycho-social needs such as domestic duties can cause additional fatigue. As with work-related fatigue, non work-related causes of fatigue contribute to overall fatigue by a reduction in the opportunity for sleep and recovery. For example, the same roster could have quite different effects according to social circumstance. For example, a 12 hour night shift might have very different consequences for an 18 year-old single male living on his own compared to a 35 year old single mother of two toddlers without access to 24h child care facilities.

Taken together, both employers and employees have clear responsibilities with respect to managing fatigue. The basic responsibilities of both parties relate to ensuring that adequate sleep can be obtained between shifts so that fatigue does not reach dangerous levels during shifts. Thus, lack of sleep causes fatigue and sleep allows recovery from fatigue.

The most critical acknowledgment to make with respect to sleep and recovery is time of day. The quantity and quality of sleep that can be obtained in a break period of particular duration is significantly dependent on the time of day it occurs. For example, a 12-hour break from 0000h to 1200h may allow for a sleep of 7-8h duration, however, a break from 1200h to 0000h may only allow for 5-6h. To a large degree, this occurs because humans are programmed to sleep at night but is exacerbated by the fact that there are more needs competing with sleep during the day. Furthermore, a shift during the nighttime hours is more fatiguing that a shift performed during the day.

2. Consequences of fatigue

As discussed above, fatigue results from not obtaining adequate quality and quantity of sleep, which can be contributed to by work and non-work factors. With respect to work-related factors, the most significant contributor is an increase in the number of hours that employees work and in particular the number of night time hours that employees work.

In general, consequences of fatigue can affect:

- Individuals
- Organisations
- Communities

Specific consequences can be categorised as being either:

- Biological
- Psychological
- Social

Individual

The effects of acute sleep loss on individual performance are profound and affect a variety of areas including:

- Biological: Cognitive performance impairment leading to decreased ability to process information and make timely, appropriate decisions and actions.

- Psychological: Alertness impairment leading to decreased ability to remain awake. Clearly, such impairment can lead to increased likelihood of accidents and injuries.

- Social: Mood changes such as increased irritability, decreased motivation and morale.

Research by the Centre for Sleep Research at the University of SA has clearly demonstrated that fatigue-related impairment is not dissimilar to the effects of moderate alcohol intoxication. That is, significantly delayed response and reaction times, impaired reasoning, reduced vigilance impaired hand-eye co-ordination.

This research indicated that at 0100-0300 on the first night of a night shift [after 18-20 hours of wakefulness] fatigue-related impairment on a hand-eye co-ordination task is equivalent to a blood alcohol concentration equivalent (BAC) of 0.05%. Furthermore, at 0700 [after 23 hours of wakefulness], impairment was equivalent to a BAC impairment of 0.10% - twice the legally prescribed limit.

ORGANISATIONAL

These consequences clearly impact on many factors related to an individual's effectiveness within the workplace. For example, there is no doubt that increases in fatigue lead to higher utilisation of sick leave. Furthermore, observed decreases in morale, concentration and communication often relate to decreased productivity and increased accident rates. Consequences such as increased accident rates clearly have community repercussions.

COMMUNITY

Consequences at a community level include an increase in the use of medical facilities, a decrease in general community participation as well as increases in counselling and childcare requirements.

Below is a table that illustrates these relationships and gives examples for each interaction.

NON-TRADITIONAL CONSEQUENCES: IMPLICATIONS FOR NATIONAL COMPETITION POLICY

The effects of fatigue can be categorised on several levels. The more traditional categorisation, that is individual, organisational and community effects are documented above. We also believe there are important non-traditional consequences that are worth noting. For example, we believe that differences in prescriptive hours legislation between transport modalities leads to significant anti-competitive outcomes. This argument is based on the idea of indirect subsidy to certain transport modalities relative to others based on the hidden social costs attributable to fatigue.

Recent research in the USA, Europe and Australia suggests that somewhere between 20-30% of all heavy vehicle accidents can be directly or indirectly attributed to fatigue-related impairment of the driver. Based on proportional gross domestic product (GDP) estimates in the US, fatigue-related accidents in the road transport sector probably cost the Australian taxpayer several hundred million dollars annually. For the road transport sector, it could be argued that the incidence and costs directly attributable to fatigue-related accidents constitute an indirect subsidy to the industry as the costs are typically borne by the tax payer.

If we view the hours of work permitted in the road transport sector relative to those permitted in rail or aviation it is clear that drivers in road transport are able to work much longer hours than is possible in these modalities. As a consequence, it is likely that the incidence of fatigue-related accidents is higher for road compared to other modalities. If this is the case, it is also likely that the aggregate social costs attributable to fatigue are higher for road transport relative to other modalities. Where these costs are not borne by the road transport sector, they constitute an indirect subsidy to the sector and, strictly speaking, could be viewed as anti-competitive under Hilmer legislation.

3. Regulatory perspectives

STRATEGIES TO INCREASE REGULATORY RESPONSIBILITY

It is our view that the major problem facing regulators are:

- Prescriptive hours legislation is inadequate as a means of controlling fatigue. Regulations that only address the length of shifts and breaks and which do not take into account 'time-of-day' factors cannot provide an adequate framework for managing fatigue.

- Employers and employees are bound under OH&S legislation to provide a demonstrably 'safe system of work'. However, it is currently possible to construct shift patterns that comply with prescriptive hours legislation but are clearly 'unsafe' with respect to 'duty of care' requirements under the act. Equally, it is possible to construct shifts that comply with OH&S requirements for a safe system of work but are precluded under prescriptive hours legislation.

The resulting conflict between prescriptive hours legislation and OH&S legislation is difficult to resolve. The current system is industrially inflexible and does not manage fatigue in a rational manner.

From a practical perspective, it is preferable that any legislative changes associated with fatigue management do not necessitate the creation of new legislation or bureaucratic structures. This could be unnecessarily complicated and expensive and divert resources away from the effective development of fatigue counter-measures that would reduce the unnecessary social costs associated with fatigue.

To increase industrial flexibility and increase employer and employee responsibility for fatigue management we would recommend that prescriptive hours legislation should be eliminated and fatigue should be specifically defined and managed as an 'identifiable workplace hazard' and controlled under existing state and federal OH&S legislation. This would eliminate the current reliance on ineffective legislation and overlapping regulatory and reporting mechanisms.

This strategy would provide the following benefits:

- There is a pre-existing regulatory infrastructure for the development and delivery of policy guidelines and standards for managing fatigue.

- The use of OH&S legislation would be administratively simple. Procedures and mechanisms for identifying, auditing, managing and minimising fatigue are already in place.

- Most organisations have a pre-existing OH&S framework that could easily embrace fatigue management as an additional 'identifiable work place hazard'.

In addition to defining fatigue as an OH&S issue it is critical that fatigue should be managed in the context of a generalised risk management model. Fatigue should not be viewed independent of the task or activity undertaken. In simple terms, the maximum acceptable level of fatigue should be linked to the inherent risk of the activity. For example, it is clearly reasonable to accept a higher level of fatigue for less risky activities and vice-versa. Good risk management practice would suggest that a lower maximum fatigue level would be desirable for landing a jumbo jet or piloting a large ship in a difficult navigational channel than for operating a photocopier.
From this perspective, OH&S regulators could draw up codes of practice in which the maximum acceptable fatigue level is linked to industry-based risk assessments.

STRATEGIES TO INCREASE COMMUNITY RESPONSIBILITY

At present there is limited community awareness of the social costs associated with fatigue-related impairment. As such, fatigue-related social costs have accrued either directly or indirectly for many years. There are several reasons for this:

- The central role of industrial relations in the development of hours-of-work legislation.

- The lack of systematic methods for determining the incidence, severity and social cost of fatigue-related performance-impairment, accidents and injuries.

- Technological limitations in our ability to quantify and measure fatigue.

- The limited expenditure on fatigue-related research projects relative to current estimates of the social cost attributable to fatigue.

If fatigue is to be managed rationally it is critical that the community costs of fatigue-related problems are quantified and any expenditure viewed as an investment in the reduction of the social costs attributable to fatigue.

We believe fatigue should be managed in a similar manner to the way the Government approached alcohol related accidents and injuries in the workplace in the 80's and 90's. That is, the community perception of fatigue-related impairment should be considered morally and legally unacceptable to have an impaired worker operating in the workplace. It should be irrelevant whether the impairment is due to drugs, alcohol or fatigue. This change of perspective could be best achieved with a federally funded national program to address the issue of fatigue management across all transport modalities. This might be best achieved through a collaborative project involving the Department of Transport and WorkSafe Australia and an appropriately constituted scientific reference group.

The project should consist of:

- An initial study to determine the best way of monitoring the social costs associated with fatigue. This study should determine what information and reporting mechanisms currently exist and what mechanisms need to be implemented in order to determine the social costs associated with fatigue.

- A research project to estimate the current and future social costs associated with fatigue in the transport sector. This could be used to determine an appropriate longer term budget to reduce the unnecessary social costs attributable to fatigue.

- A policy development program . This program should also ensure that fatigue policy is not anti-competitive with respect to different transport modalities.

- A research program quantifying the empirical relationship between fatigue, performance impairment, risk and social cost.

- An educational program to increase community and organisational awareness of the problem and ways to reduce the social costs.

- A fatigue countermeasures program to encourage initiatives that have potential to reduce the social costs attributable to fatigue.

Aviation Medicine

Third Edition

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(FRCs) for the specific aircraft. Broadly the principles are to prevent the toxic fumes from coming into contact with the respiratory tract and eyes and then to attempt to solve the problem.

Although the aircrew of military combat aircraft wear oxygen masks throughout the duration of the sortie, toxic fumes will enter the respiratory tract via the airmix orifice of the oxygen regulator (except in aircraft fitted with molecular sieve oxygen concentrating systems (MSOCS)). Management of the incident involves closing the orifice by switching to 100% oxygen. In older aircraft types aircrew were also required to select 'emergency' on the regulator which would then provide safety pressure, preventing the ingress of fumes around any poorly fitted mask. The selection of 100% oxygen on regulators in more modern military combat aircraft generally results in the switching-in of a secondary, or standby, regulator which provides 100% oxygen and safety pressure automatically. If the toxic fumes are irritating to the eyes, aircrew will generally shut down the cabin conditioning system, depressurize the cabin to 'dump' the fumes out of the aircraft, and select ram air to allow fresh air to enter the cockpit. If the incident occurs at high altitude this action necessitates a descent to prevent any risk of decompression sickness or hypoxia. A return to base, or landing at the nearest suitable airfield usually ensues. The diagnosis of the cause of the fumes is often very difficult during the sortie and is usually addressed following landing, but occasionally aircrew may identify the offending system and shut it down. As a last resort, if the severity of the incident is such that the pilot's ability to fly the aircraft is seriously impaired and deteriorating, jettisoning the cockpit canopy becomes an option.

