Women car designers and designing cars for women: The Arrol Galloway and the Volvo YCC

Dr Nina Baker, Project Assistant, Department of Architecture, University of Strathclyde, Glasgow G4 0NG nina.baker@strath.ac.uk

Abstract

Cars have been on the roads for about 120 years and women have been involved in both designing and driving them from the very start. This involvement has become largely invisible and enabled a major car manufacturer, Volvo, to announce, unchallenged, that their team of women car designers were an innovation. This paper aims to make this history visible again. It reveals the continuity of women's participation as drivers and designers of cars, from Berta Benz's pioneering road test; through the story of the Galloway car, designed by women, built by women, for women to drive; to the Volvo team's "Your concept car". By comparing the historical with the contemporary, a tool is provided which enables these experiences and their outcomes to be used to reveal both continuity and change in what is thought of as a "woman's car". Also unveiled are other important aspects of design with potential gendered differences, such as ergonomics and the use of instrumentation, that remain unconsidered if male users alone are the assumed priority.

[170 words]

Women car designers and designing cars for women: The Arrol Galloway and the Volvo YCC

Dr Nina Baker, Project Assistant, Department of Architecture, University of Strathclyde, Glasgow G4 0NG nina.baker@strath.ac.uk

Introduction

In 1888 Berta Benz became the first person to drive an internal combustion engine road vehicle on the open road. Impatient with her husband's endless tinkering and just needing a way to get herself and her two sons from Mannheim to the next town, Pforzheim, some 50km distant, she set off in Benz's prototype automobile[1]. The round trip was successfully negotiated, requiring her to find fuel along the way, push the vehicle up hills and undertake roadside repairs herself. On her return, she was able to report to her husband the design changes necessary to make the vehicle more reliable. This first automobile road test, by the pioneering Frau Benz, is celebrated with an annual run of historic cars between the two German towns.

The involvement of women with cars, their manufacture and design is otherwise rather less publicly known or celebrated than Berta's. The rather more hidden history of a female automobile pioneer designer, and the Arrol Galloway car she produced, will be compared with the recent highly-publicised "Your Concept Car" (YCC), designed by an all-female Volvo team. The paper will consider the following questions:

- What is considered to be a woman's car now and how does that compare with 80 years ago?

- What is the experience of women's involvement in car design?

Women car drivers and purchasers

The early days of the automobile were characterised by a multiplicity of small firms and individuals making vehicles, often by adding a small motor to a large tricycle or similar vehicle. The industry was very quick to develop, however, particularly in France and Germany, where concentrations of appropriate industries and good roads enabled cars to be made and sold more easily than in the USA, or even the UK. Within 10 years of Berta Benz's journey, cars had more of the features we take for granted – steering wheels instead of tillers, pneumatic tyres instead of steel wheelrims, and a roof and windows instead of an open seat. These machines were still very expensive, with a set of rubber tyres, for instance, costing the equivalent of a labourer's annual wage. Consequently, the motoring craze was largely limited to the very wealthy.

By the end of the 19th century the opportunities for women's activities outside the home were expanding, with coming of the campaigns for women's education, employment and suffrage. The same type of modern-thinking, wealthy woman, who was willing to ride a bicycle, was also likely to be excited by the idea of motoring and aviation. Many early women motorists were also keen flyers. Women often won prizes in the early long-distance races and Joan Cuneo's successes, particularly against prominent male racers in the USA, such as Ralph De Palma, lead to women being banned from racing by the American Automobile Association[2]. Many of the wives of automobile manufacturers were keen racers and even Princess Dolgorukaya, Tsar Alexander II's second wife, raced from St Petersburg to Kiev in 1911[3]. However, this early sense of equality faded somewhat, with the return to highly traditional patriarchal values after the First World War[4]. By 1933, English aviatrix and motor racer, Mrs Victor Bruce, was claiming that women were edging

their way [back?] into ‘A sport that previously had almost entirely been a man’s game’[5]. This claim resurfaces at regular intervals, to this day.

