INTERNAL MEDICINE JOURNAL

RACP Specialists. Together

doi:10.1111/imj.13975

POSITION PAPER

When should the driver with a history of substance misuse be allowed to return to the wheel? A review of the substance misuse section of the Australian national guidelines

Edward J. D Ogden [1,2] Joris C. Verster,[1,3,4] Amie C. Hayley,[1] Luke A. Downey,[1,5] Bruce Hocking,[1] Con K. Stough,[1] Andrew B. Scholey[1] and Yvonne Bonomo[2]

[1]Centre for Human Psychopharmacology, Swinburne University, [2]Department of Addiction Medicine, St Vincent's Hospital, and [5]Institute of Breathing and Sleep, Austin Hospital, Melbourne, Australia, and [3]Utrecht Centre for Drugs & Driving, IRAS, and [4]Division of Pharmacology, Utrecht University, Utrecht, The Netherlands

Key words
alcohol misuse, drug misuse, fitness to drive, driver fitness, medical guidelines, medical standards, commercial drivers.

Correspondence
Edward J. D Ogden, Department of Addiction Medicine, St Vincent's Hospital, 38 Fitzroy Street, Fitzroy, Vic. 3065, Australia
Email: edward.ogden@svha.org.au

Received 28 November 2017; accepted 18 April 2018.

Abstract

Assessing fitness to drive in applicants with a historical or current substance use disorder presents a specific clinical challenge. The Australian guidelines require evidence of remission and absence of cognitive change when considering applications for re-licensing driver or individuals applying to reengage in safety-sensitive work. This paper reviews some of the clinical and biochemical indicators that determine whether a particular person is in 'remission' and meets the criteria for return to driving or other safety-sensitive occupation. It provides an overview of the challenges in establishing an evidence-based approach to determining fitness for safety critical activities. There is no internationally accepted definition of 'remission'. Review of the literature and examination of assessment protocols from other national jurisdictions are available for alcohol and the more important drugs of interest in road safety. Assessing fitness to drive when there is a history of substance misuse and/or substance use disorders is a complex issue that requires assessment of biomarkers, clinical findings and clinical assessment before the person returns to driving. We propose that hair testing provides a reliable and reproducible way to demonstrate remission and provide cost-effective monitoring. Standardised psychological tests could provide a reproducible assessment of the cognitive effects of drug use and suitability to resume driving. We recommend that AustRoads amend the national guidelines to reflect an evidence-based approach to assessing fitness to drive after conviction for offences related to alcohol and drug use.

Background

Driving a car is an important determinant of quality of life which most people take for granted.[1] Loss of licence can have far-reaching impact for employment and social mobility, which in turn, affects mental health, education and access to many essential services.

Driving is a potentially dangerous activity, with driving errors associated with drug and alcohol consumption causing significant mortality and morbidity.[2–9] Driving requires visual acuity, perception, planning, coordination and timely reactions. There is substantial clinical and practical evidence that these skills are acutely compromised by the consumption of psychotropic drugs, and can be chronically affected in those people with drug misuse disorders.[4,10,11]

Misuse of drugs is incompatible with safety critical activities like driving, including both professional and private vehicle operation, which has substantial implications for public safety. Similar risks occur with the operation of other forms of transport, including aviation, rail and maritime operations. Safety considerations may lead to administrative or judicial suspension because of substance misuse. This raises questions about when is it safe for individuals who have history of substance misuse to regain the privilege to drive a vehicle or return to safety critical work.

In populations who misuse drugs, whether they are seeking treatment, are receiving treatment or have undergone rehabilitation, the risks for safety critical activities need to be assessed and managed. In this paper, we explore procedures that would allow practical

Funding: None
Conflict of interest: None

implementation of the Australian standards. The proposed approach has implications for other jurisdictions and for employers in safety-sensitive occupations other than driving. For simplicity, all references to driving include by implication aviation, rail and maritime operations.

The Australian guidelines

The National Transport Commission and Austroads developed medical standards for driver licensing in Australia in consultation with a range of medical experts, peak medical bodies and professional colleges, the road transport industry and State and Territory licensing authorities. All licensing authorities have adopted the national guidelines for the purpose of assessment of a licence holder's fitness to drive. The guidelines were updated in October 2016 and amended in August 2017. They can be viewed on the Austroads website at https://www.onlinepublications.austroads.com.au/items/AP-G56-17.

The guidelines provide a flexible clinical framework for recommendations about the impact of specific medical conditions on suitability for full or conditional licensing. In most cases, physicians in primary care or specialist practice can logically make decisions about suitability for driving. Many of the guidelines have clear criteria on which to base decision for many medical conditions: frequency of seizures in epilepsy syndromes, occurrence of hypoglycaemic episodes in diabetes or episodes of cardiac arrhythmia. These criteria assist the practitioner when making decisions about fitness to drive for these specific conditions.

