Pilots' cognition of airport movement area guidance signs

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Abstract: *Movement Area Guidance Signs (MAGS) are designed to assist pilots when they manoeuvre or taxi an aircraft on the airport prior to take-off and after landing. MAGS are standardized by ICAO and are installed on most major airports. Nevertheless, accident and incident surveys indicate the continuing prevalence of runway incursions and incorrect taxi procedures. The current study extends the findings of work carried out by the University of Newcastle into pilot perception and comprehension of airport movement signs. 18 pilot candidates with a mean age of 20 years and a mean flying experience of 25 hours were tested on their interpretation of MAGS during three simulated taxi manoeuvres. The experimental paradigm was more realistic than the University of Newcastle study in that the simulated taxi manoeuvre was performed with reference to a specific aerodrome chart. Subjects were instructed to taxi from a nominated position at Canberra airport to another nominated position at Canberra airport and were tested on their understanding of MAGS encountered en route. Participants displayed an excellent knowledge of the meaning of the MAGS. The mean score was 56.5 out of a possible 60 points or 94.25%. These results contradict the Newcastle study and indicate that MAGS are effective as a navigation aid for ground-based aircraft operations. Further work is indicated where pilots are tested on their cognition of MAGS when they simultaneously taxi an aircraft whilst performing other tasks associated with ground manoeuvres (for example, reading a pre take-off checklist).*

Introduction

Despite the best efforts of many aviation safety and regulatory authorities around the world, runway incursions continue to occur. Runway incursion remains a significant risk to the safety of aircraft (CAA, 2007). In Australia, 249 runway incursions occurred in the twelve months ending October 31 2007 (CASA, 2007). One definition of a runway incursion is 'any occurrence at an airport involving the unauthorized or unplanned presence of an aircraft, vehicle or person on the protected area of a surface designated for aircraft take-off and landing' (CAA, 2005).

Airservices Australia is currently surveying flight crews who have been involved in runway incursions and several causes have been identified. These causes include: flight crew inattention and distraction; high cockpit workload and problems with Air Traffic Control (ATC) instructions and communications. In a 2002 study carried out by Airservices Australia, all users of Sydney Airport were surveyed as to their experience of runway incursions at Sydney Airport. Most of the respondents were pilots (93%) and 56% of all respondents cited aerodrome signs as a contributing factor to the cause of runway incursions (Airservices Australia, 2002).

Aerodrome signs are standardised by the International Civil Aviation Organisation (ICAO) and they are recommended for use at all international airports (ICAO, 1999). Aerodrome signs pertaining to the ground-based navigation of aircraft and vehicles on airports are referred to as movement area guidance signs (MAGS).

MAGS have been used at Australian major airports since the mid-1990s. As well as being included in CASA pilot information documentation, the design, types and purpose of airport MAGS were the subject of a CASA publication that was distributed to Australian licenced pilots in 2006. This publication is also available online.

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Carrick, Pfister, Potter, & Ng, (2004) state that airport MAGS are mounted on a concrete slab, concrete pedestal or angle iron stakes so that the top of the sign is level. Signs are orientated so that the face of the sign is perpendicular to the taxiway or runway. For special situations, signs may be cantered to improve visibility. The signs are located adjacent to taxiways and runways with the distance from the edge of the taxiway being a compromise between visibility and clearance for aircraft. The signs are generally located before an intersection on the left side of the taxiway (the side of the Commander's seat in an aircraft cockpit). Confusion can arise when a number of intersecting taxiways are encountered - the sign may correspond to the approaching intersection or the intersection just passed (Carrick et al, 2004).