Inflight management in transport aircraft

In transport aircraft, where aircrew do not wear oxygen masks routinely, the protection of the respiratory tract from toxic fumes is effected by the donning of a 100% oxygen mask which, in some systems, is integral with a faceplate that seals around the face and provides protection to the eyes. Alternatively, protection of the eyes can be achieved using goggles. Management of a toxic fumes incident is similar to that described above although this will obviously be influenced by the carriage of passengers who are generally provided with 'drop-down' continuous flow rebreathing reservoir masks which provide a degree of protection from hypoxia but no protection from toxic fumes. As a general rule, the identification of the source of the problem is easier in these types of aircraft because of the greater number and improved mobility of the aircrew. If the source of the fumes is associated with the cabin pressurization system, this will be shut down and the aircraft will be descended below 10 000 feet (3048 m). Commercial airliners generally have duplicated systems that allow malfunctioning units to be shut down without depressurization of the cabin.

Medical management

A toxic fumes incident inflight, no matter how insignificant, must always be investigated by both the relevant engineering and medical authorities. All steps must be taken to attempt to identify the source of the fumes so that steps may be taken to prevent recurrence, and to ensure that no component or wiring has been damaged, failure of which could have more serious consequences in any future flights. Aircrew must be interviewed, and queried on the severity of the incident and any symptoms that were experienced. Aircrew should be examined in all but the most trivial incidents, and always if any symptoms persist. Blood should be taken with the informed consent of the aircrew for a full toxicological screening as soon as possible after landing, although the value of such action is doubtful since it extremely rare for these investigations to yield any significant findings. At present, lack of sensitivity in the analytical procedures hampers the detection of some toxic substances. The introduction of 'purge and trap' technology in conjunction with gas chromatography and mass spectrometry will lower detection thresholds significantly and widen the scope in terms of compound detection. Carbon monoxide poisoning, in the absence of fire, is very rare with modern gas turbine and jet engines, but if suspected must be treated promptly with 100% oxygen. Aircrew experiencing breathing difficulties must be referred to hospital immediately and in the case of carbon monoxide poisoning the possibility of hyperbaric therapy should be considered.

Post-accident hazards

Aircraft possess a high fire risk post-crash due to the large volumes of fuel and other combustible fluids such as hydraulic and engine oils that are carried. The ignition of spilled fuel is the cause of fires in many impact-survivable accidents. This is particularly serious because fires outside the aircraft are able to burn through the fuselage skin within 40–60 seconds (Horeff, 1982). Fire may also gain entry into the cabin through breaks in the fuselage and through melted windows. Toxic smoke can enter the cabin from the external fire, but the interior cabin materials and furnishings will generate toxic smoke as they too become hot enough to burn. As the fire gains hold in the cabin the temperature rises, the air fills with smoke and toxic gases are produced. Pyrolysis of typical cabin furnishings have been shown to produce, carbon monoxide, hydrogen cyanide, hydrogen chloride, hydrogen fluoride, sulphur dioxide, nitric oxide, nitrogen dioxide, ammonia, chlorine and phosgene (Madgwick, 1982). These gases are mainly inorganic and will be accompanied by a range of organic gases and vapours, depending upon the materials combusted and the temperatures reached. As the fire progresses the oxygen level in the cabin decreases and the level of carbon dioxide increases. Hot flammable gas tends to collect at the cabin ceiling and ultimately combusts producing a flashover. The temperature rises still further and other combustion products are formed (*Table 42.3*), so the survivability in the post-flashover environment is likely to be quite limited.

Fire atmospheres have two main toxic mechanisms, narcosis and irritation (Purser, 1989). Narcotic gases bring about loss of consciousness and death if the victim is not removed from the fire. The main gases responsible for this are carbon monoxide and hydrogen cyanide. Carbon dioxide at levels up to 5% stimulates breathing, leading to an increased uptake of other toxic gases. At concentrations above 5% carbon dioxide exerts a narcotic effect. The hypoxic effects caused by carbon monoxide and hydrogen cyanide are exacerbated by the consumption of oxygen in the fire. At atmospheric levels of oxygen below 10% narcosis occurs. Irritant fire products, which are represented by the inorganic acid gases and aldehydes such as acrolein, affect the eyes, nose, throat and lungs causing pain and discomfort. At high concentrations irreversible damage to the respiratory system can occur, leading eventually to death. The irritant effects on the eyes compound the visual impairment caused by the smoke particles, disorientating the victim and impeding the ability to reach available escape exits. It is estimated (Purser, 1989) that an otherwise healthy adult would be unlikely to escape from a severe aircraft cabin fire after two to 2.5 minutes. Crawling along at floor level where the air quality is slightly better could add a further 0.5 minute to this escape time.

Table 42.3 Combustion and pyrolysis products with source materials

Toxic gas or vapour	Source material
Carbon dioxide	All combustible materials containing carbon
Carbon monoxide	
Nitrogen oxides	Celluloid, polyurethanes
Hydrogen cyanide	Wool, silk, plastics containing nitrogen
Formic acid	Cellulose materials, cellulosic plastics, rayon
Aerolein	Wool, paper, oils
Sulphur dioxide	Rubber, thiokols
Halogen acids	Polyvinyl chloride, fire retardant plastics, fluoridated plastics
Ammonia	Melamine, nylon, ureaformaldehyde resins
Aldehydes	Phenol-formaldehydes, wood, nylon, polyester resins
Benzene	Polystyrene
Phenol	Phenol-formaldehyde
Azo-bis-succinonitrile	Plastic foam material

To illustrate an impact survivable post-crash fire it is useful to consider the toxicological examination of the 54 people killed in the British Air Tours Boeing 737–200 accident at Manchester in 1985 (Mayes, 1991). In this accident an engine exploded on take-off and ruptured the fuel tank in the port wing, the aircraft was stopped without leaving the ground. Of the 131 passengers and six crew, 52 passengers and two crew died in the aircraft. One passenger was found alive in the wreckage but died in hospital. The rear exits and the port overwing exit were not available for escape due to the proximity of the fire. Fire penetrated the cabin within 30 seconds of the explosion and the cabin was soon filled with smoke. Due to the reduction of the escape exits by 50% the time taken to escape was lengthened fatally for those seated towards the rear of the aircraft. Most of those who survived escaped within two minutes. Analysis of the blood of the victims was performed for carbon monoxide, cyanide and volatiles. It was found that 53 victims had carbon monoxide levels that can be considered to be raised, of these 27 had levels above that considered to be incapacitating (30% COHb). All victims had levels of cyanide in the blood that were elevated. Of these, 43 victims had levels above that considered to be incapacitating (1.35 mg/l). The volatile screen showed the presence of benzene in the blood of all the victims and toluene in the blood of 47 of the victims. It was concluded that six victims had less than the levels thought incapacitating for carbon monoxide and cyanide and that 48 victims had fatal or incapacitating levels of carbon monoxide and hydrogen cyanide. All victims had soot in the airway and so had been alive for some time in the fire atmosphere. The six victims with less carbon monoxide and hydrogen cyanide in the blood presumably survived for shorter times. It is clear in this accident that most, if not all, of those killed were unable to escape because of the rapid production of a toxic fire atmosphere in the aircraft cabin.

Carbon monoxide

Carbon monoxide is a toxic gas produced by the incomplete oxidation of carbon compounds. An atmosphere containing 5000 ppm (0.5%) is considered to cause rapid collapse, unconsciousness and death within a few minutes. Carbon monoxide is bound some 200 times more strongly to haemoglobin than is oxy-

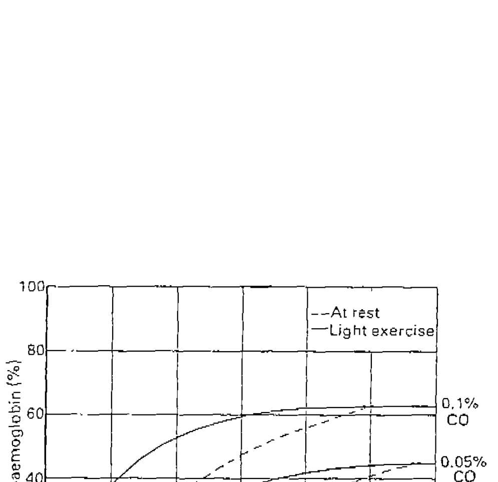

Figure 42.2 The time courses of the concentrations of carboxyhaemoglobin in the mixed venous blood on exposure to breathing carbon monoxide at inspired concentrations of 0.01%, 0.05% and 0.1% in air, at rest (dashed lines) and during light exercise (solid lines).

gen. Thus over a period of time (*Figure 42.2*), breathing an atmosphere containing carbon monoxide will increase the proportion of haemoglobin bound to carbon monoxide thus reducing the capacity of the blood to transport oxygen to the tissues (*Figure 42.3*). The situation is exacerbated because the affinity of haemoglobin for oxygen is increased in the presence of bound carbon monoxide thus impairing the release of oxygen to the tissues. Furthermore the possibility of a secondary intracellular toxic mechanism due to the binding of carbon monoxide to the haem proteins must be considered (Piantadosi, 1987).

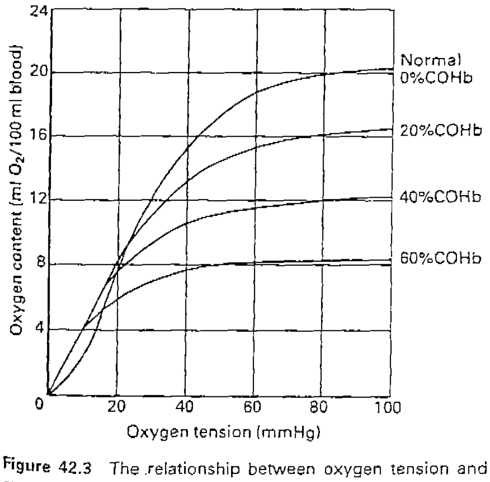

Figure 42.3 The relationship between oxygen tension and oxygen content of blood with a haemoglobin concentration of 15 g/100 ml containing, respectively, 20%, 40%, and 60% carboxyhaemoglobin.

Interpretation and analysis

Carbon monoxide is present in fire atmospheres and in the exhaust gas of piston engines, it is present to a much lower extent in gas-turbine exhausts (*Table 42.4*). The levels found in the blood of non-smokers range between 0–3% saturation. A low level of less than 1% saturation is normally present in blood as the result of haem catabolism, higher levels are presumably due to the inhalation of carbon monoxide from the urban environment. Those who smoke are likely to have a level of 3–10% of carboxyhaemoglobin. Levels above 10% saturation for individuals are attributed to inhalation of carbon monoxide from fire gases, vehicle exhaust fumes, or poorly maintained heating appliances. Raised carboxyhaemoglobin can occur in an occupational context by the inhalation of methylene chloride in paint stripper, since this is metabolized to carbon monoxide. Carbon monoxide is excreted almost entirely through the lungs, the half life being four to five hours. This time is considerably reduced by the use of oxygen and still further by the use of hyperbaric oxygen. The fatal threshold in fire deaths is taken to be 50% saturation. Carbon monoxide uptake depends upon the concentration of the gas in the atmosphere, this time of exposure and the degree of physical activity (respiratory minute volume). During early stages of intoxication (15–20% saturation) symptoms are of headache and nausea, and performance tests show a minor deficit. When significant effects do occur their onset is sudden and rapid, active subjects being seriously incapacitated at 25–35% saturation (*Table 42.5*).

