Nunes, A. (2004) An empirical investigation into the effects of controller experience on conflict detection ability under Free Flight. Proceedings of the 48th Annual Chapter Meeting of the Human Factors and Ergonomics Society, September 20 - 24, 2004, New Orleans, LA, USA.

# AN EMPIRICAL INVESTIGATION OF THE EFFECTS OF CONTROLLER EXPERIENCE ON CONFLICT DETECTION ABILITY UNDER FREE FLIGHT

Ashley Nunes*
Department of Psychology, Yale University
New Haven, CT

* Currently at University of Illinois, Aviation Human Factors Division

The progression towards the implementation of Free Flight has raised concerns over lapses in a controller's ability to detect the presence of conflicts amongst multiple aircraft pairs. These concerns have been supported through numerous empirical studies. An issue that has not received much attention is the impact of controller experience on conflict detection ability under Free flight. In the present study, fourteen controllers performed a conflict detection task. Variables manipulated included experience level and traffic load and controller performance was assessed using response time and accuracy as measures. Results from the study surprisingly suggest that controllers with more experience take longer to ascertain conflict likelihood under free flight conditions compared to their novice counterparts, even when the age factor is accounted for. We attribute the presence of the effect to the greater reliance on conventional cues, such as a route structure, and postulate that the absence of such cues produce the observed effects. The implications of these findings are discussed.

## INTRODUCTION

The provision of a safe and effective air traffic service by a controller is dependent on his/her ability to maintain adequate situation awareness (SA). The maintenance of SA in turn is aided by the procedures in effect in the current air traffic control (ATC) system. Amongst the most important of these is the restricting of travel to specified highways in the sky, known as airways (Fig. 1). Because aircraft travel along specified corridors, the controller gains a more accurate representation of where the aircraft will likely be by envisaging the relative flow of traffic along a particular airway using the radar screen. Airway usage also reduces the number of points where aircraft traveling on different routes are likely to collide with one another. Knowledge of these 'hot-spots' is stored in the underlying mental model. Collectively, an up-to-date mental model and good SA support conflict detection.

Increases in traffic have put tremendous strain on the ATC system, prompting much interest in Free Flight (FF), a concept promising reductions in air delay. A critical component of achieving reductions in air delay is the dissolution of the current route structure, which currently accounts for only 5% of available airspace. However, in doing so, a pattern of traffic flow may be lost. The route structure provides a great deal of information necessary for projecting how aircraft will transition across airspace and with whom they might have separation problems (Endsley et al, 1999). Therefore, elimination of this structure could adversely affect a controller's ability to determine where an aircraft will most likely be at some point in the future. This statement has been supported by empirical work from at least two previous studies (Endsley, Mogford, & Stein, 1997; Endsley et al, 1999).

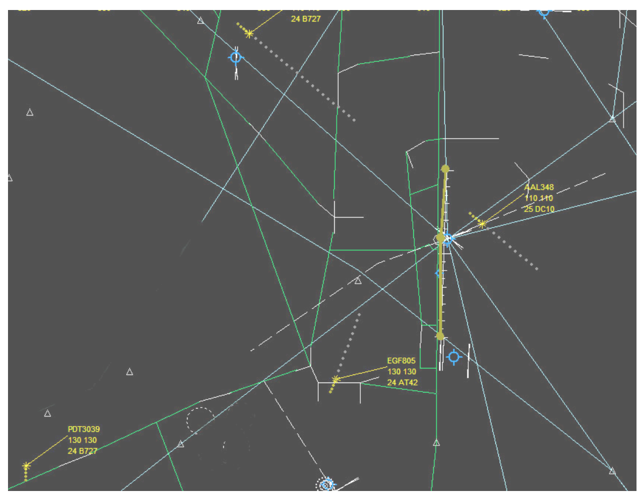

Figure 1: Radar screen depicting airways

### Experience & Age Considerations

However, the use of fully-fledged controllers used in previous FF-oriented research studies raises the issue that these individuals already have established mental models about what the ATC system should look like and how it should function on a day-to-day basis. Due to training, these controllers rely heavily on route structure and knowledge of sector 'hot-spots' to successfully perform their task. Hence, their strategies for controlling traffic may not transfer appropriately to a FF environment, resulting in a negative performance bias – lack of transfer may be one explanation of results attained in previous studies. The nature of the relationship existing between general controller experience and negative performance bias remains unclear.