According to Andre (1995), taxi manoeuvre technologies have not changed for many years. The technologies available to pilots to assist them in navigating the airport surface consist mainly of compass heading indicators. Pilots are provided with an airport chart which illustrates the airport layout and designates runways, taxiways and concourses. Reports from pilots indicate that these maps can be confusing, cluttered and difficult to read and may require extensive head-down time (Andre, 1995). Also, pilots are provided with little or no specific information about their current position other than that determined from airport signage and airport charts. These charts also have to be translated by the pilot to the out-of-window view. This requires mental rotation of the north-up chart to their actual heading. The complexity of the airport also compounds the difficulty of the taxi manoeuvre. Airports can consist of a tangled network of taxiways and runways recognised only by signs and painted markings. As these signs cannot be located overhead (like road networks) they are positioned to the side on grass or cement islands. Airport surface navigation errors are often attributed to the obligatory atypical positioning of these signs and complex taxiway geometry (Hooey & Foyle, 2001).

Though the design specifications of MAGS are obvious and consistent, it is not clear whether pilots have been trained in understanding the signs, or instructed in their logic. Krey (2000) confirms that evidence from pilot discussions reveals that this knowledge is never taught and it is uncertain whether individual pilots comprehend the conventions used. According to Foyle, Andre, McCann, Wenzel, Begault, & Battiste, (1996) pilots perceive that manoeuvring their aircraft on the airport surface is one of the least technologically sophisticated components of the airspace operating system.

Carrick et al (2004) maintains that the human factors associated with airport MAGS and their usefulness falls into three categories: the ergonomics of the sign and the aircraft; the capacity of the user to see, interpret and use the signs correctly; and the organisational issues associated with airport activity.

Laboratory versus Field Studies

When a pilot taxis an aircraft prior to take-off or after landing, or when a person drives a car, train or truck, many tasks must be performed simultaneously. According to Castro, Horberry and Tornay (2004), this is one of the criticisms of a simplified laboratory approach to understanding driver behaviour. Even so, many research facilities exist to test driver reaction to traffic signage in controlled realistic conditions (Castro et al, 2004).

There are many methodologies of measuring the effectiveness of transport signs using driver-centred paradigms. Castro et al (2004) maintain that these include the recording of eye movements, sign recognition, naming and subjective opinions, as well as recall (tested by questioning drivers about the traffic sign that they had already passed) and the analysis of traffic accidents attributed to poor signage.

Castro, Tornay, Moreno-Ríos, Vargas & Molina (2005) maintain that psychological research about traffic signs has been an active field in the last few decades. The literature has concentrated on aspects of perception and awareness (such as how to improve sign identification); memory (sign recall) and motivational issues (increasing compliance). The psychology of reasoning has also devoted a great deal of effort and time to the study of representation and use of logical information on traffic signs. This research has provided many insights about the way traffic users understand and process information from traffic signs (Castro et al, 2005).

Carrick and Nicholas (2003) assessed the knowledge of 21 Australian pilots regarding the meaning of standard MAGS and aerodrome markings. Their subjects were shown nine photographs depicting various MAGS and various aerodrome markings. They reported that, overall, their subjects displayed a poor knowledge of the meaning of such signs. Nine fully correct answers to questions relating to the nine photographs scored 36. Their subjects mean score was 16.14 (SD = 7.10) with a range of 2 to 27. Carrick and Nicholas (2003) found that the poor knowledge was not related to the type of operation (general aviation versus military/commercial) or hours of flying experience; nor by type of airport used in gaining that experience.

The aim of the current study was to investigate the level of knowledge and understanding of MAGS in a driver-centred paradigm. An experimental paradigm was employed which created a more operational aviation scenario than the Carrick and Nicholas (2003) study.

Method

Participants

Participants were recruited from a class of third-year Bachelor of Technology (Aviation) students. The eighteen subjects had a mean age of 20 years and flying experience ranging from 15 to 100 hours. Apart from approximately 15 hours of flying experience gained as part of a military flight ability assessment program, the subjects had not commenced the flight training component of their degree program.

Materials

A Cessna 182 RG aircraft was used to taxi at Canberra Airport to photograph all the MAGS. The photograph editing software – Photoshop – was used to process the photographs of the MAGS in order to eliminate any peripheral information and visual cues. A computer was used to present the edited pictures of the MAGS to the subjects.