Blood should be taken for analysis at post-mortem from peripheral veins if possible to avoid contamination by micro organisms from the gut. It should be preserved with anticoagulant in an EDTA or Heparin container. There should be a minimum surface area and volume above the blood to minimize any loss of carbon monoxide by exchange with oxygen in the headspace above the blood. In the post-mortem situation blood should always be treated with sodium dithionite before analysis to reduce any methaemoglobin present, since the presence of methaemoglobin can cause errors in both spectrophotometric and gas chromatographic methods of carbon monoxide analysis (Mayes, 1993). Blood taken from the living should

Table 42.4 Composition of engine exhausts

Component	Concentration (% wt/wt) Reciprocating	Gas turbine
Carbon dioxide	10–15	5.0
Carbon monoxide	3–9	0.003
Total aldehydes	–	0.01
Acetylene	0.37	–
Oxygen, nitrogen, water (approx.)	80	95

Table 42.5 Symptoms induced by various blood concentrations of carbon monoxide (at sea level with a normal haemoglobin level)

Saturation of haemoglobin with carbon monoxide (%)	Symptoms
Less than 10	None
10	No appreciable effects other than mild headache and slight dyspnoea on vigorous exertion
20	Slight headache, fatigue and dyspnoea even on mild exertion
30	Headache, increasing fatigue, impaired judgement and gross dyspnoea and impairment of vision on exercise
40–50	Severe throbbing headache, confusion, fainting and collapse even at rest
60–70	Unconsciousness

also be taken into anticoagulant. In either case it is wise to analyse the blood as quickly as possible. The Differential Spectrophotometric Method is most convenient, but in badly putrefied or contaminated blood Gas Chromatography may be the only reliable method.

Hydrogen cyanide

Hydrogen cyanide is a toxic gas produced in fairly high temperature fires (Fardell *et al.*, 1987) by the combustion of organic compounds containing nitrogen. Data (Kimmerle, 1974) indicates 45–54 ppm is tolerated without difficulty, 100 ppm is fatal after one hour, 135 ppm is fatal after 30 minutes, 181 ppm is fatal after 10 minutes and 280 is immediately fatal. Thus a modest increase in hydrogen cyanide in a fire atmosphere from about 180 to 280 ppm may cause a reduction in time to loss of consciousness from 10 minutes to immediate collapse. The toxic mechanism is well established, in that cellular respiration in the mitochondrion is interrupted by the inhibition of cytochrome C oxidase and involves an interaction with cytochrome a_3 (Ballantyne, 1987). Low levels of cyanide are found in the blood normally due to metabolic processes and eating cyanogenic food. The cyanide is found associated with the red cell and ranges between 0–0.22 mg/l with a mean of 0.08 mg/l (Anderson and Harland, 1982). Higher levels are found in smokers, up to 0.52 mg/l with a mean of 0.18 mg/l. In deaths associated with fires the fatal threshold has been taken to be 2.70 mg/l, with incapacitation occurring at levels of 1.35 mg/l.

Analysis of blood for cyanide presents more difficulties because it is labile and can be lost quite quickly from blood when the pH becomes acidic. Conversely cyanide, can be produced in very high levels, albeit rarely, by micro organisms. These changes can be prevented in the blood sample by taking blood from a vein in a limb to minimize contamination by micro organisms from the gut, and by preserving the blood with 1% sodium fluoride to inhibit the growth of micro organisms. The initial separation of cyanide from the blood should be carried out as soon as possible. This is achieved by acidifying the blood and trapping the hydrogen cyanide evolved in alkaline solution. The solution can be analysed by colorimetric methods or by Gas Chromatography (Mayes, 1993).

Smokehoods

Since the major disaster at Manchester airport in 1985 (*Figure 42.4*), and several other accidents where many people lost their lives due to smoke inhalation, often whilst the aircraft was on the ground, the appropriate

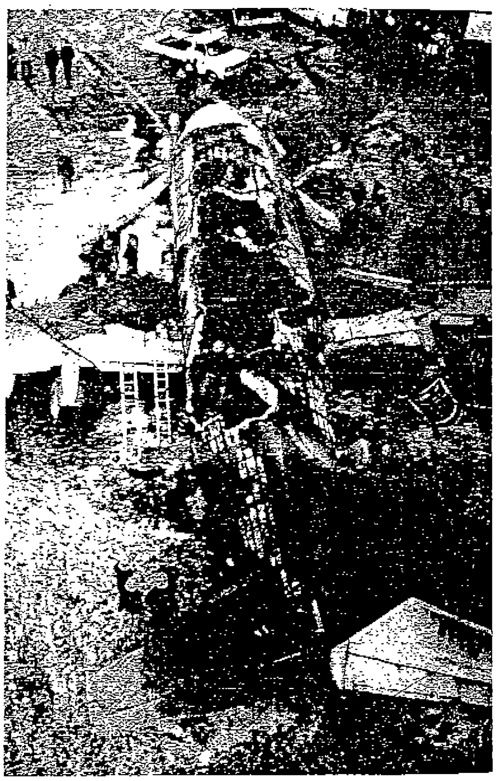

Figure 42.4 Photograph showing the burned out wreckage of the British Air Tours Boeing 737–200 after the fire at Manchester airport in 1985.

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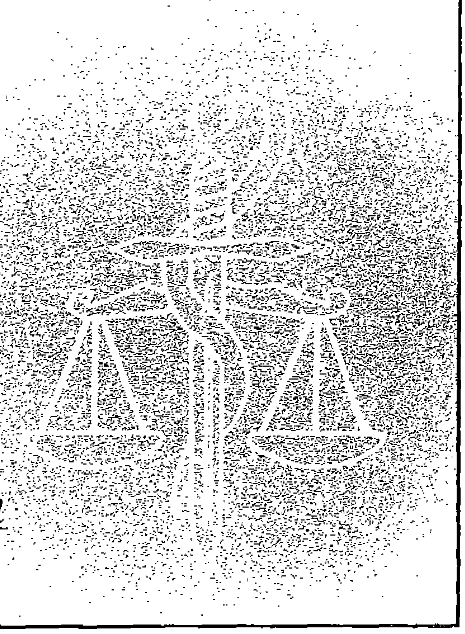

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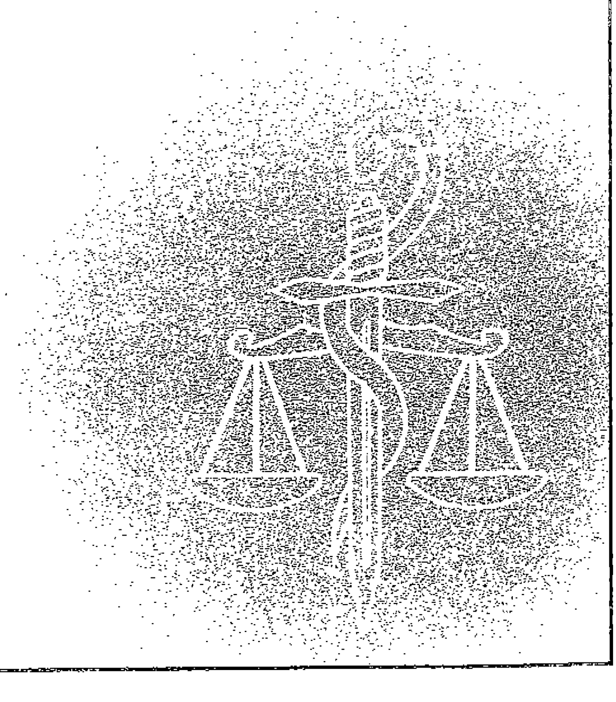

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concentration in the air in the lungs will balance that in the pulmonary circulation.

Elimination

Only a small percentage of the ethanol consumed is eliminated unchanged from the human body. Not more than 10 per cent is excreted unchanged in the urine, sweat, saliva and expired air. In the process of its elimination ethanol will normally release about seven kcal (30 kJ) of energy per gram. The central and major mechanism of oxidation of alcohol in the body is its reaction in the liver with the cytoplasmic enzyme, alcohol dehydrogenase, with nicotinamide adenine dehydrogenase (NAD) as the cofactor. This reaction leads to the formation of acetaldehyde and to the reduction of NAD to NADH. Two other enzyme systems—namely, catalase together with hydrogen peroxide, and the 'microsomal ethanol oxidizing system'—may be involved to a lesser extent in the oxidation of alcohol in the human body.[68,69] Disease of the liver or pancreas may modify the rate of oxidation and removal of alcohol from the body. Under 'normal' drinking conditions the rate of elimination of alcohol from the circulation varies considerably between individuals, and even in the same individual, under what appear to be virtually the same conditions of drinking.[69–71]

Blood Alcohol Curves

The processes of absorption and elimination of alcohol from the human body may be graphically shown by plotting the resultant concentration of alcohol in the blood at given times against the time elapsed since commencing drinking. Such blood alcohol curves characteristically contain three sections:

- *An Absorption Phase.* Here the concentration of alcohol within the stomach or duodenum is greater than that in the surrounding blood supply. In this phase alcohol will diffuse through the stomach and duodenal walls and contribute to increasing concentrations of alcohol in the bloodstream and tissues.
- *A 'Peak' of Absorption.* Providing more and more alcohol is not imbibed, a time will be reached at which the rate of absorption and elimination are in balance. This point on the curve is called the 'peak of absorption'.
- *An Elimination Phase.* For some time absorption will predominate over elimination. When these balance—that is, once the peak BAC has been reached—the elimination phase is said to commence.

Peak of Absorption

The interval of time at which the peak BAC may occur after first drinking alcohol may vary considerably, even in the same person and when the conditions of drinking and the amount of alcohol imbibed seem to be virtually the same. The various factors which may contribute to this variability are:

- The presence or absence of food in the stomach.[66,67]
- The loading dose and rate of drinking.[70]
- The nature and strength of the beverage consumed.[72,73]
- The height, weight and physical build of the drinker, including the total body water content.
- The presence or otherwise of any residual alcohol in the circulation from previous drinking.
- Various biological factors which may modify the diffusion of alcohol into the bloodstream. For example, the presence of irritants, as high concentrations of alcohol, may stimulate lining cells of the stomach and so increase the rate of secretion of gastric juices or retard the opening of the pylorus.
- The emotional state of the drinker.
- The posture of the individual.