Occupational therapists have a range of tools to employ assessing older drivers or drivers with specific diseases, such as Parkinson disease or epilepsy.[12–15]

Practitioners specialising in addiction medicine have guidelines that call for the following criteria to be met before a person is permitted to return to driving after losing their licence for substance use. The standard requires an objective clinical assessment that establishes the client is actually in remission (not just saying so) and that substance use has not resulted in brain or other end-organ damage that creates secondary safety concerns.

1 Evidence of remission.
2 Absence of cognitive impairment relevant to driving.
3 Absence of end-organ effects relevant to driving.
4 Periodic review.

DSM-5 criteria for substance misuse

Diagnostic classification of drug use has traditionally attempted to separate people who use excessive quantities of drugs from those who are dependent on them (drug dependent). Analysis of 39 papers representing over 200 000 study participants concluded that the problem of drug use lies on a continuum, with little to no clear distinction between substance misuse and dependence.[16]

Consequently, the classification system of the Diagnostic and Statistical Manual of Mental Disorders of the American Psychiatric Association (DSM-5) makes no distinction between abuse and dependence: rather, it separates individuals on the basis of severity of impact.[17] DSM-5 has 11 elements to consider in classifying the severity of substance use disorder (Table 1).

Deciding on the degree of severity is relatively simple – if the answers is 'yes' to 2 or 3 items in the list, then the disorder is 'mild', if the total of positive answers is 4 or 5, the condition is considered moderate and if the person scores 6 or more, the condition is severe. However, assessment of severity this way is subjective and relies on the subject being truthful. This does not assist in deciding whether the individual should return to driving.

Evidence of remission

The Australian standard calls for evidence of remission. The guidelines indicate that 'remission is attained when there is abstinence from use of impairing substance/s or where substance use has reduced in frequency to the point where it is unlikely to cause impairment'.[18]

Table 1 DSM 5 criteria for substance misuse disorder

1 Taking the substance in larger amounts or for longer than the you meant to
2 Wanting to cut down or stop using the substance but not managing to
3 Spending a lot of time getting, using or recovering from use of the substance
4 Cravings and urges to use the substance
5 Not managing to do what you should at work, home or school, because of substance use
6 Continuing to use, even when it causes problems in relationships
7 Giving up important social, occupational or recreational activities because of substance use
8 Using substances again and again, even when it puts the you in danger
9 Continuing to use, even when the you know you have a physical or psychological problem that could have been caused or made worse by the substance
10 Needing more of the substance to get the effect you want (tolerance)
11 Developing of withdrawal symptoms, which can be relieved by taking more of the substance.

Remission is a 'temporary diminution of the severity of disease or pain'.[19] How is a practitioner to make consistent clinical assessments about whether a reported change in drug use is meaningful or lasting? It is not enough to accept self-reported abstinence.

Licensing and occupational health services expect the clinical assessment to determine fitness to drive not just at the time of examination, but in anticipation of future performance. There is no simple clinical test to determine past, let alone predict future drug use. Clinical examination offers a mere snapshot of the applicant's current medical condition. The licensing authority or employer needs a system that allows for systematic review of alcohol- or drug-related issues.

The design and execution of such an assessment is not a straightforward process, and considerable care and expertise is required to ensure that it provides a true evaluation of the present health status and has predictive value for the future. The aim is accurate assessment that reliably detects individuals who are unfit to drive. The threshold for that decision is critical. 'Any test can be made to look good … if the threshold for a positive test is set very high'.[20] With a high threshold, few people will return to driving which may unfairly discriminate against applicants who pose a low safety risk, but setting the assessment standard too low will result in an unacceptable number of people allowed to drive who should not.

In any decision-making process, there is a matrix of outcomes (Fig. 1):[21,22]

	Positive assessment	**Negative assessment**
Fit to drive	Correct assessment	False negative
Not fit to drive	False positive	Correct assessment

Figure 1 Risk matrix.

Risk matrix

Relying on interview and standard diagnostic scales is not sufficient for this purpose. A multicentre study conducted by the World Health Organization found that concordance between diagnostic tools based on self-report varied from 0.43 for cannabis use to 0.76 for alcohol use and 0.93 for opiate use.[23] The low reliability of the interview instruments makes this an unsuitable approach for safety critical decisions (Fig. 1).

The guidelines recognise the need to strike a balance between the needs of the community and the needs of the individual. The guidelines ask 'Is there a likelihood the person will be unable to control the vehicle and act or react appropriately to the driving environment in a safe, consistent and timely manner?'.[18]

In other specialist areas, there are objective decision points: such as clearly defined standards for visual acuity, a requirement for seizure-free periods in epilepsy, no hypoglycaemic episodes in diabetes and no loss of consciousness with cardiac rhythm disturbances. For drug misuse, there are no objective criteria for consistent decision-making. Moreover, the current guidelines do not define an objective basis on which to make consistent decisions, so we propose some practical solutions.

