

# *Neuropsychological assessment of a group of BAe 146 aircraft crew members exposed to jet engine oil emissions*

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Neuropsychological assessment was carried out using a battery of tests on two pilots and six flight attendants who reported symptoms following exposure to jet engine oil emissions from the BAe 146. Results indicate significant impairments on tests of reaction time, information processing speed and fine motor skills among the majority of testees. These findings are significant in that, if they are extrapolated across the aviation industry, they could indicate a serious aviation safety problem. Further, the possibility of consistent neuropsychological impairment within an admittedly small group of individuals indicates the need for a more robust study.

## KEYWORDS

- AVIATION INDUSTRY
- BAe 146
- OCCUPATIONAL HEALTH AND SAFETY
- NEUROPSYCHOLOGICAL DYSFUNCTION
- AIRBORNE CONTAMINANTS

## Introduction

Over the past six years, reports have been made by airline pilots, cabin crew and passengers of an array of symptoms arising from travel on BAe 146 aircraft. The BAe 146 is a small jet aircraft that operates on short domestic flights within (among other places) Australia, Britain, Canada and the United States. In Australia, it is used predominantly in the less populated States of Western Australia, Queensland and South Australia as a means of transporting small numbers of passengers to remote areas (for example, holiday destinations).

The most common complaints which have been made by individuals exposed to engine oil emissions while flying on the BAe 146 are: breathing difficulties; chest pain; nausea; fatigue; chronic headache; dizziness; light-headedness; confusion; concentration problems; memory difficulties; and hypersensitivity to a range of chemicals.<sup>1,2</sup>

Complaints are generally made when the aircrew and passengers are exposed to engine oil emissions through the airconditioning system of the aircraft during take-off and landing. The oil escapes through faulty engine seals into the compressor bleed air, which is used to ventilate and pressurise BAe 146 cabins.<sup>3</sup> The concentration of these emissions is considered to peak at take-off and landing of the aircraft, or at other times when the engine is under load. Reports of foul smelling gases and the subsequent development of symptoms of nausea, breathing difficulties, chest pain, confusion and dizziness are most common at these times when the airconditioning systems are on full volume.

The engine oil used by the BAe 146 is a synthetic phosphate ester oil in which tri-cresyl phosphates are constituents. One of these tri-cresyl phosphates, tri-ortho-cresyl phosphate (TOCP), is said to be a highly neurotoxic contaminant.<sup>4</sup> However, other ortho-cresyl phosphates in the oil are present in higher concentrations and are known to be more neurotoxic than TOCP.<sup>5</sup> The oil also contains naphthylamine and a broad range of other chemicals, many of which are considered hazardous to human health.<sup>4,6</sup>

The BAe 146, the MD80, the B737 and the A320 have been the cause of over 90% of the worldwide cabin contamination problems identified. It is considered that this is due to the fact that these types of aircraft are more prone to leakages of oil emissions due to their design. The BAe 146 engine was reported to have been designed for use in combat helicopters during the Vietnam War. Post-war, these engines were modified to fit small jet aircraft operating on short domestic flights. Statistically, BAe 146 aircraft operating in Australia and the US are the highest ranking for cabin air problems.<sup>6</sup>

Several case reports and epidemiological studies suggest that chronic central nervous system effects may occur in solvent-exposed workers, such as workers exposed to jet engine oils. Headache, dizziness, concentration difficulties, memory impairment, fatigue, irritability, depression, alcohol intolerance and personality changes are the most frequently reported symptoms. Psychometric testing revealed disturbances in memory and perception, prolonged reaction times and some loss of coordination.<sup>7</sup>

Hartman cited studies which demonstrate acute neuropsychological effects on jet engine oil workers, which include dizziness, headache and fatigue. Chronic exposure produces symptoms of neuroaesthesia, anxiety, depression and increased reaction time to stimuli. Of the most severely affected, 50% were considered to have mild organic brain syndrome.<sup>8</sup>

Flight safety is a major issue with regard to the effects from exposure to such jet engine oil emissions.<sup>9</sup> A pilot with disorientation, altered memory, concentration difficulties, blurred vision, slurred speech, and loss of balance and coordination could not be expected to operate and land an aircraft safely, nor could cabin crew be expected to carry out their duties adequately when experiencing these problems.