It is obvious that the majority of the above factors may vary from individual to individual and from day to day in the same individual. As a very rough generalization, when five 'standard' drinks are imbibed in one hour by a 'normally' sized person, and as further alcohol is consumed, the 'peak' concentration will be reached within about 10–15 minutes after the last drink. There is no known way to estimate the rate of absorption from the stomach and duodenum, largely because there are so many situational factors that may affect it. It is therefore virtually impossible to estimate the peak BAC, and the BAC during and shortly after drinking. It is possible, however, to calculate the blood alcohol concentration during the elimination phase with reasonable accuracy. The various empirical studies of resulting BACs following particular drinking patterns give some idea of the range of concentrations that might be expected under such conditions, but generalization from such findings to different situations and different drinking patterns is not scientifically justified.[69-75]

Accuracy of BACs

There is no such thing as a 'true' blood alcohol concentration for a person. Immediately after first drinking alcohol the concentration of alcohol in the arterial blood is greater than that in the venous blood. The magnitude of the differences in BACs throughout the body can be significant when the BAC is rising and the period of time between the last drink and the withdrawal of blood is less than one hour. Under these latter conditions the BAC of venous blood taken from the arm may be as much as 66 mg/100 ml (0.066%) higher than that taken from the opposite ankle. After the 'peak' has been reached the differences tend to level out; and when the period of time between the last drink and the withdrawal of blood exceeds an hour, there is no difference.[73,74]

One criticism of the use of blood tests on the effect of alcohol on a person is that the BAC in a specimen of blood taken from the cubital vein is not an accurate indication of that in the blood about the brain, particularly when the blood specimen is taken in the absorption phase. These criticisms do not apply as strongly to capillary blood, where the alcohol content is very nearly that of arterial blood. Possible differences in the BAC throughout the body are of more than academic interest, and are certainly the cause of some of the apparent disparity between blood and breath analyses where, in effect, pulmonary arterial blood is compared with peripheral venous blood. These differences may also account for some of the apparent failures to correlate the BAC with degree of impairment, as the cerebral BAC may, at times, bear no relationship to the BAC in the superficial veins from which blood is most commonly taken for analysis for alcohol concentration.

'Typical' Blood Alcohol Curves

Figure 23.2 is derived from the results of an Australian study in 1979.[72] The study was designed to determine the shape of 'ethanol tolerance curves' under various conditions of drinking. Specimens of blood for alcohol analysis were taken at five-minute intervals for up to two to three hours and then at ten-minute intervals. The curve shows the mean BACs observed in multiple specimens of blood taken from four male medical students of average weights and heights during the following two separate episodes of drinking:

- 5 × 200 ml of 'normal' beer (i.e. 38 g of ethanol) in one hour on an empty stomach.
- 5 × 200 ml of 'normal' beer (i.e. 38 g of ethanol) in one hour following a meal consisting of steak, chips, salad, bread, butter and a beverage such as tea or coffee.

The mean peak BAC was 65 mg/100 ml (0.065%) in the fasting state. The peak BAC ranged from 55 to 77 mg/100 ml (0.055%–0.077%) and occurred in the range of five to thirty minutes after the last drink. The mean peak BAC was 60 mg/100 ml (0.06%) in the fed state. The peak BAC ranged between 51 and 65 mg/100 ml (0.051%–0.065%) and occurred in the range of five to fifteen minutes after the last drink. The following conclusions were made as a result of this study:

- One gram of ethanol as beverage beer will raise the BAC by *about* 1.8 mg/100 ml in a fasting state.
- Five × 200 mls of beer (38 g of ethanol) in one hour will give a peak BAC of *about* 68 mg/100 ml (0.068% i.e. 15 mmol/L).
- The BAC will decline at an approximate rate of 15 mg/100 ml (0.015%) per hour.
- There is no close correlation between the peak BAC and weight of the individuals over the range of weights tested (69.5 kg to 87.2 kg).
- The effect of food on reducing the peak BAC is not a consistent finding.
- The rate of removal of ethanol from the blood varied from 10 to 20 mg/100 ml/hour.[72]

The peak values reported in this study are very similar to those reported by McCallum and Scroggie in 1959, but are somewhat lower than those reported by Starmer and Teo in 1978.[70,73]

Urine Alcohol Concentrations

Alcohol is not found in the urine until about twenty minutes after it has appeared in the blood. During the absorption phase the alcohol concentration in the urine is lower than that in the blood. After the blood alcohol peak has been reached, the urine alcohol concentration reaches and passes the decreasing alcohol concentration in the blood. The alcohol peak is reached in the urine about twenty minutes after that of the blood alcohol peak. During the elim-

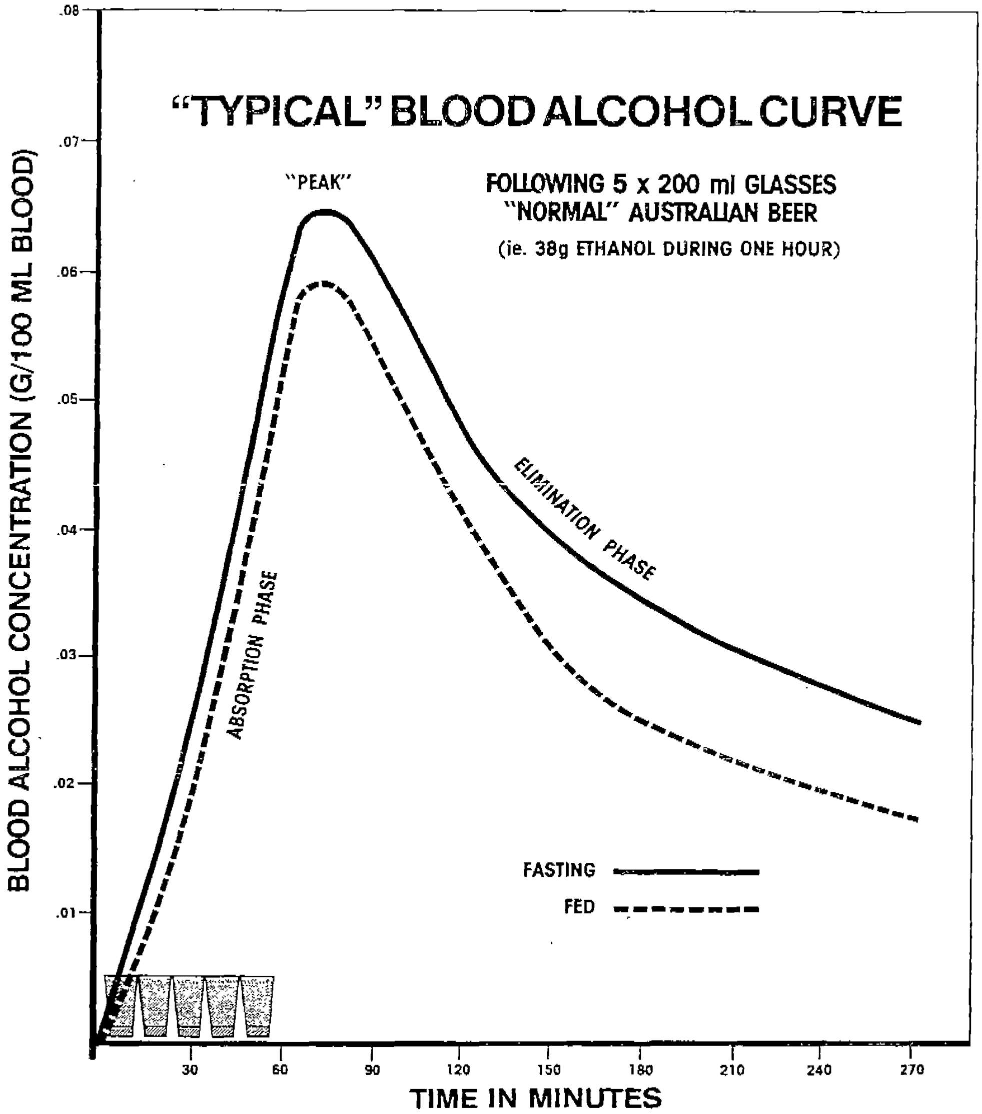


Figure 23.2 'Typical' blood alcohol curve derived from a 1979 Australian study

ination phase, urine and blood concentrations decline at approximately the same rate. The actual urine alcohol concentration is dependent also on the quantity of urine in the urinary bladder and on the time that the urine has been in the bladder.

The urine alcohol concentration was used in many countries until about 1955 for the indirect determination of the presumed concentration of alcohol in the blood. It is now seldom used other than when comparing relative concentrations in fluids and tissues taken from various sites in a putrefying body. The results of such urine analyses are converted to the corresponding BAC on the basis that alcohol is distributed between blood and urine in the ratio 3:4. Evidence shows that a definite alcohol distribution ratio exists between the blood and the urine as it is secreted, and that the concentration in the urine changes in accordance with the changes occurring in the blood at the time. The subsequent storage of urine in the bladder may result in serious discrepancies when the alcohol concentration of voided urine is compared with the BAC.[76-78]

AUTOPSY BLOOD ALCOHOL CONCENTRATIONS

There may be considerable medico-legal importance concerning whether an autopsy BAC is a valid measure of the BAC of the deceased at the time of death. Such BACs are of importance not only in attempting to assess the part played by alcohol as a causative or contributory factor in many deaths, whether these be suicidal, accidental or homicidal, but also in subsequent legal proceedings. Such proceedings may be in a criminal jurisdiction resulting from vehicular or other accidents, or in civil litigation related to increasing numbers of exclusion clauses written into many accident insurance policies. Such clauses are generally worded to the effect that the 'policy does not extend to, or cover death caused wholly or partly, directly or indirectly, whilst the insured is by intoxicating liquor, narcotics or drugs rendered less capable than usual of exercising care'. The expression 'rendered by intoxicating liquor less capable than usual of exercising care' is vague, and the degree of impairment or deterioration necessary to establish this can result in much legal debate in courts of law. Because of this, most insurance companies have now replaced such loose expressions in their policies by specifying a definite BAC above which the company will not undertake the driver's liability. The concentration specified is usually 100 mg/100 ml (0.10%) but may be as low as 50 mg/100 ml (0.05%).