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Perhaps negative transfer of training effects increase with experiences; the greater the experience level of the controller in the present system, the greater the performance detriment observed in a FF environment. This supposition assumes that a greater amount of time spent operating in a conventional ATC environment makes the controller more reliant on route structure and sector hot-spots. When these cues are taken away, a more experienced controller may have difficulty in utilizing a new set of cues. Ironically, greater performance detriments amongst more experienced controllers may occur under FF. As FF becomes a reality, controllers will be required to provide a service in an environment that differs markedly from their current situation. If experience causes a performance detriment under FF, it would suggest a need for emphasized training for certain segments of the controller population.

It is recognized however that performance detriments observed amongst the more experienced controller population may be attributed to age, given that age and experience are confounded with one another. It is a factor that is nonetheless worthy of consideration given that in the North America, there is a relatively fixed cohort of ATC specialists who are moving through the workforce (Becker & Milke, 1998), whose median age, currently at 41 will have reached 45 by 2006. The prospect of an aging controller population raises the issue of whether the same cognitive decline observed in the general population may also be observed amongst older controllers, and whether or not such declines may be magnified under certain FF conditions. Only one known empirical study has directly tackled the age/experience issue. Becker & Milke (1998) conducted a study that assessed the impact of age and experience on performance (quantified by time and accuracy) on an ATC task. The researchers documented a significant negative correlation between controller age and task performance in a structured environment, not unlike the one they currently operate in. However, whereas the study also found that experience could mitigate the effects of age-related decline, it did not specifically assess the extent to which experience can hurt performance under FF conditions over and above the already observed age-effects, a major focus of the efforts described here.

*Current Study:* The present study had two goals. First, to determine whether operational experience adversely affects controller performance under FF conditions. Second, to investigate how experience mediates the effects of traffic load on performance. Due to the tremendous increase in traffic volume that FF implementation promises, any interaction of experience and traffic load on performance effects of traffic load is important. It was predicted that the performance of controllers with more experience would be lower than those with less experience, this hypothesis being based on the degree of transfer of training argument previously discussed. An interaction between experience and traffic load was also predicted, whereby traffic load would amplify any effects experience may have on performance.

## METHOD

### Participants

Fourteen licensed controllers from a Canadian ATC facility participated in the present study, with union approval. The ages of the controllers, who were all male, ranged from 31 to 57 (mean = 40.2), with an experience range of 5 to 30 years (mean = 13.6). Monetary compensation was provided for participation in the study.

### Task

The task of the controller in the present study was to determine whether or not a conflict was present between a pair of aircraft on a radar screen that depicted a 60 * 60 mile sector of airspace. To make the task more challenging, a (systematically varied) number of distracter aircraft were also present so that controllers had to first find the target pair amongst the distracters and then provide their assessment of conflict likelihood. The target aircraft pair was always traveling at the same altitude, whereas all distracters were traveling at different altitudes. To limit possible confounds by extraneous variables, all aircraft traveled at the same speed and the target aircraft pair reached their point of closest approach (CPA) approximately five minutes into the trial. A conflict was defined as a situation where the aircraft came less than 5 miles from one another. A non-conflict situation arose when the CPA between the aircraft was greater than 5 miles. The distribution of conflict and non-conflict trials was equal.

### Apparatus and Display

The ARTT Radar Simulation was used in the present study to generate and run the scenarios. The simulation was presented on a 15” monitor and each aircraft’s data-tag was presented in such a manner as to ensure that the controller’s view of other traffic was not obstructed. To simulate a FF environment, there were no airways or ‘hot-spots’ depicted on the radar screen. Finally, initial aircraft positions were chosen randomly to ensure novelty of each scenario (Fig. 2).

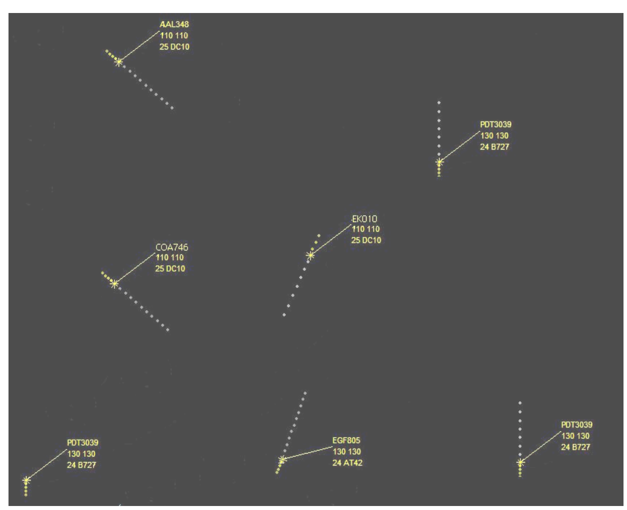


Figure 2: Radar Screen (FF condition)

**Design & Variables**

A mixed design was used for the experiment and two independent variables were manipulated. They were experience level, which served as a between-subjects variable and traffic load, which served as a within-subjects variable.