The subjects were supplied with an Airservices Australia Canberra Aerodrome chart.

A questionnaire pertaining to the viewed MAGS was constructed and supplied to each subject.

Design and Procedure

A Cessna 182 RG general aviation aircraft was taxied along all the taxiways and across all the surface manoeuvring areas at Canberra Airport. At each runway and taxiway intersection and junction thereof, a photograph was taken of the adjacent MAG(S).

These photographs were processed so as to eliminate any peripheral information and visual cues. The edited photographs were loaded on to a computer in the order of a planned aircraft taxi manoeuvre from a designated point on the aerodrome to another designated point on the aerodrome. Three such taxi manoeuvres were constructed.

The subjects were seated in front of a computer screen and briefed that they were about to perform a taxi manoeuvre from a point on the aerodrome to another point on the aerodrome. For example, a parking position adjacent to the Royal Australian Air Force 34 Squadron hangar to a parking position in the general aviation parking area. This taxi manoeuvre would take the subject across the aerodrome via taxiways and across two runways during daytime (both runways to be considered active). Subjects were briefed to answer the investigator's questions reactively – as if the subject were actually taxiing past MAGS in an aircraft. Pictures of each taxiway intersection or junction encountered en route were then presented to the subject in sequential order. At each new presentation of the picture of the MAGS the subject was questioned regarding the meaning and interpretation of the MAG(S). The subject's answer was recorded on the questionnaire.

Results

Each participant's response to each image of the MAG was scored from zero (plainly wrong or no answer offered) to four (a fully correct response). The highest possible total score was 60.

The participants exhibited a very good knowledge and understanding of MAGS. The mean score was 56.6 (ie. 94.24%) with standard deviation of 5.0. The range of scores was 43 to 60. Seven participants achieved the maximum score of 60. Scores were grouped in categories encompassing a score range of five and are shown as a frequency distribution histogram in figure 1.