When a victim has died within a short time of accident, and the autopsy is performed within twenty-four hours of death, the autopsy BAC, if taken with proper precautions, will be a valid index of that existing at the time of death. When, however, the patient survives for some hours before death, a low blood alcohol concentration or one that is 'nil' may have no relevance to the level at the time of the accident. The interpretation of an autopsy BAC has to be undertaken with caution and in the knowledge of such variables and factors as the significance of alcohol concentrations in specimens of blood taken from various sites in deceased persons at various intervals of time after death, the stability of such blood specimens during storage, and the effectiveness of various chemical reagents as preservatives in specimens of blood taken at a post-mortem examination[79-83]

The basic information required before a proper assessment of the validity of an autopsy BAC as an index of that at the moment of death is:

- The time after death, and the condition of the body of the deceased when the blood specimen was collected.
- The conditions of storage of the body after death. This includes: (a) the interval of time between death and when the body was placed under refrigeration, and (b) when the body was not refrigerated, then how, where and at what temperature and moisture conditions the body was kept.
- A knowledge of the site from which the specimen was taken and the method of collection of the specimen. It is fundamental and obvious that all blood specimens and other specimens must be collected before any embalming process, and placed in suitably prepared and appropriately sized containers.
- A knowledge of the conditions of storage of the blood specimen from the time it is collected until analysed, including the preservative used, the date and time of analysis, and the temperature at which the blood specimen was stored whilst awaiting analysis.
- A knowledge of the experience of the chemist in this type of analysis and the method used by the analyst of the specimen.

A knowledge of the sites suitable for the collection of autopsy specimens of blood for alcohol analysis becomes particularly important if a body is severely traumatized or incinerated, or is undergoing putrefaction. Undoubtedly the best site and time for taking blood specimens from the dead (and this should be a routine procedure) is from the femoral and axillary vessels before starting an autopsy. Unfortunately there are occasions when blood cannot be collected from such sites. In such circumstances, the vitreous humour of the eye, bile from the gallbladder and the intact chambers of the heart are the most satisfactory alternative sites (see colour Plates 65 and 66).[80,84]

Diffusion of Alcohol

If a person has been drinking alcohol shortly before death, relatively large amounts of alcohol at a high concentration may remain in the stomach at death. Such alcohol may diffuse across the stomach wall into adjacent tissues and fluids. Studies show that significant quantities of alcohol may diffuse into the pericardial sac or pleural cavity, and that, provided simple principles are observed in the collection of blood specimens at autopsy, the BAC in specimens taken from the intact heart chambers may be as significant as those from the femoral vessels.[85]

Preservation of Autopsy Blood Specimens

All blood specimens should be refrigerated at 4–6°C (39–44°F) within two hours of collection. Significant increases in blood ethanol concentrations may occur if autopsy blood specimens do not have an adequate amount of preservative added, and are left at room temperature after collection. One mg NaF/ml blood used as a preservative for blood specimens taken for the estimation of alcohol concentrations in living persons is *not* satisfactory for the preservation of autopsy blood specimens. Satisfactory preservation of autopsy blood specimens at room temperature requires a concentration of 1.0 per cent NaF (10 mg/ml of blood). This concentration of NaF will prevent generation of alcohol in blood specimens kept at room temperature for up to ten days. Should an autopsy blood specimen *not* contain this concentration of preservative, it must be analysed within twenty-four hours of collection or stored below 6°C.[79–81]

Summary

Any analysis for alcohol of a specimen of blood taken after death is only as reliable as the conditions surrounding its collection, and the following precautions must be observed in specimens taken for medico-legal purposes:

- The identity of the specimen must be able to be proved.
- The body and containers for the blood specimens must not be contaminated with 'alcoholic' preparations after death. Such contamination includes that by embalming fluids, which almost invariably contain alcohols.
- Specimens must be collected in properly prepared containers, of suitable size, and containing not less than 10 mg NaF as a preservative for each 1.0 ml of autopsy blood collected. It is desirable also that the blood specimen should almost fill the container, as alcohol may diffuse into the space above the blood in the container if this space is large.
- If the chemical analysis of the specimen cannot be performed within twenty-four hours of collection, it must be stored below 6°C.

ALCOHOL AND THE LAW

All States and Territories have enacted legislation and set up governmental agencies and other organizations in an attempt to deal with the social, legal and other problems related to the dependence of many people on the use of alcohol and other drugs. By far the most common offence associated with the excessive use of alcohol is 'being found drunk and disorderly in a public place'.

Public Drunkenness

The intervention of the criminal law in relation to public drunkenness commenced in 1606 when the English Parliament passed an Act 'for repressing the odious and loathsome sin of drunkenness'. The aim of the legislation was to punish those found drunk and to deter them and others from drinking to excess. In its more modern form, the offence reflects concerns about the offensiveness of public drunkenness and the preservation of public order. Public drunkenness has been decriminalized in New South Wales, South Australia, Western Australia, the Northern Territory and the Australian Capital Territory. In each of these jurisdictions there is still the power to apprehend, detain and search intoxicated persons. This includes the power to use reasonable force. Queensland, Victoria and Western Australia still retain public drunkenness offences although both Western Australia and Victoria are moving towards decriminalizing these offences. The principal objectives of decriminalization are to redress the significant injustice of the stigmatization of alcoholic, homeless people by the criminal justice system concentration exceeds that of the prescribed limit. In Western Australia a driver may request a blood test as an alternative, or in addition, to breath analysis.

- *Hospital Blood Test*. In Queensland, Victoria, South Australia and Western Australia legislative provisions are made for the taking of blood for alcohol analysis from persons admitted to hospital as the result of a road traffic accident.

Provisions are made in all State and Territory Acts as to how the blood specimens are to be taken by medical practitioners, and what uses are to be made of them. All Acts provide for the specimens to be divided into two or more parts, with one part being made available to the person from whom the specimen was taken and the other to the police for analysis for alcohol by an 'approved' analyst. There are also statutory provisions to facilitate the admission of evidence by certificates.

'Relating Back'

Some State Acts provide also for the 'relation back' of the result of the breath analysis or blood test to the time of the driving occurrence which led to the test being made (usually an accident or apprehension). In essence this attempts to determine the BAC at the time of the offence. At its very best, relating back is only a very rough approximation of the actual BAC at that time. Section 48(1)(a) of the *Road Safety Act* 1986 of Victoria prescribes as follows in order to take this 'relating back' out of the realms of quasi-scientific argument:

> 48.(1) For the purposes of this Part—
> (a) if it is established that at any time within 3 hours after an alleged offence against paragraph (a) or (b) of section 49(1), a certain concentration of alcohol was present in the blood of the person charged with the offence it must be presumed, until the contrary is proved, that not less than that concentration of alcohol was present in the person's blood at the time at which the offence is alleged to have been committed.

Section 49(1)(a) and (b) of the Act provides that:

> A person is guilty of an offence if he or she—
> (a) drives a motor vehicle or is in charge of a motor vehicle while under the influence of intoxicating liquor or of any drug to such an extent as to be incapable of having proper control of the motor vehicle; or
> (b) drives a motor vehicle or is in charge of a motor vehicle while more than the prescribed concentration of alcohol is present in his or her blood.

The Tasmanian and Western Australian Acts both have 'relation back' provisions for breath and blood analyses up to four hours after the event. Section 71 of the *Road Traffic Act* 1974 of Western Australia prescribes:

> 71.(1) In any proceeding such as is mentioned in subsection (1) of section 70, the percentage of alcohol present in the blood of a person at any time which is or may be material in the proceeding shall be calculated, having regard to that time, the time of the person's last drink containing alcohol taken at or before the time which is or may be material in the proceedings, and the time at which the sample of the person's breath or blood was provided or taken for analysis, by varying the analysis result referred to in section 68 or section 69 by such amount, if any, necessary to give effect to the presumption that the percentage of alcohol in the blood of a person increases at the rate of 0.016 per centum per hour for a period of two hours after his latest drink containing alcohol and, after that period, decreases at the rate of 0.016 per centum per hour.

Such provisions cannot be scientifically supported in the light of present-day knowledge concerning the absorption and elimination of alcohol in the human body. The back calculated BAC would at its best be bordering on a guess as to the possible BAC at the time of an accident four hours previously.

ROAD ACCIDENTS AND ALCOHOL

Road traffic accidents were responsible for 3078 deaths and more than 100 000 injured people in Australia during 1988. Approximately one in every three of those killed was aged between fifteen and twenty-four. Thirty-seven per cent of those killed in road traffic accidents in 1987 had BACs greater than 50 mg/100 ml (0.05%).[89]

Driving

There is insufficient appreciation of the number, variety, complexity and subtlety of the many cues and sensory stimuli which drivers constantly use and need in order to drive safely on public roads, particularly when faced with a potential accident. Drivers, both consciously and by conditioned reflexes, must compute ahead their course and speed, and at the same time make appropriate allowances for possible variations in the speed and direction of other moving objects in their path, and adjust their speed and course to cope with curves, intersections and various fixed obstructions such as kerbs, poles, trees, road signs and the like. A safe driving situation is never dependent on just one cue or sensory stimulus. The safe driver requires perception, judgement and concentration. His forward planning and decision-making depends on the integrity of his varied physiological functions including visual acuity, binocular vision, hearing, reaction time and co-ordination. Tracking tests show that the normal driver has a time lag of about 0.3 second between receiving a signal and taking the corresponding positive or preventative action. All driving situations are of the multiple stimuli response type. All drivers show definite impairment in their driving ability before any deterioration is evident on the standard clinical tests used for evidence of intoxication.

Depressant Effect

From a medico-legal point of view, the most important physiological effect of alcohol is its depressant effect on the central nervous system. Any apparent stimulant effect is always illusory and is due to a depression of the higher centres of the brain which control our conditioned reflexes. This depression may result in a lowering of the accepted standards of behaviour in some persons, or in increased talkativeness in others, or in 'Dutch courage' in others. Such effects of alcohol were noted by Loomis and West in 1958 during a study of the effects of small quantities of alcohol on the driving ability of ten male drivers. They said:

> When the blood alcohol concentration was in the range of 0.03 to 0.09 per cent, all showed increased talkativeness and release of inhibitions as manifested in the occasional use of profanity by subjects who rarely used it otherwise. About half showed a tendency to become argumentative over minor topics of discussion.[90]

A similar study concerning the effect of low concentrations of alcohol on the ability and behaviour of fifty experienced drivers noted that 'with respect to driving, the effect of alcohol on judgement and personality may be just as important as its effect on motor co-ordination'.[91]

Among other early depressant effects of alcohol are a decrease in the awareness and ability to react to sensory stimuli. One of the first noticeable effects of this on a driver is a reduction in his capacity to deal with a crisis or abnormal situation. Such depression occurs in the great majority of drivers at about a BAC of 30 mg/100 ml (0.03%). Some of the major skills and senses which begin to be adversely affected at such a relatively low BAC are vision, hearing, co-ordination, reaction time, touch, perception and judgement.