In normal clinical encounters, everyone assumes that the patient is honestly presenting the clinical issues. We assume that clinicians and patients share the common goal of reaching a diagnosis and instigating useful treatment.

In forensic practice, the subject and clinician may not share a common goal. Applicants for relicensing will minimise their account of drug use in order to maximise the chance of successful licence restoration. The clinician on the other hand should focus not just on the applicant, but also on community safety creating a genuine conflict of interest and potentially to natural tensions and mistrust.

Taking a history from a subject to establish patterns of drug use is not sufficient for this purpose because self-report can be unreliable. A meta-analysis of self-reported drug use when toxicology was available for validation found that at best, only 42% of subjects correctly reported drug use.[24] Objective evidence of abstinence is therefore required.

Short-term abstinence is relatively easy to validate with oral fluid or urine drug screening, but gaining a longitudinal perspective of lasting abstinence is more difficult. The presence of drugs in most substrates is transient with detection usually possible for hours or, at most, days.[25]

Ease of specimen collection, storage and transmission of samples, cost of analysis and the availability of expertise to interpret the result all influence choice of appropriate tests. While several biological matrices are available for the assessment, we argue that hair testing is the method of choice for this assessment.

Oral fluid has the advantage of being relatively easy to collect under direct supervision without privacy

Internal Medicine Journal **48** (2018) 908–915

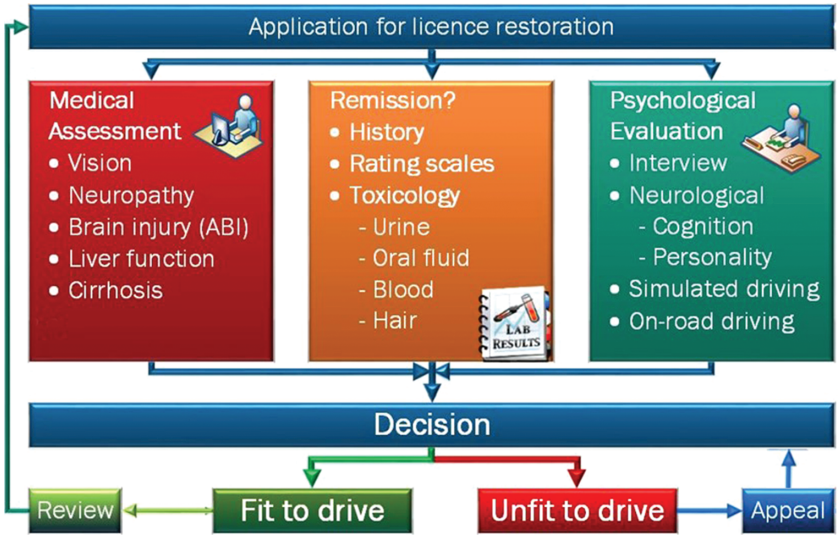

Figure 2 Proposed flow chart for assessing fitness to drive.

concerns. Immediate screening tests can provide a result in minutes. Oral fluid is convenient when screening for recent use.[25–28]

Urine is relatively easy to collect and screening kits allow immediate interpretation, but specimens must be collected with careful supervision to avoid dilution, adulteration or substitution.[29–33] There are privacy concerns when collecting supervised samples. Some individuals will struggle to provide a sample because of paruresis.[34] There are innumerable websites offering artificial urine and prostheses of various skin shades to facilitate cheating. Integrity testing is required to ensure that the liquid provided is actually urine.

Blood testing requires a skilled phlebotomist.[35,36] Sample collection is invasive and associated with biohazard. Blood samples need to be kept cool during storage and transport.[37]

Hair testing provides the best opportunity to be confident that the subject is abstinent. Hair has been recognised as a stable matrix for detection of some poisons since the 1850s.[38] Hair is mostly keratin, the same tough, highly stable protein that makes up fingernails, horses hooves and animal horns. Hair follicles are closely associated with sebaceous glands and sweat glands and drugs are thought to enter the hair complex from the blood supply to the follicle, and from deposition of sweat and sebum onto the surface.[39] In theory, the concentration of a drug in hair should reflect the blood levels at the time the hair was developing. However, the movement of secretions along the hair shaft and exposure to the environment make the distribution of drug along the shaft less than precise.[29]

The primary advantage of hair testing is that the window of detection is so long. Head hair grows at about 1 cm per month (range 0.7–1.4 cm/month). Pubic hair grows more slowly but may be suitable when head hair is unavailable.