Car makers were quick to realise that a woman seen with their car could imply reliability, comfort and ease of use. Female figures, both idealised “goddess” types and “real” women drivers, were used to advertise cars from the earliest times. Roberts[6] notes that many manufacturers sold to the woman, even if the man was the driver, from the very beginning. To our modern eyes, the interiors of many early elite cars resembled living rooms, with seating often styled like a deep-buttoned leather settee with arms. This enabled women to feel comfortable as both passengers and drivers, when surrounded by a more or less domestic interior and elegant, beautifully decorated shiny exterior. The mechanisation and modernist styling of the early 20th century, epitomised by the standard Model T Ford, was in many ways the antithesis: very plain, famously only available in black and with no variations. Sparke[7] points out that the automobile industry itself recognised the conflict between the adverts aimed at, and including images of, women drivers and the product with its harsh, plain and unappealing appearance, at that time. The industry also saw the way to rectify this, by seeking new paint technologies that enabled them to reintroduce more colours, in ways not possible since the end of hand-produced elite cars. This seemingly trivial change also prompted major design changes to bodywork so that a wider range of elegant (feminised?) bodywork shapes, emulating the use of modernist streamlining in elite cars, was possible for mass-produced cheap cars too. The quality of beauty expected in the domestic sphere was reintroduced to some extent in the mass-produced, quintessentially external sphere of the automobile. The car as an extension of the living space was made available to a wider range of buyers and the concept is with us still, as we shall see in the case of the Volvo YCC designs.

Still only an option for well-off women, motoring became more routine between the wars, particularly for professionals who needed transport for their work – doctors for

example. In 1936, Packard advertised its new car as ‘An exceptionally good choice for the woman motorist’, on the basis of its low cost, reliability and ease of handing[8]. In the post-WW2 traditionalist effort to relocate women’s lives in the home, after their war work, there was a lot of attention paid to modern design of consumer goods and domestic appliances, in which Sparkes[7] includes the automobile. She describes how pink was used in every possible circumstance and shade, to stamp the feminine brand upon an item. Car makers used colours freely, often using two-tone styling, with lots of chrome decoration and elaborate bodywork shapes, with rocket-fins. Whilst this type of styling might nowadays be regarded as bordering on the phallic, at the time these massive cars were advertised to the American housewife, for whom a car was essential if she was to leave her home to go anywhere in the vast suburban sprawls of the USA. Again, Sparkes likens these large cars to mobile living rooms and points out that this was no accident, since all the major US car makers employed female designers at this time, to ensure they were getting it right for the female target market.

In the 1960s, Fords advertised their Anglia car in a number of ways that aimed at the female market as well as the male. A range of “typical” users, invited to contribute their views on the car to an advertising brochure, included one woman[9] and a Ford Anglia poster invited women to buy the “world’s most exciting light car”, implying that, again, easy handling was regarded as a particularly feminine demand.

At various times since, cars “for women” have been deemed to be:

- The small car, often the family’s second car, small cheap, “runabout”, for shopping, picking the kids up.
- The massive “people carrier”, the strong, high “tank” that will armour the family against the hazards of the road and carry most of their friends too, for the shared school run.

- The small sporty car that isn't as fast as it seems.
- The cute car; small, rounded, personalised. Epitomised by the Volkswagen Beetle and Cabrio models, now considered the number one "Chick cars" for the young, single, funky woman[10].

Whilst the majority of car adverts today seem to be aimed at the status and speed oriented male market[11], rather than the female preferences for safety and drivability, there are some advertising campaigns that include women as users rather than decorative bystanders. The advertising industry knows that it has to work differently if it is to reach women: it recognises that women respond differently to use of language and images than men[12]. It is as though each generation of advertising creatives has to rediscover the female car buying market, all over again.

Women as workers in the car manufacturing industry

As a contrast to women's involvement as car buyers and drivers since the industry's pioneering days, women's position as workers in the automobile manufacturing industry developed slowly and rather later. At the time of the invention of the car, Victorian ideals of womanhood were at their most restrictive. In 1888 women could not vote, they were only just starting to get access to secondary education and only a few European universities would admit female students. Women were idealised as wives and mothers, primarily in the private sphere of the home. Poor women, of course, had to work outside the home and rich women could use their wealth to allow themselves freedoms denied to their middleclass sisters. The history of women in engineering is still little known and, ironically, we may currently know more about semi-skilled women's work in factories than we do about the few women who were able to find ways of working at a higher professional level in any aspect of engineering. As with Berta Benz, it is evident that women in car manufacturing

families were involved at a practical level and may perhaps have learnt some metalworking skills informally. Initially, most cars were made by hand by skilled craftsMEN – a field literally locked closed against women until the First World War came. By this time car makers were starting to use Ford's production line system and the whole industry was no longer solely the preserve of the rich enthusiast – it was a mass market. Even though many car factories converted to war work, the remainder continued and needed to replace the men lost at war, with women. In 1915 about a third of Ford employees were women, by the end of the war this had risen to one half[1]. This situation was replicated across the USA and European car plants. After the war women were expelled from their jobs, more or less forcibly, as in most of the metal industries, to make room for the men returning from the war.