Despite numerous complaints of cognitive problems following exposure to BAe 146 aircraft emissions, few psychometric assessments have been conducted to determine the nature and magnitude of the reported difficulties.

However, one study by Teo, in which he assessed five aircrew (including two pilots and three flight attendants) who had been exposed to jet oil emissions, demonstrated significant findings.<sup>10</sup> Teo assessed each of the five individuals using Auditory Evoked Response Potentials. He reported that the Auditory Evoked Response Potentials Test was a useful tool for the detection of chemical exposure effects as it can detect the depressant effects of organophosphates and other chemicals, even at sub-clinical levels. The resultant effects of organophosphates and solvents are that the ability to attend and respond to stimuli is decreased.<sup>11</sup> The results of Teo's study revealed that, in each case, there was a significant deficit in the individual's capacity to process information efficiently. The dysfunction impacted on the individuals' performances on cognitive and psychomotor tasks. This was considered by Teo to be an air safety risk factor.<sup>10</sup>

Despite these findings, there do not appear to have been any comprehensive neuropsychological studies carried out in Australia on groups of individuals exposed to jet engine oil emissions. According to Lezak, the lack of thorough investigation of reported cognitive problems among chemically exposed employees generally occurs because of the similarity between some of the reported complaints and those of both depression and neuroticism. This confusion, often coupled with the absence of distinct neurological symptoms, can lead naive investigators into discounting chemically exposed workers' complaints of cognitive deficits.<sup>12</sup> However, Lezak reported that when neuropsychological evidence is presented, individuals' symptoms are often supported by positive objective findings.<sup>12</sup>

The health problems of aircrew exposed to BAe 146 engine oil emissions were considered to be significant enough to warrant an inquiry by the Australian Senate. On 22 March 1999, the Senate referred the following matter to the Rural and Regional Affairs and Transport References Committee for inquiry and report:

“(d) The examination of air safety, with particular reference to cabin air quality in BAe 146 aircraft.”

Six senators representing five Australian States subsequently met in 1999 and 2000 to investigate the 24 public and a number of other private submissions on the air quality in BAe 146 aircraft. A report was tabled in the Australian Parliament in October 2000.<sup>13</sup>

The aim of the present study was to determine the presence of any neuropsychological deficits among a small group of aviation aircrew who were exposed to jet engine oil emissions from the BAe 146 in the course of their work.

## Method

### Participants

A medical practitioner, who is based in Perth and has seen a number of aircrew members affected by BAe 146 emissions, considered that neuropsychological assessment was important in determining the nature and extent of the problems which were being reported. She therefore referred five flight attendants for assessment. Another flight attendant and two pilots were referred by their own medical practitioners in the eastern States.

In total, eight aircrew who had been exposed to BAe 146 oil emissions were referred by their medical practitioners for neuropsychological assessment. These individuals had reported cognitive difficulties, such as mental confusion, concentration difficulties and memory problems, following their exposure to oil emissions.

The eight individuals assessed were all females. Their ages ranged from 24 to 56 years and they had worked in their respective positions on the BAe 146 from two to 12 years. All had completed six years of secondary school education and most had studied at a tertiary level. All participants were right-side dominant.

### Measures

Each of the eight participants was administered a battery of neuropsychological tests which had been used in previous research studies on neurotoxicants.<sup>7,8,12,14</sup> The test battery included:

- WAIS-III Subtests
- Wechsler Memory Scale — Russell Adaptation
- Rey Complex Figure
- Controlled Oral Word Association Test (FAS Test)
- Symbol Digit Modalities Test
- Trail Making Tests “A” and “B”
- Card Version of Category Test
- Rey 15-Item Test
- Dynamometer Grip Test
- Reitan Finger Tapping Test
- Grooved Pegboard Test
- National Adult Reading Test
- California Computer Assessment Package.