*I. Experience*: The fourteen controllers selected for the study were rank ordered by experience and a median split was performed. They were then assigned to one of two groups. The less experienced group consisted of seven controllers whose experience level ranged between 5 and 11 years (mean = 7.5) whereas the experience level of the more experienced group ranged between 15 and 30 years (mean = 20).

*II. Traffic Load*: The number of aircraft present on the radar screen for each trial served as an independent variable. Three different variations of traffic load were tested (four, six and eight aircraft).

Two dependent variables were used to assess performance. They were response time and response accuracy.

*I. Response time:* Time taken for the controller to provide a response regarding conflict likelihood from the onset of the trial.

*II. Response accuracy:* Evaluation of the correctness of a controller's response to conflict presence/absence on each trial. An overall score was computed and expressed as a percentage correct.

**Procedure**

Subjects were informed about the nature of the experiment, conditions of testing, experimental protocol and potential risks during an introductory briefing. At this time, they were also made familiar with the hardware being used for running the experiment and given verbal instructions for the task to be performed. This instruction set familiarized the participant with the radar screen, aircraft symbology and task demands. Subjects then viewed multiple practice trials to familiarize them with the simulation. Following this, the experiment began, with participants experiencing 90 trials that were presented in two blocks of 45. Each trial began with the aircraft (target and distracter), their associated data-tags, leader lines and history trails being fully visible to on the radar screen and the radar image was updated once every 5 seconds. The controller had to provide a dichotomous response regarding conflict presence (yes/no), and response time as well as response accuracy was recorded for each trial by the computer. Following completion of the two blocks, controllers were debriefed and compensated for participation

**RESULTS**

Data from the experiment was subjected to a repeated measures analysis of variance (ANOVA) and significant effects were identified. Analysis of response time data revealed a significant main effect for experience level ($F(1,12) = 13.34$, $p < 0.01$) and traffic load ($F(2,24)=64.37$, $p < 0.01$). However, both main effects must be considered in light of their significant interaction ($F(2,24)=4.41$, $p < 0.05$), which suggests that whereas more experienced controllers took longer to ascertain conflict likelihood, this temporal cost was magnified when traffic load was high (Fig. 3). Analysis of response accuracy data revealed a significant main effect for traffic load ($F(2,24)=3.57$, $p < 0.05$), highlighting the difficulty associated with conflict detection as aircraft density increases. However the main effect for experience was non-significant ($F(1,12)=0.02$, $P > 0.88$), as was the interaction between traffic load and experience ($F(2,24)=0.41$, $p > 0.66$).

To examine the robustness of the effects of experience, a correlation between the number of years of operational experience and response time/accuracy was conducted, partialing out the effects of controller age, which may have been a confounding factor, as has been demonstrated in previous work (Becker & Milke, 1998). Although, the detrimental effects associated with higher experience levels were more profound for response time ($r = 0.53$, $p<0.03$: Fig. 4) than response accuracy measures ($r = 0.\ 15$, $p>0.31$: Fig. 5), collectively the evidence does support the notion that whereas increased latency amongst older controller may be due to age, a significant portion of variance may also be due to increased experience levels.