The cost of hair testing is a factor to consider. Testing for a single substance group, for instance amphetamines, costs about AU$500 per test, and the panel of illicit substances is about AU$1000 per test. A urine drug screen is AU$25–AU$50 per test. When the total cost, including administration, supervision and transport of samples is considered, hair sampling at three monthly intervals is cost-effective, less time consuming and less subject to adulteration or deliberate tampering.

Hair sampling provides a detection window measured in months. The sample is relatively easy to collect and does not require special conditions in transport. Most drugs are stable in hair at room temperature for months. Cutting a hair sample into segments can provide a time course of drug use.

Environmental contamination is a potential confounder. Most contaminants are only loosely bound to the surface of the hair and can be removed by washing the sample prior to analysis.[40,41] Detection of drugs in the hair washings is evidence of environmental contamination.[42] However, even with the most rigorous procedures, it is not always possible to 'distinguish a drug contaminated subject from an active user'.[43]

Many drugs bind directly to the pigment melanin, which means that hair colour can be a factor in the sensitivity of the hair testing.[44] This factor alone could theoretically produce a bias against dark haired individuals if the cut-offs were set inappropriately low.[45] Hair treatments can strip colour and reduce the concentration of drugs in hair.[40] In spite of these limitations, hair testing offers the best opportunity to detect drug use in the

recent past.[46] Bald and/or depilated subjects can provide fingernails or toenails as an alternative keratin matrix.[47,48]

Absence of cognitive impairment

Human failure is the commonest cause of motor vehicle collisions, yet there is no single personality trait that predicts safe driving. Research has typically looked at 'abilities' (e.g. reaction time, perceptual speed, attention, divided attention, problem solving) or personality traits (e.g. emotional stability, social responsibility, self-control, sensation-seeking, willingness to take risks) in relative isolation.[49–51]

There are few clinical data that help physicians make decisions about cognition and fitness to drive.[52] Many tests have been used ranging from clock drawing[53] through simulated driving[54] to tests of driving on the road,[55] but the research in this area has largely focused on medical conditions in the older driver. There is relatively little information about younger drivers or drivers with a history of drug use. Bedard *et al*.[56] wrote:

> … a statistically significant association between a test result and poor driving performance does not guarantee that the test can be used to classify drivers as safe or unsafe. (p. 339)

Ball assessed 1910 older drivers and followed their driving records for 5 years. Performance-based cognitive measures were found to be predictive of future at-fault motor vehicle collisions in older adults, and that high-risk drivers can be identified through brief, performance-based measures.[57]

Despite this, there is a fundamental difference between assessing older drivers for the ability to keep driving and assessing younger, drug using drivers for their ability to return to driving. The older drivers are more likely to have relatively stable, progressive medical conditions with a predictable rate of decline. The drug-using driver has an unpredictable future: their personal situation may be dynamic.

In several European countries, notably Austria and Germany, returning to drive requires the applicant to pass both medical and psychological tests (die Medizinische-Psychologische Untersuchung or MPU).[58,59] The MPU uses a combination of clinical examination and psychological test battery to determine fitness to drive. The MPU explains up to 70% of the results on a standardised driving test,[60] predicts repeat offending[61] and the performance of professional bus drivers.[62]

The subject puts on headphones and sits in front of a computer with a specialised response panel. The operator explains each test and the subject has a chance to practise. The tests lead from relatively simple tasks to a higher level of difficulty. For instance, a stimulus appears on the monitor for a short time and the subject identifies what he or she saw in the picture: Was there a stop sign? Was a pedestrian on the roadside? The test battery looks at critical elements of the driving task: choice reaction time (simple and complex) perceptual speed, risk acceptance and social responsibility, which holds even after injury.[60,63] The tests are validated.[60,63–66] They do not require literacy or computer skills. Given the accumulation of over 60 years of normative data, this methodology is suitable for the assessment of driving-related cognitive impairment in Australia.

Absence of end-organ effects relevant to driving

Alcohol and other drugs have effects on multiple organ systems. A general clinical examination can yield some useful information about past and present drug use. Specific examinations the clinician might consider include:

- Ear nose and throat for mucosal irritation and other sites of insufflation.
- Mouth and teeth show signs of xerostomia with stimulant use.
- Abdominal examination for hepatomegaly, liver tenderness and ascites.
- Lymphadenopathy.
- Cardiovascular effects of the stimulants (hypertension, tachycardia, arrhythmia)
- Endocrine changes (testicular atrophy, gynaecomastia).
- Neurological signs (tremor, sensory impairment, memory impairment, coordination difficulty, ataxia, neuropathy), eye signs particularly pupil size and mental state (cognitive difficulty, delusions, hallucinations, paranoia).
- Imaging, blood tests and electrocardiogram (ECG) may also assist.