Even in the heyday of European car manufacturing, in the 1960s, the lines were mainly male, with women only working in the sewing rooms, making upholstery at lower pay than skilled men in other parts of the plant[13]. However, by the end of the 20th century, some companies had increased women's participation in the process of designing and making cars. Volvo's innovative move away from production lines to production "islands" in 1988[1] coincided with societal changes leading to a nearly even gender balance on the Swedish factory's shopfloor.

This study is, however, primarily interested in the car industry's designers and compares two attempts to create female design teams and to design a car for women. Although the most recent - the Volvo project - has been widely publicised, it seems that even the car industry itself knows so little of its own history that it is not aware of the precedent set 80 years ago. Nor does the industry significantly celebrate other women who have been involved in car design in that time. This paper aims to ignite some interest in them and to consider whether their intentions and objectives have changed.

Method

Women's involvement in the higher reaches of car manufacture – design and supervision has been both rare and rarely written about. This research compares two small groups of women about 80 years apart. In the earlier case, most of the information available pertains to an individual (Pullinger) about whom much information came from her son. The Myreton Motor Museum has one of the few extant examples of the car she was involved in making, and the staff there were most helpful with information.

Using a biographical approach to look at the lives and work of women who design cars, this paper seeks similarities and differences between the two periods.

In the case of the recent, well-publicised, Volvo concept car, I the company's publicity material and other media information has been used extensively. Other literature and archival material has been sought from libraries and online archives, primarily relating to the history of the car industry.

Dorothée Pullinger and the Galloway

Dorothée Aurélie Marianne Pullinger, MBE, was born in Calais, France, on the 13th January 1892, the eldest of the 12 children of Aurélie Bérénice Sitwell and Thomas Charles Pullinger. Her father was a well-known automobile designer who had previously worked for Darracq and Teste de Moret in France. Returning to Britain, in 1902, he introduced many continental ideas to British car makers and worked for several automobile manufacturers: Sunbeam, Humber and, finally, Arrol Johnston's factory at Paisley.

Dorothée attended Loughborough Girls Grammar School and, at the age of 16, joined her father, who was managing director at Sir William Beardmore's Arrol Johnston car works in Paisley. She did drawing office work, and converted German aero engine designs from metric to imperial measurements for UK use[14]. These four years of experience with car and aero engines, plus her bilingual ability with French, led to her being "headhunted" by Vickers, at the onset of the first World War. She was employed by them to supervise the thousands of women munitions workers they had in Barrow-in-Furness, many of whom were French or Belgian refugees. She started a women's apprenticeship scheme and managed the female staff, who had their own football team. This high level of responsibility at such a young age won her an MBE after the war.

When the war ended, she returned to Scotland and Arrol Johnstons, this time at their works in Tongland, Dumfries and Galloway. This was a new factory, specially built during the war, as an experimental effort to establish a "University for women engineers" training women to be professional engineers[15]. The factory was of the most modern design, with a canteen and rooftop tennis court. The women lived in a purpose-built hostel nearby and were expected to follow a specially-devised apprenticeship, initially supervised by Dorothy Rowbotham. The aim was to attract middle class women but the extremely isolated environment eventually discouraged many and ultimately the workers were predominantly local women and the educational side quietly allowed to decline.

Post-war, Arrol Johnstons needed to get back into the mainstream of car production again and one of their efforts was to turn the Tongland plant, and its women workers, over to the production of a small, economical car. The product made by the women was the Galloway car, which remained in production until 1925. They were produced

with an all-female workforce under the supervision of Dorothée Pullinger. The car design was based on an existing Arrol Johnston car, (10/20 CV, 4 cylinders, and 1528 cc capacity) but adapted for women.