Sight, Driving and Alcohol

Even slight impairments to visual acuity in drivers and pedestrians may become a major contributory factor in accidents, especially at dusk, or in rainy or dull weather. Such impairment may commence at a BAC of 20 mg/100 ml (0.02%) and occurs in all those at a BAC of 50 mg/100 ml (0.05%).[92] Drivers also become increasingly less able to deal with the other visual cues required for driving, such as eye movement, accommodation, flicker vision and co-ordination, as their BACs increase above 30 mg/100 ml (0.03%). A study in 1958 showed that as their BACs increased from 30 mg/100 ml (0.03%) to 170 mg/100 ml (0.17%), all ten drivers tested became progressively less able to divide their attention between road and traffic lights, sacrificed one cue for another and progressively lost visual co-ordination and the capacity to deal with the multiple cues necessary for safe driving.[90] At a BAC of 100 mg/100 ml (0.10%), eye movement latency increases by up to 0.1 second, and accommodation by up to 0.4 seconds. The practical result of the latter is an increase of up to 1.0 second to the round trip of eye movement and accommodation when shifting sight from a far to near object. At a speed of 100 kph a driver will travel up to thirty metres further than the normal sixty metres, without a clear and concentrated view of the road.[93]

Simulated Driving Experiments

In simulated driving experiments the response of a driver and the time taken by him, before and after consuming known quantities of alcohol, are measured, or related, to one or more of the various normal skills and cues required for safe driving. Braking, parking, backing, avoiding obstructions, reaction times, time of response to signals by hands or lights and time taken to complete set courses are all commonly tested. One such study showed that at BACs between 40 mg/100 ml (0.04%) and 60 mg/100 ml (0.06%), there is with experienced drivers an average increase in time of 39 per cent with steering tests, and 72 per cent in the time taken to park a car.[94] In a further study, ten drivers showed a definite impairment in their reaction times and times taken to track and complete a course at BAC of 50 mg/100 ml (0.05%). At a BAC of 150 mg/100 ml (0.15%) they showed a decrease of approximately 66 per cent in all the previously established normal values.[90] None of these latter drivers showed any deterioration in their performance of the standard clinical tests used to assess 'sobriety' before a BAC of 90 mg/100 ml (0.09%) was reached. Five out of seven drivers in a similar study showed definite signs of impairment of driving skills with BACs of 50 mg/100 ml (0.05%). Their car-handling ability, as distinct from their ability to avoid hitting objects, deteriorated considerably in most drivers even at relatively low BACs, and the conclusion was made that under actual driving conditions, the effect of alcohol on driving performance would be more pronounced than that observed in the simulated driving experiments reported.[91] Tiredness also considerably increases the 'viso-motoric' reaction times of drivers.[95]

Controlled Accident Studies

In controlled accident studies the proportions of drinking drivers in groups of individuals involved in traffic accidents are compared with the proportions of similarly aged persons in non-accident groups. The studies are costly and time consuming, and require the co-ordination and diversion of specialized personnel and resources from other activities. To date no large-scale study of this type has been conducted in Australia. In 1938, in Evanston in the United States of America, the frequencies of various BACs in a control group of 1750 drivers not involved in accidents were compared with those of 720 drivers hospitalized as a result of road accidents. The study showed that there was a seventeen-fold increase in the normal liability of being in an accident at a BAC of 100 mg/100 ml (0.10%), and that this liability increased to 34-fold at a BAC of 150 mg/100 ml (0.15%).[96] In 1953, in Toronto, Canada, the BACs of 423 drivers involved in accidents were compared with a control group of 2015 non-accident drivers who passed the scenes of the various accidents. This study concluded that the hazard of accident is approximately ten times greater at a BAC of 150 mg/100 ml (0.15%) in drinking drivers than it is in drivers who are sober and 'operating' under identical conditions.[97] In 1964, in Grand Rapids in the United States of America, the BACs of 5985 drivers involved in accidents were compared with a control group of 7590 non-involved drivers passing the same accident sites, at the same time of day, and on the same day of the week. From this extensive study Borkenstein and co-workers concluded that the probability of accident involvement first increased at a BAC of 40 mg/100 ml (0.04%) and rapidly thereafter. And when drivers with a BAC of over 80 mg/100 ml (0.08%) do have an accident, they tend to have more single-vehicle accidents, and accidents which are more severe in terms of injury and damage.[98] These workers concluded that while many factors other than alcohol are related to the probability of an accident occurring, the excessive consumption of alcohol remains the principal aetiological factor.

The results of the above studies and the enormous amount of other evidence concerning the effect of alcohol on the skills of driving were summarized in the following statement prepared in 1965 for the Royal Commission into the Sale, Supply, Disposal or Consumption of Liquor in the State of Victoria:

- For blood alcohol levels of 0.05% and below, some individuals are impaired by alcohol but most drivers, even if affected, are affected only slightly. While deterioration in performance of tasks related to driving can be demonstrated below 0.05%, increased liability to accident appears first somewhat about 0.05%. It is, therefore, reasonable to say that at blood alcohol levels of 0.05% or less the person concerned is unaffected, in a practical sense, as regards road safety.
- Blood alcohol levels in the range of 0.05% to 0.10%. All individuals are affected at or before 0.10% is reached. In some people this time may be largely compensated by slower or more careful driving—but even in these cases the person concerned is less able to cope with

the demands made on his driving ability in emergency situations which often precede accidents and to this extent alcohol in this range is a contributing factor towards accidents. It is in this range that measurably increased liability to accident appears, taking drivers as a group.

- Drivers with blood alcohol levels about 0.10% are affected to the extent that their driving becomes distinctly impaired. The impairment increases progressively as the blood alcohol level rises until at levels of 0.15% there is substantially increased liability to accident.
- At levels of 0.20% and above most people are obviously intoxicated. The increased risk of accidents is now severe.[99]

Relative Increased Risks of Accident

Figure 23.3 is prepared from detailed data contained in the controlled accident study conducted in 1964, in Grand Rapids in the United States of America.[98] The relative increased risk of accident shown is plotted semilogarithmically against the increasing BAC of a motor vehicle driver. A risk of '1' represents the 'normal' risk of a driver who has not consumed alcohol.

Figure 23.3 shows that the probability of involvement of a motor vehicle driver in a road accident will increase by up to sevenfold at a BAC of 100 mg/100 ml (0.10%) and up to thirtyfold at a BAC of 150 mg/100 ml (0.15%). As both the number of motor vehicles on roads and the consumption of alcohol have increased in most countries of the world since the Grand Rapids study was conducted, it is logical to project that at the present time in Australia the increased risk of road accidents in drivers with increasing BACs is not less than that shown in Figure 23.3.

DRUGS AND DRIVING

It is generally accepted that many of the commonly prescribed and illicit drugs may affect various of the complex psychomotor skills necessary for safe driving and so contribute to road accidents. Hard data, however, concerning the involvement of such drugs in motor vehicle accidents are not readily available. Among the difficulties associated with accumulating meaningful statistical and scientific evidence is the great number of central nervous system (CNS) active drugs that are commonly used, the complexity of the analytical methods available for the detection of the majority of these drugs, the absence of simple screening tests for most of these drugs other than alcohol, the variability of dose-response, and difficulties in selecting appropriate control groups of subjects. There is, however, increasing evidence that many of the prescribed and illegal CNS-active drugs will impair driving ability when taken in conjunction with alcohol.[100-105] Among the more commonly prescribed drugs whose action or side effects are potentiated by alcohol are: hypnotics and sedatives such as the barbiturates, chloral hydrate, glutethimide and nitrazepam; narcotic analgesics such as morphine, codeine, dextropropoxyphene and pethidine; antidepressants such as amitriptyline; 'older' antihistamines such as promezathine, dimenhydrinate and diphenhydramine; and minor tranquillizers such as chlordiazepoxide, diazepam, oxazepam, chlorpromazine and meprobamate.[100-107] In a prospective study of 43 117 people, an increased relative risk estimate of 4.9 was demonstrated between the use of minor tranquillizers such as diazepam, chlordiazepoxide and meprobamate and the risk of serious road accident. While this study did not distinguish whether the latter was directly the result of the use of the minor tranquillizers themselves or from the underlying conditions being treated, the advice given should be heeded by all:

> Drivers taking minor tranquillizers are at increased risk of having a road accident (for whichever reason); and the results of our small study suggest that the risk may be substantial. This has implications for the safety of other road users as well as the patients themselves. Patients given tranquillizers should at least be warned that they are at special risk and that, if they must drive, they should take particular care not to exceed the prescribed dose or to combine their drugs with alcohol.[103]

Studies of the effects of cannabis on driving skills presents various difficulties. First, the consumption of alcohol and multi-drug use is common among cannabis users.[108-111] Secondly, the correlation between psychomotor impairment and blood or urinary levels of cannabis metabolites is poor. In addition tetrahydrocannabinol metabolites can be detected for several weeks after exposure to cannabis.[112] In 1984 Mason and

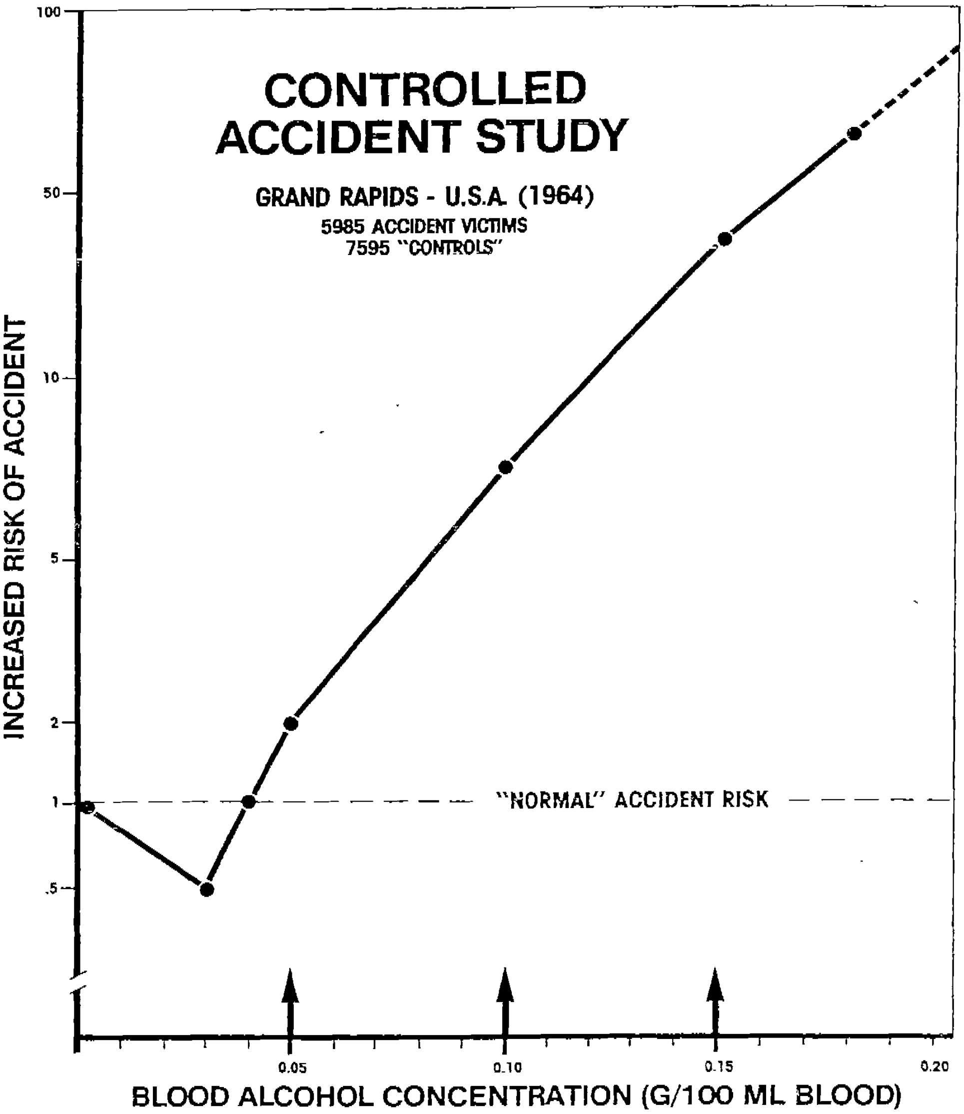


Figure 23.3 Controlled accident study and risk of motor car accident

McBay reported on the use of alcohol, marijuana and other drugs in six hundred drivers killed in single-vehicle accidents in North Carolina during 1978–81. They concluded that alcohol was the only drug tested for that appeared to have a significantly adverse effect on driving safety and that 'there was probably only one driver who could have been significantly impaired by marijuana use alone'.[113]