The pattern of significant signs will depend on the substance in question and underlying medical conditions. A thorough examination may allow the clinician to determine if there are lasting end-organ effects. Most of the end-organ effects are useful for assessment of severity of substance misuse and may aid monitoring remission.

There are specific signs that are critical to the determination of fitness for safety critical activities:

- Neurological signs (peripheral neuropathy, seizure disorders, impaired coordination).

- Cognitive impairment (memory impairment, problem solving).
- Mental health (delusions, hallucinations, paranoia).
- Cardiovascular effects (ischaemic heart disease, arrhythmias).

Periodic review

There is always a risk of relapse no matter how long the patient has been in remission. This creates the challenge of determining the prognosis for future behaviour. Clinical and biochemical assessments can help to establish that the individual is currently 'in remission' but cannot shed light on future drug use.

A person could present as fit and well in the morning and be totally incapacitated by drug use a few hours later. This means that monitoring in the community and/or the work place may be essential. Many jurisdictions mandate fitting of 'interlock' devices that ensure that the driver has no alcohol on the breath before driving. There is good evidence for interlock programmes reducing injury and fatal collisions.[67,68] Many authors have suggested that it would be cost-effective to build interlocks into all new vehicles.[69] In the meantime, individuals can be required to install an interlock as a condition of resuming driving.

Fitting interlock devices is not a solution for fleet operators who cannot have an individual vehicle reserved for a particular driver and cannot justify the expense of retrofitting a fleet. Requiring everyone to provide a breath sample or undergo drug testing before starting work is already the norm in many industries. This is a superficially attractive approach. A Cochrane review of *Alcohol and drug screening of occupational drivers for preventing injury* found '… insufficient evidence to advise for or against the use of drug and alcohol testing of occupational drivers for preventing injuries as a sole, effective, long-term solution in the context of workplace culture, peer interaction and other local factors'.[70,71] However, high-profile testing provides a powerful signal of the seriousness with which management views alcohol and drug misuse in a safety critical environment. Random breath testing of drivers has been successful in all countries that have robustly applied the policy.[72]

Practical issues in implementation

Review of assessments by medical practitioners found a significant difference in the rate of rejection of applicants for driver licensing when the assessment was made by a doctor who did not know the patient compared to the patient's own doctor.[73] Only 3% of patients were found 'unfit to drive' by their own doctor, whereas 17% were judged unfit to drive on independent assessment. In consideration of public safety, there is no room for incomplete assessment.

There are very few addiction specialists in each Australian jurisdiction. Many have personally communicated a lack of willingness and/or expertise to undertake medico-legal assessments of this type. There are no resources for a psychological assessment similar to the MPU. When administrators insist that a driver obtain a specialist report prior to considering an application for relicensing, they are placing an unrealistic and insurmountable hurdle in the driver's path.

In order to overcome this, we propose the assessment of reliable biological matrices; namely, hair samples, as standard.

Using this method, the licensing authority is able to refer the applicant to an authorised agent who collects the hair sample and forwards it to the appropriate laboratory for testing.

- Absence of cognitive impairment as demonstrated by completion of a standardised psychological test battery that could include simulated driving.
- Absence of end-organ effects as demonstrated by a clinical examination.
- Periodic review at the discretion of the licensing authority.

This simple scheme would allow the limited number of addiction specialists to leverage their expertise and support community-wide policies. We estimate that this scheme of assessment would cost the applicant between AU$750 and AU$1250 per subject, depending on the substances to be tested in the hair sample. In Europe, specialist clinics are available for these assessments.

Conclusion

The current Australian guidelines to assess drivers for relicensing after conviction for alcohol or drug offences do not specify a framework to assist the practitioner arrive at a reasoned, evidence-based judgement. Hair testing provides a reliable and reproducible way to demonstrate remission. Standardised psychological tests are widely used in Europe and could provide a reproducible assessment of the cognitive effects of past drug use and suitability to resume driving. We recommend that national guidelines reflect an evidence-based approach to assessing fitness to drive after conviction for offences related to alcohol and drug use.