It was a lighter, smaller version with a better sightline for the driver, a more conveniently situated handbrake, the first rear-view mirror, better storage and a reliable, easily maintained engine. The importance of some of these changes can be appreciated by trying both the "male" and "female" versions[16]. For a woman of average modern height (165cm), the former provides virtually no view of the road. The unadjustable driver's seat is very low and the only view is through the steering wheel, rather than over the top. This is made worse by an additional set of controls superimposed within the steering wheel itself, thus further obscuring what little can be seen. The handbrake, near the gear lever and beside the driver's right knee requires the user to lean so far forward to full engage it as to be actually under the dashboard. In the Galloway "woman's" car, these difficulties have been rectified, by raising the seat, reducing the size of the additional controls on the steering wheel and moving the handbrake to beside the seat.

Only a couple of hundred Galloways were built, at the Tongland site under a co-operative system, before it became evident that this was not viable and Tongland was closed. Production transferred to Heathall and ultimately about 4,000 Galloways, in a variety of sizes, were built before that too failed in 1929. Dorothée was a successful participant in various time and reliability trials, driving her 10 h.p. Galloway around the Scottish countryside, rarely losing any marks against the other male and female competitors[17].

After her marriage, to Edward Martin in 1924, Dorothée moved to the sales side of the operation, often using her own experience to sell to women customers at motor

shows. However, there was a general hostility at the time to women who were perceived to be stealing a ‘man’s job’, so she transferred her engineering skills to “taking in washing”, as she put it. She imported the latest steam-laundry machinery from the USA and started the White Service Laundries Ltd in Croydon, with her husband[18]. The main establishment, at Canterbury Road, Croydon, had its own steam-driven power station and an on-site artesian well. During the war it was on standby to be a decontamination centre in the event of a gas attack[19]. In 1940, the Nuffield Group employed her to organise women recruits to their munitions factories and she was also the only woman on a post-war government committee formed to recruit women into factories. Dorothée Pullinger died in 1986 and there is a plaque to her memory, in the Engineering Trail of Success, Barrow-in-Furness.

Volvo’s “Your Concept Car”

A concept car is a platform to try out novel ideas in appearance and performance of a car. It is not a prototype for a proposed production model, although designers would normally expect that some features would be used in the development of new production models. Volvo has a number of concept cars under consideration, each aimed at different sectors of their perceived market. Volvo was inspired by marketing guru, Martha Barletta, with her phrase: “If you meet the expectations of women, you exceed the expectations of men”.

Starting with a project management team of 5 women in March 2003, a core team of 9 women designers was put together:

- Camilla Palmertz, Project Manager
- Eva-Lisa Andersson, Project Manager
- Dr Elna Holmberg, Technical Project Manager
- Maria Widell Christiansen, Design Manager
- Tatiana Butovitsch Temm, Communications Manager

- Lena Ekelund, Deputy Technical Project Manager
- Anna Rosén, Exterior Designer
- Cynthia Charwick, Interior Designer

Maria Uggla, Color and Trim Designer

The team started by establishing the "Reference customer"[11] for whom they would design the concept car. A reference customer is neither the mean, the median, nor the modal, but a snapshot of a mythical individual on a single occasion in "her" life. Their reference woman was described as:

- A professional woman, who will be buying her own car, has money to spend, and expects to have her own way.
- Mainly interested in cars as the means to an end, as a convenience: she has been shopping, has little time to waste, is meeting her sister for lunch, has phone calls to make and yoga class to get to.
- Not transporting children.
- Having a "good hair day", wearing a jean skirt and interested in style and quality.
- She needs to find a parking spot, to stow her laptop.

The design criteria that followed from the "reference woman" were that women want everything that men want, e.g. performance, style etc, and have more demands to add:

- Better storage
- Easy to get in and out
- Good visibility
- A car that can be personalised
- High reliability leading to minimal maintenance
- Easy handling, e.g. for parking

Based on Volvo's PZEV 5-cylinder, 215bhp engine, with an integrated starter generator, the YCC demonstrates how these needs might be met. Some of these demands required radical changes, especially within the driver/passenger space[20].

Having identified the space between the front seats as the ideal place for putting items that the driver wants close-to-hand (bag, phone, keys, laptop), it was then necessary to clear the gear lever and handbrake away from that gap, and move them up to the wheel column. On the assumption that their reference woman was only rarely carrying more than one passenger, the rear seats' default position is folded, like a cinema seat, giving space behind the front seats to load larger bags from the side door. The doors themselves are, controversially, gull-wings like the failed DeLorean. This was done to enable easy entry, since the sill is part of the door and moves away on opening, but has been widely criticised as impractical in most urban parking situations.