The California Computer Assessment Package (CALCAP) was added to the test battery as it is regarded as a sensitive measure of subtle changes in cognitive functioning among a number of populations, including HIV-positive individuals, chronic fatigue syndrome sufferers, and those with mild head injuries.<sup>14,17</sup>

## Results

The mean age of participants was 36.13 years and the mean education was 13.67 years.

Surface examination of test results are shown in Table 1. These indicate that the tests which demonstrated greatest sensitivity to neurotoxic exposure were the CALCAP Reaction Time Tests. Of the participants, 87.5% demonstrated impairments in the choice and sequential reaction time tasks. Interestingly, the simpler tests demonstrated the most severe impairments.

Test scores of grip strength were also impaired in 100% of participants on the dominant side and 87.5% on the non-dominant side, although the majority of these were of a mild nature.

Impairments on both the Digit Symbol Subtest of the WAIS-III and the Symbol Digit Modalities Test — which are similar tasks of processing speed — occurred in 87.5% of participants (mean 7.38 and 43.88, respectively). However, only 62.5% of participants demonstrated impairments on the oral version of the Symbol Digit Modalities Test (mean 49.00). Among other subtests of the WAIS-III, 62.5% showed impairments on the Picture Arrangement Test of sequencing (mean 9.38), while 50% were impaired on both the Letter Number Sequencing Test (mean 8.75) and the Digit Span Test (mean 9.88). These are both tests of concentration and attention span. All other subtests of the WAIS-III showed impairments in none, one or only two individuals, so were not considered of significance.

The National Adult Reading Test results of all eight individuals (mean 18.38) suggested that all pre-morbid IQs would have been in the average to high average range (from 108 to 116; mean = 113), and academic records supported these findings. Of the eight participants, 62.5% demonstrated losses in Full-scale, Verbal and Performance IQ.

Although memory deficits, as measured by the Wechsler Memory Scale — Russell Adaptation, were only mild, 87.5% of participants demonstrated impairments in both short and longer-term verbal recall. Only 12.5% of participants (one out of the eight) demonstrated a mild to moderate impairment in short-term non-verbal recall, but 50% demonstrated mild to moderate impairments in longer-term non-verbal recall.

The Trail Making Test of processing speed demonstrated only mild impairments in performance among 37.5% of participants in both the “A” and “B” versions. Mean scores were slightly below average.

The tests which were least sensitive to neurotoxic exposure were the fine motor skills tests of manual speed and manual dexterity. Only 25% of participants showed impairments in tapping speed and manual dexterity of the dominant hand. Although 25% showed impairments in manual dexterity on the dominant side, none showed impairments in tapping speed on the non-dominant side.