References

1 Evans L. *Traffic Safety*. Bloomfield Hills, MI: Science Serving Society; 2004.
2 Alvarez FJ, del Rio MC. Drugs and driving. *Lancet* 1994; **344**: 282.
3 Alvarez FJ, Fierro I, Del Rio MC. Cannabis and driving: results from a general population survey. *Forensic Sci Int* 2007; **170**: 111–6.
4 Bosanquet D, Macdougall HG, Rogers SJ, Starmer GA, McKetin R, Blaszczynski A *et al*. Driving on ice: impaired driving skills in current methamphetamine users. *Psychopharmacology (Berl)* 2013; **225**: 161–72.
5 Chesher G, Lemon J, Gomel M, Murphy G, editors. Are the driving related skills of clients in a methadone maintenance programme affected by methadone? 13th International Conference on Alcohol, Drugs and Traffic Safety; 1995 Aug; Adelaide: NHMRC Road Accident Research Unit.
6 Christensen L, Nielsen L, Nielsen S. Traffic accidents and drivers suspected for drug influence. *Forensic Sci Int* 1990; **45**: 273–80.
7 Clarkson JE, Gordon AM, Logan BK. Lorazepam and driving impairment. *J Anal Toxicol* 2004; **28**: 475–80.
8 Downey LA, King R, Papafotiou K, Swann P, Ogden E, Boorman M *et al*. The effects of cannabis and alcohol on simulated driving: influences of dose and experience. *Accid Anal Prev* 2013; **50**: 879–86.
9 Drummer OH, Gerostamoulos J, Batziris H, Chu M, Caplehorn J, Robertson MD *et al*. The involvement of drugs in drivers of motor vehicles killed in Australian road traffic crashes. *Accid Anal Prev* 2004; **36**: 239–48.
10 Albery IP, Strang J, Gossop M, Griffiths P. Illicit drugs and driving: prevalence, beliefs and accident involvement among a cohort of current out-of-treatment drug users. *Drug Alcohol Depend* 2000; **58**: 197–204.
11 Elvik R. Risk of road accident associated with the use of drugs: a systematic review and meta-analysis of evidence from epidemiological studies. *Accid Anal Prev* 2013; **60**: 254–67.
12 Asimakopulos J, Boychuck Z, Sondergaard D, Poulin V, Ménard I, Korner-Bitensky N. Assessing executive function in relation to fitness to drive: a review of tools and their ability to predict safe driving. *Aust Occup Ther J* 2012; **59**: 402–27.
13 Dickerson AE. Screening and assessment tools for determining fitness to drive: a review of the literature for the pathways project. *Occup Ther Health Care* 2014; **28**: 82–121.
14 Kay LG, Bundy AC, Clemson LM. Predicting fitness to drive in people with cognitive impairments by using DriveSafe and DriveAware. *Arch Phys Med Rehabil* 2009; **90**: 1514–22.
15 Vrkljan BH, McGrath CE, Letts LJ. Assessment tools for evaluating fitness to drive: a critical appraisal of evidence. *Can J Occup Ther* 2011; **78**: 80–96.
16 Hasin DS, O'Brien CP, Auriacombe M, Borges G, Bucholz K, Budney A *et al*. DSM-5 criteria for substance use disorders: recommendations and rationale. *Am J Psychiatry* 2013; **170**: 834–51.
17 American Psychiatric Association. *DSM 5* . Washington, DC: American Psychiatric Association; 2013.
18 AustRoads. *Assessing Fitness to Drive: Guidelines and Standards for Health Professionals in Australia: Medical Standards for Licensing and Clinical Management Guidelines for Commercial and Private Vehicle Drivers*. Canberra: AustRoads; 2016. [cited 2018 Jul 11]. Available from URL: http://www.austroads.com.au/drivers-vehicles/assessing-fitness-to-drive
19 Moore B. *The Australian Oxford Dictionary*, Vol. **xviii**, Fifth edn. Melbourne, Victoria ; New York: Oxford University Press; 2000; 1597.
20 Littenberg B, Moses LE. Estimating diagnostic accuracy from multiple conflicting reports: a new meta-analytic method. *Med Decis Making* 1993; **13**: 313–21.
21 Fawcett T. An introduction to ROC analysis. *Pattern Recogn Lett* 2006; **27**: 861–74.
22 Metz CE. Basic principles of ROC analysis. Seminars in nuclear medicine. *Semin Nucl Med* 1978; **8**: 283–98.
23 Üstün B, Compton W, Mager D, Babor T, Baiyewu O, Se C *et al*. WHO study on the reliability and validity of the alcohol and drug use disorder instruments: overview of methods and results. *Drug Alcohol Depend* 1997; **47**: 161–9.
24 Magura S, Kang S-Y. Validity of self-reported drug use in high risk populations: a meta-analytical review. *Subst Use Misuse* 1996; **31**: 1131–53.
25 Verstraete AG. Detection times of drugs of abuse in blood, urine, and oral fluid. *Ther Drug Monit* 2004; **26**: 200–5.
26 Bosker WM, Huestis MA. Oral fluid testing for drugs of abuse. *Clin Chem* 2009; **55**: 1910–31.
27 Drummer OH. Drug testing in oral fluid. *Clin Biochem Rev* 2006; **27**: 147–59.
28 Verstraete AG. Oral fluid testing for driving under the influence of drugs: history, recent progress and remaining challenges. *Forensic Sci Int* 2005; **150**: 143–50.
29 Musshoff F, Madea B. Review of biologic matrices (urine, blood, hair) as indicators of recent or ongoing cannabis use. *Ther Drug Monit* 2006; **28**: 155–63.
30 Rouen D, Dolan KA, Kimber J. *A Review of Drug Detection Testing and an Examination of Urine, Hair, Saliva and Sweat*. Sydney: National Drug and Alcohol Research Centre, University of New South Wales; 2001.
31 Tomaszewski C, Kirk M, Bingham E, Saltzman B, Cook R, Kulig K. Urine toxicology screens in drivers suspected of driving while impaired from drugs. *Clin Toxicol* 1996; **34**: 37–44.
32 Beard CL. *The Effectiveness of the Alere iScreen© Urine Adulteration Test Strip at Detecting Six Common Urine Adulterants*. Greenville, NC; 2016.
33 Moeller KE, Lee KC, Kissack JC. Urine drug screening: practical guide for clinicians. *Mayo Clin Proc* 2008; **83**: 66–76.
34 Hammelstein P, Soifer S. Is 'shy bladder syndrome'(paruresis) correctly classified as social phobia? *J Anxiety Disord* 2006; **20**: 296–311.
35 Lippi G, Salvagno GL, Montagnana M, Guidi GC. The skilled phlebotomist. *Arch Pathol Lab Med* 2006; **130**: 1260–1.
36 Stewart KR, France CR, Rader AW, Stewart JC. Phlebotomist interpersonal skill predicts a reduction in reactions among volunteer blood donors. *Transfusion* 2006; **46**: 1394–401.
37 Cohle SD, Saleem A, Makkaoui DE. Effects of storage of blood on stability of hematologic parameters. *Am J Clin Pathol* 1981; **76**: 67–9.
38 Sachs H. History of hair analysis. *Forensic Sci Int* 1997; **84**: 7–16.
39 Henderson G. Mechanisms of drug incorporation into hair. *Forensic Sci Int* 1993; **63**: 19–29.
40 Boumba VA, Ziavrou KS, Vougiouklakis T. Hair as a biological indicator of drug use, drug abuse or