The driver's seating position, relative to the hand and foot controls and her line of vision, were considered to be very important. The YCC solution to this is one of the more adventurous proposals: the driver's ergonomic measurements are held in a digital personal key. The key docks with the car and tells it to adjust the seat, steering column, pedals and other features, to best suit the driver and provide her with the perfect access to controls and lines of vision. The car can be set to ride in a high position or low position, for a better view or sporty feel respectively, and an Autopark function steers the car while the driver controls the speed during awkward parking situations. This technological personalisation of the interior is complemented by aesthetic possibilities for personalisation: the team wanted to create a "beautiful car". The car's seats are augmented by seat pads, which are available in a range of materials including leather or printed or embroidered fabrics, with matching carpets. Both are removable and washable

One of the most radical changes has resulted in the disappearance of the bonnet (hood). The car is as maintenance free as possible, with windscreen wash fluid being topped up from a capless filling point next to a similar fuel filling point. Hence there is no need for owners to raise a bonnet and access is therefore only available at the

service centre, where the mechanic will raise the entire front part of the bodywork, as with many trucks.

These remarkable features may not all make it into the next generation of Volvo's production line models, but some will certainly appeal to a wide enough market for Volvo to consider suitable.

What do women really, really want?

We can see a remarkable continuity of demands from women in the 80 years of car design under consideration. The Galloway, in the 1920s, aimed to be a lighter car which would be easier for women to handle, featuring the first rear-view mirror, improved sight-lines for the driver, better storage and an engine that would be easy to maintain. Eighty years later the YCC featured easy handling and "Autopark", better sight-lines, innovative storage solutions, and an engine so reliable that no access for maintenance is available to the owner.

In between these two stellar examples there have been numerous efforts to address the "women's market". At about the same time as the Galloway was in production in Scotland, across the Atlantic in the USA a few women were associated with car design at the elite end of the scale. A banking heiress, Miriam Warren Hubbard made design suggestions to the Biddle Motor Car Company[21]. In the 1930s, aviatrix and motorist Anna Biddle, whose family made Biddle cars until 1923, was working with Buckminster-Fuller on the design of his extraordinary Dymaxion car. Nissan's chief designer, Diane Allen, has reworked some of their truck and SUV designs to appeal to women buyers. In the 1940s and 50s, both Ford and General Motors employed small numbers of women in their design studios, but their influence at that time was restricted to the interior (=female/domestic) of the cars[22]. Ford's "Windstar Moms" and their Probe designer, Mimi Vandermolen; General Motors' Saturn designer, Kate Zak, and Buick Rendezvous designer, Liz Wetzel; and Daimler Chrysler's Anne

Asensio have all lead design teams on major model lines, with a specific view to appealing to the 80% of car purchase decisions that are made by women[23]. In each case, the attempt has been to start with a “male” car and adapt it to include what it is thought that women might want. Although not specifically mentioned in any of the reports about the YCC, or Galloway, the instrumentation layouts, but not the instruments themselves, were generally different from the "men's” cars from which they derived. Although it is known, from aviation research, that women read instrumentation differently from men[24], it is not clear as to whether this has ever been taken into account when designing driver controls and instrumentation. The prime features claimed for these “female” demands have been:

- Reliability
- Comfort
- Easy handling, drivability
- Convenient to use

The questions these outcomes raise would seem to be:

- Why are such criteria not the norm anyway, for all designs?
- Do men not want these same features?
- What would a car be like, if designed from first principles, on the assumption that **only** a woman was going to drive it?

In conclusion, we can see that there is a substantial level of involvement by women in car design, almost from the start. This is not well recognised and it seems that each generation finds this a surprise and hence needs to remember that women not only drive cars but also design them. Many assumptions about the role of masculinity in car design, use and marketing may be misplaced and wasteful. The features and criteria that women seek are so basic to a good car that it can be seen that such features will result in benefits for all car users.