Each year about 12 000 Norwegian drivers are apprehended, suspected of driving under the influence of alcohol. Two hundred and twenty-three randomly selected blood samples from such drivers were screened for the presence of amphetamines, benzodiazepines, cannabinoids, tetrahydrocannabinol (THC) and cocaine. Benzodiazepines were present in 17 per cent, cannabinoids in 26 per cent, THC in 13 per cent and amphetamine in 2 per cent of the blood samples. Cocaine was not detected in any sample. The frequency of drug detection was 40 per cent in blood specimens where the BAC was less than 50 mg/100 ml (0.05%). The authors concluded that the results of their study 'strongly indicate that all blood samples with a BAC below the legal limit should also be screened for other drugs' in such apprehended drivers.[114] Studies in Geelong showed also that a proportion of fatally injured drivers with a low or negative BAC at autopsy had evidence of recent drug use.[109,115]

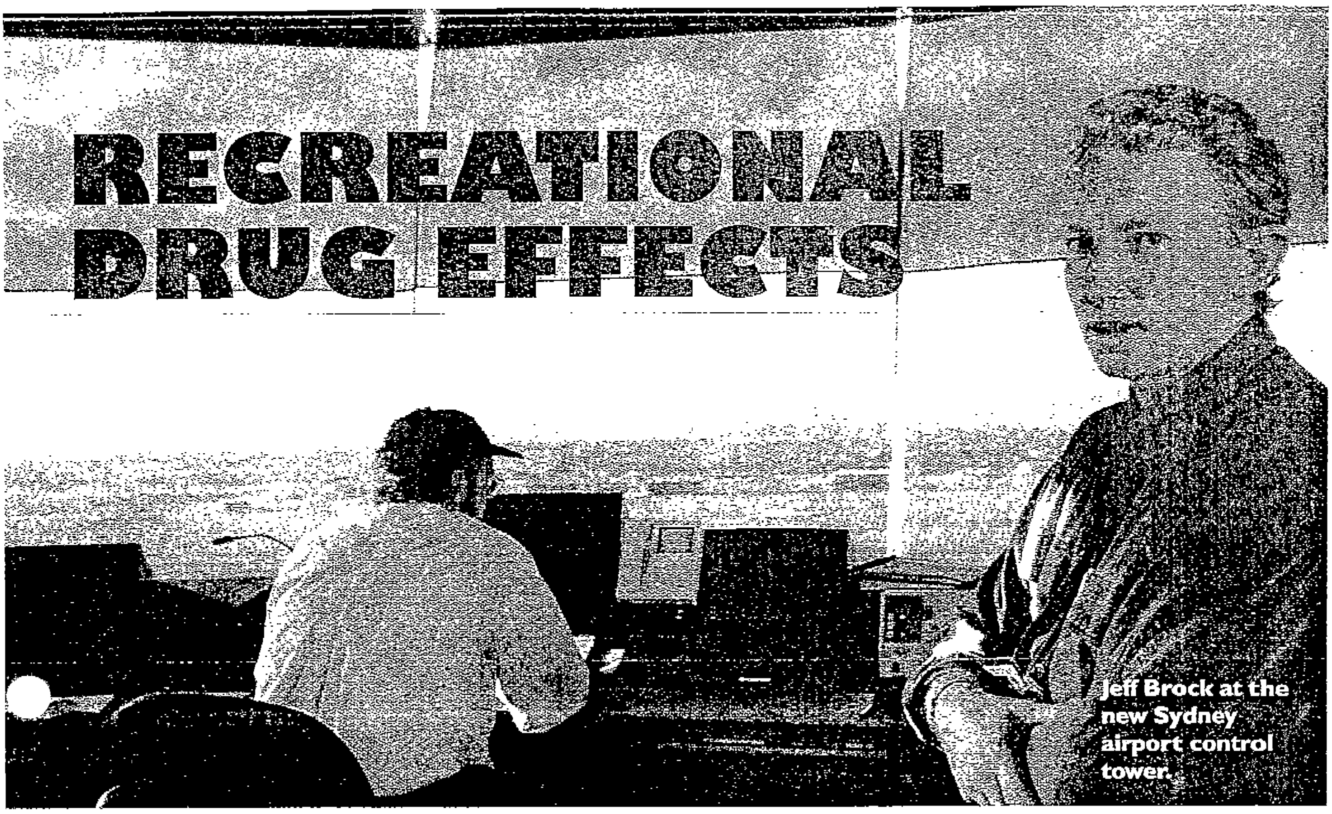
ALCOHOL AND CRIMINAL LIABILITY

At law, as in medicine, many words take on a particular colour and continued interpretation can lead to a word coming to have widely different meanings when used in different contexts. In the case of the word '*intoxication*', the differences in its various contexts generally relate to the degree of insobriety required to constitute 'intoxication' in the particular circumstances. As an example, an allegation of 'intoxication' made against an airline pilot in a prosecution under the *Air Navigation Regulations* could well be substantiated by proof that the pilot had a BAC of 30 mg/100 ml (0.03%). Such a BAC, however, would be far too low to be classed as 'intoxication' for the purposes of a charge of being 'drunk in charge of a motor vehicle'.

In the case of 'intoxication' as a defence to a criminal charge, it is clear that limited scope is given to the term. In this particular context the concentration of alcohol in the body is not the deciding factor—the relevant question is the effect the alcohol exerted on the mind of the accused at the time he committed the offence with which he is charged. For many years the law has recognized that a degree of intoxication sufficient to deprive the accused of all conscious control over his or her actions will in certain instances serve as a defence. In 1977 the English House of Lords ruled by unanimous decision that a defence of intoxication should be confined only to crimes with a specific intent. Before this decision, the defence of intoxication could only reduce the crime from murder to manslaughter. The House of Lords decision enabled the defence of intoxication to result in an acquittal on both these latter charges and so rejected what up to that time had been a long settled common law principle. In June 1980 the High Court of Australia, by a 4–3 majority, refused to apply this House of Lords ruling to Australia and dismissed an appeal by the Victorian Attorney-General in what was known as the O'Connor Case.[116,117] O'Connor had been observed by a police officer pilfering from a parked car; and when the officer attempted to make an arrest, O'Connor stabbed him with a knife taken from the glove box. At his subsequent trial for theft and 'wounding with intent to do grievous bodily harm', O'Connor stated that shortly before the offences he had been drinking heavily and taking a hallucinatory drug, and that at the time of the offence he had no control over himself and claimed: 'I don't know anything—I wasn't there'. He was convicted. The case subsequently went on appeal to the High Court, where O'Connor repeated his argument that his intoxicated state should serve to exculpate him from all criminal responsibility. The High Court agreed with his arguments and quashed his conviction. What the High Court of Australia ruled in effect was that the common law principles still applied in all cases in Australia. This means that a defence of severe intoxication by alcohol or drugs can be raised to show that a criminal act was done involuntarily, without the intention required by the law to establish guilt. The following practical constraints exist, however:

- It is not sufficient for the accused to establish that he or she was disinhibited or otherwise less capable of resisting the temptation of the crime by alcohol, but must raise a reasonable doubt that he or she was so affected as not to be able to form any intent to commit the crime.
- It still rests with the jury to decide whether or not any weight is to be attached to the evidence.
- Any crime in which any degree of 'planning' was evident would be well nigh impossible to defend on intoxication grounds because the degree of drunkenness required is so great that the ability to carry such a plan to fruition

RECREATIONAL DRUG EFFECTS



Jeff Brock at the new Sydney airport control tower.

How recreational drugs like alcohol, tobacco and caffeine – and the illicit drug marijuana – can affect your performance. By Jeff Brock

So you have a drink occasionally and smoke, maybe 10-20 cigarettes a day. Surely that couldn't have an effect on your performance, or make you unsafe.

Wrong, it could. Cigarettes, coffee, tea and alcohol can have a subtle or serious impact on safety. And the effects of the illicit recreational drug, marijuana, can be worse.

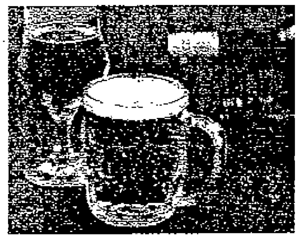
Other than the stipulations regarding intoxicated ersons in Civil Aviation Regulation 256, parts 1 through to 7, there are no other regulations regarding the use of alcohol or substances of abuse by pilots or other personnel in safety-critical areas. CAR 256 (2) states:

"A person acting as a member of the operating crew of an aircraft, or carried in the aircraft for the purpose of so acting, shall not, whilst so acting or carried, be in a state which, by reason of his or her having consumed, used, or absorbed any alcoholic liquor, drug, pharmaceutical or medicinal preparation or other substance, such that his or her capacity so to act is impaired."

CAR 256 (5) and (7) refer similarly to Air Traffic Controllers.

While there exists little Australian data on the effects of illicit drug use in aviation, there are known incidents in which the use of alcohol, caffeine and nicotine have had adverse effects on safe operation.

Alcohol



In the USA, about seven per cent of aviation accidents are related to alcohol misuse.

Simulator studies around the world have consistently demonstrated that as blood alcohol concentrations increase, serious error rates rise. Failures of vigilance and lapses in crew coordination also increase.

These problems were found even at the lowest alcohol level studied (0.025 per cent, which is equivalent to half the legal driving limit in most States and Territories).