chronic exposure to environmental toxicants. *Int J Toxicol* 2006; **25**: 143–63.
41 Schaffer M, Hill V, Cairns T. Hair analysis for cocaine: the requirement for effective wash procedures and effects of drug concentration and hair porosity in contamination and decontamination. *J Anal Toxicol* 2005; **29**: 319–26.
42 Tsanaclis L, Wicks JF. Differentiation between drug use and environmental contamination when testing for drugs in hair. *Forensic Sci Int* 2008; **176**: 19–22.
43 Romano G, Barbera N, Lombardo I. Hair testing for drugs of abuse: evaluation of external cocaine contamination and risk of false positives. *Forensic Sci Int* 2001; **123**: 119–29.
44 Joseph RE, Su T-P, Cone EJ. In vitro binding studies of drugs to hair: influence of melanin and lipids on cocaine binding to Caucasoid and Africoid hair. *J Anal Toxicol* 1996; **20**: 338–44.
45 Lewis JH. *Drug Detection and Its Role in Law Enforcement*. Canberra: Australian Institute of Criminology; 2001.
46 Tagliaro F, Smith F, De Battisti Z, Manetto G, Marigo M. Hair analysis, a novel tool in forensic and biomedical sciences: new chromatographic and electrophoretic/electrokinetic analytical strategies. *J Chrom B Biomed Sci Appl* 1997; **689**: 261–71.
47 Shen M, Chen H, Xiang P. Determination of opiates in human fingernail—comparison to hair. *J Chromatogr B* 2014; **967**: 84–9.
48 Palmeri A, Pichini S, Pacifici R, Zuccaro P, Lopez A. Drugs in nails. *Clin Pharmacokinet* 2000; **38**: 95–110.
49 Moskowitz H, Fiorentino D. *A Review of Experimental Studies of Low BAC Effects on Skills Performance*. Los Angeles: Southern California Research Institute; 2000.
50 Hayley AC, de Ridder B, Stough C, Ford TC, Downey LA. Emotional intelligence and risky driving behaviour in adults. *Transport Res F Traffic Psychol Behav* 2017; **49**: 124–31.
51 Hole GJ. *The Psychology of Driving*. Philadelphia: Psychology Press; 2014.
52 Molnar FJ, Byszewski AM, Marshall SC, Man-Son-Hing M. In-office evaluation of medical fitness to drive: practical approaches for assessing older people. *Can Fam Physician* 2005; **51**: 372–9.
53 Freund B, Gravenstein S, Ferris R, Burke BL, Shaheen E. Drawing clocks and driving cars. *J Gen Intern Med* 2005; **20**: 240–4.
54 Davenne D, Lericollais R, Sagaspe P, Taillard J, Gauthier A, Espié S *et al*. Reliability of simulator driving tool for evaluation of sleepiness, fatigue and driving performance. *Accid Anal Prev* 2012; **45**: 677–82.
55 Shechtman O, Awadzi KD, Classen S, Lanford DN, Joo Y. Validity and critical driving errors of on-road assessment for older drivers. *Am J Occup Ther* 2010; **64**: 242–51.
56 Bedard M, Weaver B, Dārzin P, Porter MM. Predicting driving performance in older adults: we are not there yet! *Traffic Inj Prev* 2008; **9**: 336–41.
57 Ball KK, Roenker DL, Wadley VG, Edwards JD, Roth DL, McGwin G *et al*. Can high-risk older drivers be identified through performance-based measures in a Department of Motor Vehicles Setting? *J Am Geriatr Soc* 2006; **54**: 77–84.
58 Schuhfried G. Verfälschungssichere Erfassung der Persönlichkeit in der Fahreignungsdiagnostik. Wien: Tagungsband; 2010; 59.