Acknowledgements

I am indebted to the following for helping me to find sources in the history of the automobile, a new area of women's history for me: Stephen Laing, British Motor Industry Heritage Trust; Beverly Rae Kimes, Automobile Quarterly, USA; Professor Fred Amram, University of Minnesota, USA; Bill Chapin, Society of Automotive Historians, USA; Marjorie McNinch, Hagley Museum, Delaware, USA; Dr Paul Frost, Historic Vehicle Research Institute, University of Brighton, UK; and of course, Lewis Martin, Dorothée Pullinger's son, for information about her.

I am also very grateful to the **Women's Engineering Society** for providing very generous bursary support to enable me to give a lecture about Dorothée Pullinger and Volvo's YCC, at their 2005 annual conference, thus prompting me to write this paper.

References

[1] J. M. Laux, *The European Automobile Industry*, Twayne Publishers, New York, 1992.

[2] V.Scharff, *Taking the wheel: women and the coming of the automobile age,* University of New Mexico Press, 1992.

[3] The first women-motorists. *Devichnick* archive. Retrieved August 2005, from: http://www.devichnick.ru/07enauto.htm

[4] G. Holloway, *Women and work in Britain since 1840*, Routledge, 2005.

[5] R. Prior, *Motoring, the golden years,* H.C. Blossom Ltd, 1991.

[6] P. Roberts, *Any color so long as it's black, the first fifty years of automobile advertising*, David & Charles, 1976.

[7] P. Sparke, *As long as it's pink: the sexual politics of taste,* Pandora/Harper Collins, 1995.

[8] Windsor public library. Retrieved August 2005, from: http://www.windsorpubliclibrary.com/digi/wow/plants/packard.htm

[9] Ford, *First owners' reports on the Anglia,* retrieved August 2005, from: http://www.saturn1000.com/anglia/angliareport.htm

[10] T. Barrientos, What makes a "chick car"? *Seattle Times*, 13th November 2004, Retrieved September 2005, from: http://seattletimes.nwsource.com/html/nationworld/2002089891_chickcars13.html

[11] M. Backman, S. Borjesson, & F. Dahlsten, Mirroring Images: customer knowledge driven concept car development at Volvo Cars*, Executive doctoral colloquium of the Academy of Management conference*, Chalmers University of Technology, Sweden, 2004.

[12] R. White, Advertising to women, *WARC Quick Briefs*, November 2002. Retrieved September 2005, from: http://www.trial.warc.com/WARCAdvice/QickBriefs/Sample.asp

[13] H. Beynon, *Working for Ford*, Penguin,1984.

[14] This may have been the Beardmore-Halford-Pullinger aero engine, which her father was working on at the time. It was copied from the Austro-Daimler engine, but was not very reliable and was ultimately further developed by Siddeley's into the more successful Puma.

15 G.Clarsen, A fine university for women engineers: a Scottish munitions factory in World War 1, *Women's History Review*, vol.12, no.3, 2003, pp333-356.

[16] Myreton Motor Museum, near Edinburgh, Scotland has both the Galloway and its "male" predecessor and the proprietors were kind enough to let me sit in each car and try the controls. There are other examples of Galloway cars, in their various forms, in museums and private collections around the country, many in driving condition.

[17] Eskdale motor reliability trial, *Scotsman* 18th October 1921, p.7 and others.

[18] G.Clarsen, D. Pullinger, entry in *Oxford dictionary of national biography*: in association with the British Academy, H.C.G. Matthew and B. Harrison (editors), Oxford University Press, 2004.

[19] L. Martin, private communications. I am indebted to Dorothée Pullinger's son, Lewis Martin, for the recollections of his mother's life, in several personal communications, 2003-5.

[20] Volvo, Your concept car – by women for modern people. Retrieved September 2005, from: http://www.volvocars-pr.com/index.asp?par=conceptcars&pag=overview&model=195&lang=1&flash=1

[21] B. R. Kimes, A little on the Biddle, *Automobile Quarterly*, 1961, v 11, no.3, pp.313-321

[22] P. Sparke, *A century of car design*, Mitchell Beazley, 2002.

[23] J. Walczak, *Women truck designers.* Retrieved September 2005, from: http://4wheeldrive.about.com/cs/forwomenonly/a/aa062101a.htm

[24] T.R. Carretta, & M.J. Ree, A preliminary evaluation of causal models of male and female acquisition of pilot skills, *The International Journal of Aviation Psychology*, 1997, 7, 353-364