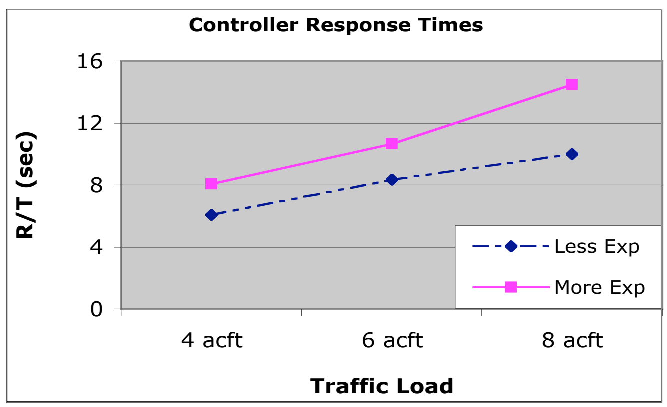


Figure. 3: Response Times

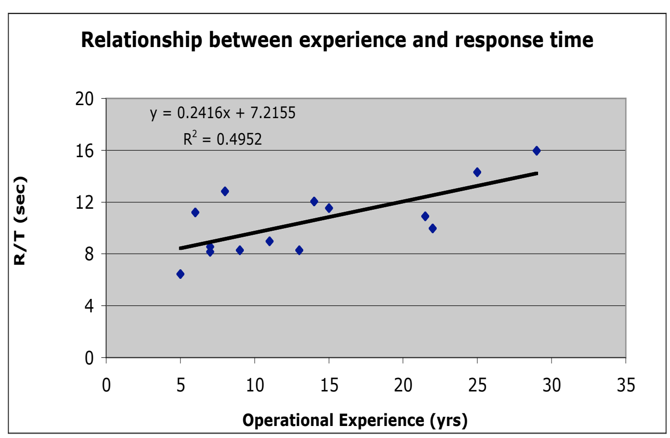


Figure 4: Experience/Response Time Relationship

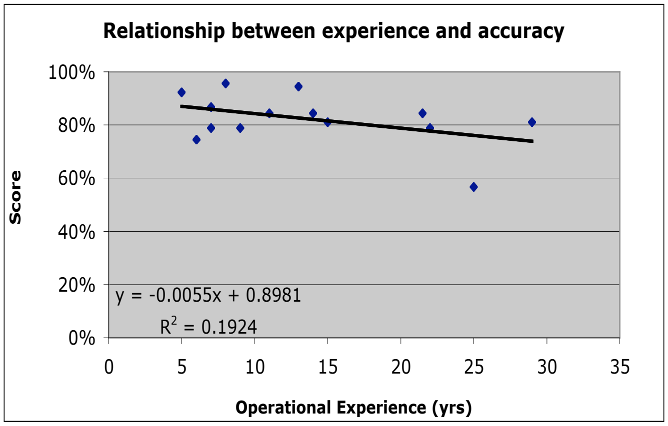


Figure 5: Experience/Response Accuracy Relationship

## DISCUSSION

A major focus of this study was to determine whether previous operational experience adversely affects controller performance under FF conditions. It was predicted that an experienced controller's reliance on conventional cues (airways structure, knowledge of sector 'hotspots') to perform conflict detection was greater compared to his/her novice counterpart and that greater reliance would result in more a profound performance detriment under FF conditions. Whereas support for this was found in both performance measures, evidence was stronger for the response time data. We found that more experienced controllers took longer to arrive at an assessment of conflict likelihood compared to their novice counterparts with increases in traffic load magnifying the expert/novice effect. This effect is particularly intriguing given that previous work has found that controllers are capable of employing unique strategies in order to ensure that task performance is not compromised (e.g.: Sperandio, 1971, 1978) and intuitively speaking, one would expect both the number and diversity of strategies to be greater for more experienced controllers, given that they have more time on the job: this should enable them to attain performance that is either equal to or greater than less experienced controllers. However, note once again that the works of Sperandio examined performance strategies in a conventional ATC environment, versus the FF version tested here: a critical difference that we postulate may account for the discrepancy in results.

The expertise effects (or side-effects) observed here are however confounded by age, given that a more experienced controller will usually be one who is older than a novice. This reality makes it difficult to deconfound the relationship between age and experience. Therefore, the temporal costs observed in the present study may just be due to the more experienced controller group being part of an older population. On average, the older population tends to perform less efficiently as their younger counterparts as has been demonstrated in studies from various domains (e.g.: Kramer, Larish & Strayer, 1995). However, we do not believe this to be the case for two reasons. Firstly, the ATC domain is not one that affords the operator the luxury of time; a controller, regardless of age, must be able to detect a conflict in an efficient manner without any loss in accuracy. Secondly, analysis of the relationship between experience and response time, partialing out the effects of age still revealed a significant correlation between the two variables, highlighting the robustness of this relationship. Therefore, a more plausible explanation for the 'expert' temporal cost is related to a greater negative performance bias exhibited by individuals with more operational experience. Greater exposure to the conventional ATC system not only results in more familiarity with the system but also greater reliance on that system's cues. When the operator is placed in a new environment (such as FF), a detriment in performance naturally occurs. The results in the present study empirically demonstrate that magnitude of the detriments observed is related to the amount of experience the human has had working in a conventional ATC system; higher the experience level, greater the performance detriment.

## CONCLUSION

From a practical standpoint, FF implementation will not begin with the usage of 'new controllers' who are only experienced in providing a service under advanced ATC operations. Nor will it begin with old controllers working a system in which they have had no training at all. FF implementation will be a gradual process in which controllers working under current conditions will have to be trained to work in a new system: one which lacks many of the cues they would conventionally rely on. The results presented here suggest that the magnitude of the performance detriment observed as a result of FF implementation, may vary as a function of previous operational experience. Consequently, it may prudent to ensure the amount of training received by controllers who work under this new system be proportional to their prior operational experience: only in doing so will safe separation between aircraft be maintained.

## ACKNOWLEDGEMENTS

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