**TABLE 1**  
**Test results**

Tests	Participants								Percentage impairments
	1	2	3	4	5	6	7	8	
Digit Symbol Test	5***	8*	9*	6***	4***	10	8*	9*	87.5%
Picture Arrangement Test	8*	13	7**	12	8*	9*	11	7**	62.5%
Digit Span Test	5***	16	12	10	8*	10	9*	9*	50%
Letter Number Sequencing Test	8*	13	4***	10	7**	8*	10	10	50%
Symbol Digit Modalities Test: written	46*	51*	48**	44**	32***	39***	44*	47	87.5%
Symbol Digit Modalities Test: oral	59	59	45***	50*	34***	40***	49*	56	62.5%
Trail Making Test "A"	30	34	25	55**	41*	29	38	51*	37.5%
Trail Making Test "B"	68	50	54	87*	106**	99*	67	80	37.5%
Grip: right	30*	24*	30*	20***	17***	24*	25*	22**	100%
Grip: left	27*	25*	29*	23**	21***	20**	29*	25	87.5%
Reitan Finger Tapping Test: right	40.25*	60	49.67	46	36.3**	62	55.67	42	25%
Reitan Finger Tapping Test: left	40.0	58	48.67	43	41.3	55.3	48.67	40	0%
Grooved Pegboard Test: right	53	61	82***	66	60	58	49	78*	25%
Grooved Pegboard Test: left	52	63	81*	76	51	70	55	100***	25%
FAS Test	34*	69	36*	43	45	42	65	21***	37.5%
CALCAP Simple Reaction Time	0.14	0.49	-0.69*	-3.56***	-8.77***	-5.12***	0.43	-0.44*	62.5%
CALCAP Choice Reaction Time	-4.08***	0.80	-0.09*	-4.71***	-12.49***	-6.48***	-0.18*	-4.03***	87.5%
CALCAP Sequential Reaction 1	-0.93**	0.37	-0.25*	-2.84***	-3.63***	-2.88***	-1.6**	-0.34*	87.5%
CALCAP Sequential Reaction 2	-0.56*	0.75	-0.92**	-1.57**	-2.62***	-1.12**	-1.04**	-0.34*	87.5%
ShorHerm Verbal Memory	2*	2*	2*	1	2*	2*	2*	2*	87.5%
Long-term Verbal Memory	2*	0	2*	2*	2*	2*	2*	2*	87.5%
ShorHerm Non-verbal Memory	1	0	1	1	1	3**	1	1	12.5%
Long-term Non-verbal Memory	1	0	2**	3**	2*	3**	1	1	50%
Category Test Errors	46**	33		7	45**	4**	32	43**	57.1%

**Impairments:** \* mild; \*\* mild to moderate; \*\*\* moderate; \*\*\*\* moderate to severe; \*\*\*\*\* severe.

## Discussion

Although a statistical analysis has not been carried out on these test results and there is no control group of individuals working in the same field but not exposed to BAe 146 jet engine oil emissions, there are sufficient grounds to warrant further investigation of aircrew on the BAe 146.

The pattern of test results reflects studies that have been carried out in other occupational settings where workers were exposed to organophosphates and solvents. According to Lezak, most chronic solvent toxicity occurs in the workplace as a result of long-term exposure to fumes from such substances as paints, glues, cleaning fluids, petroleum fuel, and lubricating and degreasing agents. The most prominent cognitive deficits found among these groups involve many aspects of attention and memory, and also response slowing.<sup>12</sup>

As a result of the Senate Inquiry, eight recommendations have been made with the aim of ensuring that appropriate assessments are made of BAe 146 and other passenger aircraft in order to guarantee that proper standards of air quality become mandatory for Australian aircraft (while being mindful of operational activities in Australia).<sup>13</sup>

The recommendations made by the Senate Inquiry were addressed in particular to the Civil Aviation Safety Authority as it is Australia's air safety agency and administrator of aircraft operating regulations and standards. In addition, the Committee recommended that the Commonwealth initiate a number of responses to ensure that OHS issues are addressed.<sup>13</sup>

## Conclusion

Bearing in mind the above neuropsychological findings, coupled with the outcome of the Senate Inquiry, it would be of considerable interest to conduct a wider-scale study of BAe 146 aircrew.

The hypothesis would be that BAe 146 aircrew who have been exposed to engine fumes would demonstrate neuropsychological impairments on a number of neuropsychological measures.

It is envisaged that an experimental group of at least 30 individuals could be administered the neuropsychological tests which proved most sensitive to the oil fumes in the present study. These test results could then be compared with a control group (of the same number of individuals who do not fly on the BAe 146 and are therefore not exposed to BAe 146 oil fumes) and be statistically analysed by analysis of variance to determine the presence of any significant differences between the groups.

The data gathered from this recommended research project, if positive, could be used as evidence to initiate the introduction of better working conditions for employees in the aviation industry.

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