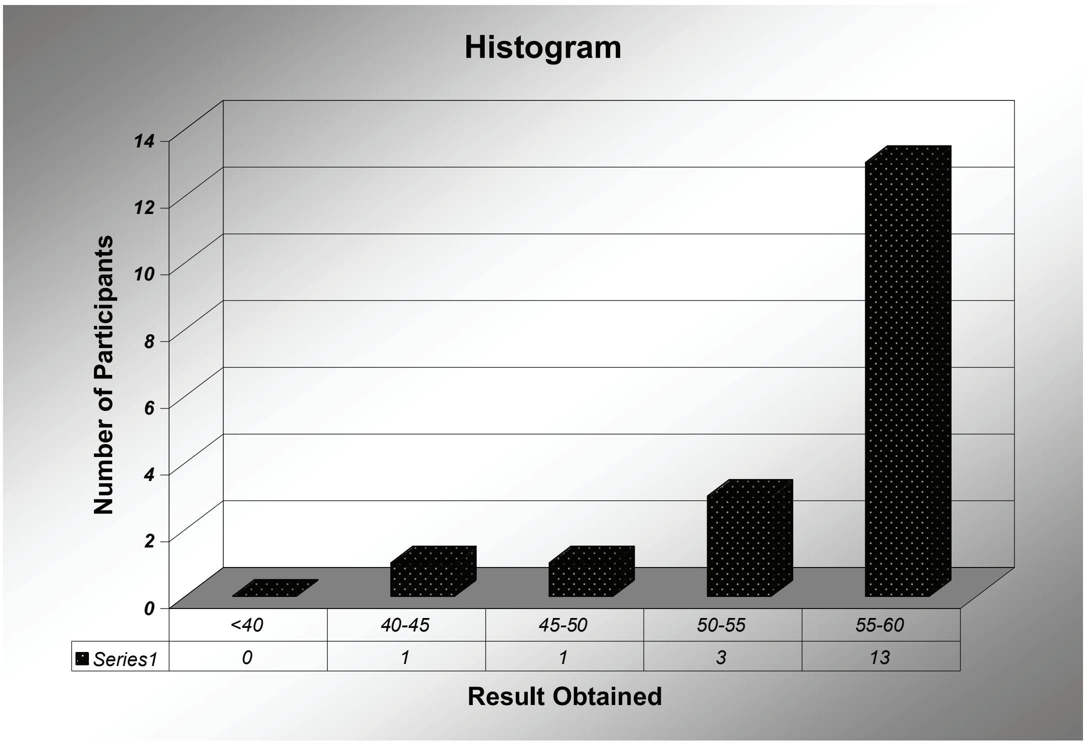

Figure 1. Scores of participants grouped in categories encompassing a score range of five.

Discussion

In a driver-centred experimental paradigm, participants with a very low experience of flying and practical aviation operations, exhibited a high level of knowledge and understanding of MAGS. Combined with an Airservices Australia aerodrome chart, the participants navigated themselves across a major airport with reference to a series of MAGS. In creating a context of a more operationally-based aviation scenario to that employed by Carrick and Nicholas (2003), participants were able to give a meaningful and accurate interpretation of the MAGS.

The importance of the Airservices Australia aerodrome chart in this investigation appears to be quite significant. An analysis of the questionnaire answers revealed that many participants mapped out each taxi scenario on the Airservices Australia aerodrome chart in order to gain an understanding of their location, the location of the signs and an overall sense of orientation.

The previous investigation conducted by Carrick and Nicholas (2003) tested the effectiveness of airport MAGS by providing pilots and post-graduate aviation students with a questionnaire that consisted of nine photographs of airport markings and MAGS. This questionnaire was a stand-alone document and no information was attached to provide the test subjects with any understanding of the meaning of the markings or signs. This lack of cues would have placed doubt in the minds of the participants on the location of the MAGS and markings and also the airport layout. MAGS and marking by themselves may provide no real indications of their meaning and may not show whether they are effective in their design as a ground-based navigation aid. The results obtained by Carrick and Nicholas (2003) indicated that their participants displayed a poor knowledge of MAGS - 44.8%. This result bears comparison to the present study where the level of knowledge of MAGS was assessed to be 94.25%.

At major airports, when a pilot is ready to taxi an aircraft from (say) the parking area or terminal gate to the runway in preparation for take-off, they receive a taxiway clearance from ground or surface movement control. This clearance may provide the aircrew with information on which taxiways to take, also clearances and other important information. After reading back this information to ground or surface movement control, a pilot usually refers to an Airservices Australia aerodrome chart and forms a mental picture of the required taxi manoeuvre. While a pilot is taxiing an aircraft he or she may refer to the Airservices Australia aerodrome chart to ensure they are heading in the right direction. In combination with the Airservices Australia aerodrome chart, MAGS may provide the pilot with a measure of self-assurance of upcoming turns and a confirmation of the location of the aircraft on the airport surface.

This finding is consistent with the methodology and design behind MAGS and traffic signs. The principles used in the development of MAGS and similar signs have been modified and improved in the land transport and aviation industry. Rules and regulations have also been incorporated to ensure that the signs are universal and conform to a set of standards.

The design of this investigation was very simple – an outcome was to see if MAGS, by themselves, may be easily ‘read’ by aircrew taxiing an aircraft. The finding of this investigation that participants with scant operational aeronautical experience can comprehend and understand the meaning of MAGS begs the question as to the contribution or otherwise of MAGS to runway incursions.

In a work describing some of the technological solutions to the problem of a rising trend in the numbers of runway incursions, Young and Jones (2001) detail some of the factors that presently contribute to runway incursions. These include: traffic congestion; increased airport layout complexity; low visibility; radio communication congestion; night operations. Further work is indicated regarding the 'readability' of MAGS where the 'readability' of MAGS is combined with some or all of these factors.

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