A daily ethanol intake of 80gms or more exposes a person to possible disease, including damage of the liver central nervous system gastro-intestinal tract and heart. An intake of 100gms per day or more is hazardous (a "standard" or "normal" beer contains about 6gms per 100mls; table wines contain 8-11gms

Alcohol
For up to 72 hours after even mild intoxication there is measurable degradation of psychomotor performance, decision making, visual acuity, and the ability to track and maintain a target.9-
Effects aggravated by altitude induced hypoxia and reduced temperature.

Caffeine
Can cause dehydration; withdrawal effects can lead to difficulty concentrating.

Tobacco
Impairs oxygen carrying ability of the blood. At 8-10,000ft, visual acuity and colour perception reduced.

Marijuana
Impaired attention, cognitive and psychomotor performance for at least 24 hours, possibly longer.

per 100mls; spirits 32-40gms per 100 mls).

The major health concerns regarding habitual use of alcohol are:

• Central nervous system tolerance, in which the dependent person can sustain an increasing alcohol intake, yet go about his or her business at a blood alcohol concentration that would incapacitate the non-tolerant drinker.

• Peripheral nervous system disease which can produce altered sensation and function of the lower limbs due to irreversible nerve damage.

• Organ damage resulting from toxic effects on cells, particularly in the liver, central nervous system, gastrointestinal tract and heart.

• Interference with vision, balance, co-ordination and motor functions.

• Predisposition to other serious diseases such as diabetes, pancreatitis, epilepsy and vitamin deficiency syndromes.

• Serious impairment of psychomotor skills, reaction times, judgement, decision-making and cognitive function.

Alcohol misuse is still a potent contributory factor in aircraft accidents, the same way it is factored into motor vehicle and industrial accidents.

In Australia, alcohol-related disease is a significant cause of temporary or permanent loss of aviation qualifications.

For up to 72 hours after even mild intoxication, there can be measurable degradation of psychomotor performance, decision-making, visual acuity and the ability to track and maintain a target. This is the "hangover."

A zero blood alcohol level, even in the presence of hangover symptoms, does not equate to the return of normal human performance.

The symptoms associated with a hangover – lethargy, fatigue, nausea, vertigo and headache – can all seriously impair decision-making, concentration and attention to detail. Sensory functions, in particular vision, awareness of movement and orientation, are compromised.

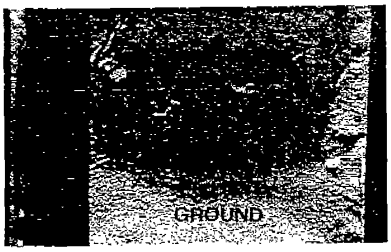
If you have a hangover, you should definitely not fly, or participate in a safety-critical procedure. You will have low blood sugar, and will be suffering from dehydration. Changes to the density of fluid in your ear canals due to alcohol can affect your balance, and are compounded by hypoxia and turbulence. You will be more susceptible to disorientation and motion sickness, and you will find yourself flying less smoothly, as your fine motor skills will be impaired.

These hangover effects can have very serious consequences during instrument flying, in bad weather, and while night flying. They are aggravated by altitude-induced hypoxia and reduced temperature.

If you are an air traffic controller, and present for work with a hangover, you are just as much a safety hazard as a pilot trying to fly with a hangover.

Regular intake of alcohol between shifts can seriously interfere with a healthy sleep pattern and interfere with your appetite, thereby compounding the fatigue problem.

Trying to offset the fatigue with an increased intake of caffeine and cigarettes will further interfere with your metabolic, physiological and cognitive functions.



Caffeine

Most of us, when we are tired, or in need of a "pick-me-up," know that we can reach for some caffeine. How many times have we made ourselves yet another cup of coffee or tea to help us study through the night, or to keep awake during night shift duty, or while flying or driving at night.

The average cup of coffee contains approximately 75 milligrams of caffeine with a moderate/strong cup containing closer to 100 milligrams. By comparison, a cup of tea contains 30 to 60 milligrams and a cola drink 30 to 40 milligrams. After drinking coffee, the caffeine is almost completely absorbed within 15 to 45 minutes, with its clinical effects lasting approximately three hours. Caffeine can make you feel as though you are more awake and able to perform better. Research evidence suggests that complex decision-making and problem-solving are unaffected by caffeine consumption.

There are, however, some harmful effects which are recognised.

Caffeine is a diuretic, so it can exacerbate or cause dehydration in the dry atmosphere of a pressurised aircraft cabin or dehumidified conditioned air in a control tower.

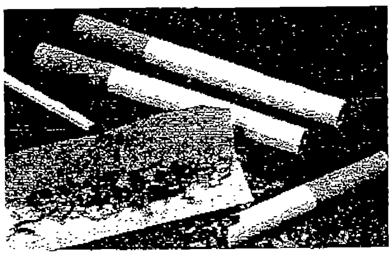
Abstinence from caffeine can be associated with some unpleasant withdrawal effects. These can include irritability, difficulty in concentrating, headache, tremor and difficulty sleeping.

A state of over-arousal caused by too much caffeine could precipitate an episode of disorientation through the over-interpretation of visual cues.

More than about four cups per day is probably classified as excessive, and can cause a loss of appetite. Coupled with night shift, fatigue and increased nicotine intake, appetite can be seriously affected.

This can result in some people relying for energy on "snack" foods such as chocolate bars, potato crisps and biscuits.

If you work shifts, you should discipline yourself to devote time to the preparation of good, nutritious food during your shift, and put more emphasis on drinking water or fruit juice instead of



using coffee and tea as your only fluid intake.

Tobacco

The dangers of tobacco smoking are well documented. Serious cardiovascular disease, bronchitis, emphysema and lung cancer are all well recognised. There is also a risk of oral cancer, cancer of the head and neck, bladder and renal cancer. Smoking impairs the haemoglobin transport of oxygen in the blood to vital organs, reducing its effectiveness by up to 10 per cent. Loss of effective haemoglobin from smoking can have subtle, usually unnoticed cerebral effects, especially if compounded by altitude-induced hypoxia and cold.

Above 4000ft, the effects of smoking become apparent, particularly the impairment of night vision. Visual acuity is reduced, as is colour perception.

This effect is significant, but most smokers are unable to notice it. If they inhale some oxygen, they will notice that lights become brighter, and vision is sharper.

Nicotine, which is contained in tobacco smoke, appears to have very specific stimulant properties. Like so many other drugs, tolerance, physical dependence and the withdrawal syndrome are associated with tobacco and nicotine.

Withdrawal effects after cessation vary greatly from one person to another in both intensity and in specific signs and symptoms. Nausea, headache, constipation, diarrhoea, increased appetite, irritability and insomnia are all well recognised in individuals who withdraw from the smoking habit. Symptoms may persist for weeks.

Marijuana

The immediate effects of smoking marijuana include the creation of a pleasant, dreamy state, with impairment of attention, cognitive and psychomotor performance, which appears to the subject to be reversible. Because of its lack of acute, life-threatening effects, cannabis has been called a "soft" or "recreational" drug, no more damaging than coffee or tobacco. However, this designation should be revised in view of the drug's impairing effects on memory and learning, and its effects on the lung, immune defences, brain and reproductive function.

Many polyaromatic hydrocarbons have been identified in marijuana smoke, some of which are known to be carcinogenic. There is strong evidence to suggest that – like tobacco smoking – cancer of the mouth, larynx, tongue, upper jaw and respiratory tract are more common in marijuana smokers.

Cannabis and its by-products are highly fat soluble and are stored in the body's fat, liver, lung and spleen for lengthy periods.

Its long-term "down-stream" effects are still unknown, but are suspected to be adverse.

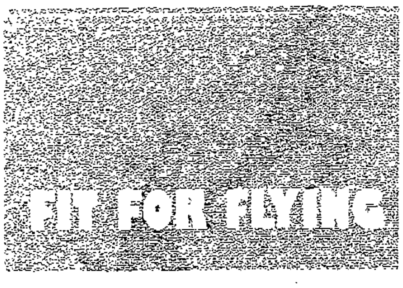
"Day-after" marijuana effects will impair the performance of an individual, may alter mood or alertness and may make tasks, such as operating complicated equipment, flying an aeroplane, or working on an engine, more difficult – and errors more likely.

Some reports suggest that marijuana may be up to 4000 times more potent (gram for gram) than alcohol in producing decrements in the performance of subjects studied under controlled conditions.

At very high doses, the risk of experiencing psychotic symptoms is increased. The chronic health effects of cannabis use over many years may include respiratory diseases associated with smoking; the development of cannabis-dependent syndromes, char-acterised by loss of control over cannabis use; subtle forms of cognitive impairment which persist while the user remains chronically intoxicated, and which may not reverse after abstinence; and an increased risk of certain cancers.

There is no place for any form of cannabis use in the aviation environment; even the infrequent recreational user of cannabis may put others at risk the day after a few smokes.

Jeff Brock is the Senior Medical Officer in aviation medicine for CASA. The third part of his series on drug effects, discussing illegal drugs such as amphetamines and anabolic steroids, will appear in the Spring issue of Flight Safety Australia.



If a pilot is unfit, the physical discomfort of flying for four or five hours without a break can be exhausting. If the pilot has poor muscle tone due to an inactive lifestlyle, it is likely that his or her posture will be adversely affected causing further discomfort.

If the flight has been turbulent, the stresses of countering it will cause fatigue more quickly in someone who is not physically fit.

The overall effect of this increasing physical fatigue is a lowered ability to concentrate.

In contrast, people who exercise regularly are often able to concentrate for longer periods of time, and to recover from fatigue more quickly than those who do not exercise.

Unfortunately, the caloric cost of piloting an aeroplane, for example, is only about half that of driving a train. If you combine this relative inactivity with poor eating habits and a few beers, before you know it the kilos will start to increase.

There are a number of things that you can do to increase your vitality and enhance flying performance. If you exercise regularly, eat sensibly, and reduce stress, then you are well on the path to success.

Even a light exercise program will improve your ability to concentrate, reduce fatigue and stress, and improve oxygen assimilation. All of these benefits can improve pilot performance, particularly under high mental workload situations.

Cardiovascular or aerobic exercise improves the condition of the heart and increases oxygen assimilation. This is particularly important for pilots.

If you exercise moderately for up to 40 minutes at least three times a week, you will begin to experience some of the benefits.

One way to help your exercise program be successful is to make it enjoyable, not a chore. If you are a bit of a loner, then exercises such as jogging, walking, cycling, swimming and bushwalking may well suit you. Whereas, if you are a gregarious person, ball games or team activities might be better.

Remember, if you are trying to lose weight, it took a while to put it on – so be patient. If you lose only 1kg each week, then in a couple of months you will be 8kg lighter.

– *Ian Dix, Safety Education Officer, CASA.*