59 Aniţei M, Chraif M, Schuhfried G, Sommer M. The validation of expert system traffic psychological assessment to Romanian driving schools. *Procedia-Soc Behav Sci* 2011; **30**: 457–64.
60 Sommer M, Herle M, Häusler J, Risser R, Schützhofer B, Chaloupka C. Cognitive and personality determinants of fitness to drive. *Transport Res F Traffic Psychol Behav* 2008; **11**: 362–75.
61 Hilger N, Ziegler H, Rudinger G, DeVol D, Jansen J, Laub G *et al*. EVA-MPU. Zur Legalbewaehrung alkoholauffaelliger Kraftfahrer nach einer medizinisch-psychologischen Fahreignungsbegutachtung (MPU)/ EVA-MPA. Recidivism of DWI drivers after medical-pychological assessment (MPA). *Zeitschrift für Verkehrssicherheit* 2012; **58** (Sonderdruck).
62 Vetter M, Schuenemann L, Debelak R, Gatscha M, Herle M, Mandler G *et al*. Vorhersage von sicherheitsrelevantem Fahrverhalten bei Berufskraftfahrern: eine theoriegeleitete Validierung von Leistungs-und Persoenlichkeitstests. *Zeitschrift fuer Verkehrssicherheit* 2015; **61**.
63 Sommer M, Heidinger C, Arendasy M, Schauer S, Schmitz-Gielsdorf J, Häusler J. Cognitive and personality determinants of post-injury driving fitness. *Arch Clin Neuropsychol* 2010; **25**: 99–117.
64 Cippitelli A, Ainhoa Bilbao ACH, del Arco I, Sommer W, Heilig M, Massi M *et al*. Cannabinoid CB1 receptor antagonism reduces conditioned reinstatement of ethanol-seeking behavior in rats. *Eur J Neurosci* 2005; **21**: 2243–51.
65 Risser R, Chaloupka C, Grundler W, Sommer M, Häusler J, Kaufmann C. Using non-linear methods to investigate the criterion validity of traffic-psychological test batteries. *Accid Anal Prev* 2008; **40**: 149–57.
66 Sommer M, Arendasy M, Schuhfried G, Litzenberger M. Diagnostische Unterscheidbarkeit unfallfreier und mehrfach unfallbelasteter Kraftfahrer mit Hilfe nicht-linearer Auswertemethoden/ Possibility to differentiate between accident-free drivers and drivers with multiple accidents using non-linear statistical methods. *Zeitschrift für Verkehrssicherheit* 2005; **52**.
67 Sweedler BM. Preventing alcohol crashes: the role of ignition interlocks. *Traffic Inj Prev* 2003; **4**: 35–6.
68 Beirness DJ, Marques PR. Alcohol ignition interlock programs. *Traffic Inj Prev* 2004; **5**: 299–308.
69 Carter PM, Flannagan CA, Bingham CR, Cunningham RM, Rupp JD. Modeling the injury prevention impact of mandatory alcohol ignition interlock installation in all new US vehicles. *Am J Public Health* 2015; **105**: 1028–35.
70 Cashman CM, Ruotsalainen JH, Greiner BA, Beirne PV, Verbeek JH. Alcohol and drug screening of occupational drivers for preventing injury. *Cochrane Libr* 2009; CD006566.
71 Kraus JF. The effects of certain drug-testing programs on injury reduction in the workplace: an evidence-based review. *Int J Occup Environ Health* 2001; **7**: 103–8.
72 Whiteford HA, Degenhardt L, Rehm J, Baxter AJ, Ferrari AJ, Erskine HE *et al*. Global burden of disease attributable to mental and substance use disorders: findings from the global burden of disease study 2010. *Lancet* 2013; **382**: 1575–86.
73 Steier T, Kitai E, Wiener A, Kahan E. Are medical reports on fitness to drive trustworthy? *Postgrad Med J* 2003; **79**: 52–4.