Air Traffic Control Communications Simulation: Frequency Chatter and Aircrew Behavior

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Aircrew training and evaluation in airline operations is conducted almost exclusively in ground-based flight training devices or flight simulators. These devices are capable of providing levels of operational realism that are often indistinguishable from the real world flight environment. In visual scene and sound generation, manual control feel, instrument display, and motion disturbance cueing, the modern airline simulator can immerse aircrews in an cockpit environment of unparalleled realism.

In some areas of flight simulation, however, technology has not evolved as rapidly as in others. Realistic simulation of the air traffic environment, particularly air traffic communications, is notably lacking in even the most advanced airline flight simulators. A survey of instructor/evaluators (I/Es) in U.S. air carriers revealed that air traffic control (ATC) communications have to be provided by the I/Es playing the role of air traffic controllers (Burke-Cohen, Kendra, Kanki, and Lee, 2000). These ATC communications[1] to the simulated aircraft, or "ownship" communications, are provided by the I/Es in addition to their teaching and evaluation tasks. The same survey found that the other main element of ATC communications simulation, communications transmitted to other aircraft on the ownship's radio frequency or "frequency chatter", is only rarely simulated. Frequency chatter simulation is particularly pertinent to airline operations training as their aircraft routinely operate in high traffic environments where radio communications frequencies are in heavy use.

There are two main reasons why ATC communications simulation has lagged behind other aspects of flight simulation technology development. The first reason is technical. To automatically recreate ATC ownship communications comparable to that of a professional air traffic controller would require a very high level of voice recognition capability and reliability. This advanced level of voice recognition technology has yet to be demonstrated for the type of speaker-independent, continuous voice recognition needed in an aircrew training environment (Lee, 1999). Such a system would also need to have sufficient intelligence to comprehend the meaning of pilot communications within the current flight scenario context and be able to generate a plausible controller communication in response to pilot queries. This level of intelligence and natural language understanding has proven difficult and costly to develop. In the area of frequency chatter simulation, some limited success has been achieved in the realistic generation of frequency chatter. But the systems are difficult to tailor to individual air carrier needs and their need for frequent updating[2] can be problematic given the very limited resources available in training organizations.

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[1] ATC communications include pre-departure clearances, takeoff and enroute clearances, traffic calls, and approach, landing and taxi clearances. The I/E also needs to provide airport and weather information and may need to simulate automated terminal information systems such as ATIS and ASOS.
[2] Volatility in the airline industry means changes to routings and even airline closures so that their presence in simulated radio traffic is no longer appropriate. ATC clearance and other information given in frequency

The second impediment to the provision of realistic ATC communications simulation is the lack of a regulatory requirement that could serve to justify the cost of the technology. Currently, there are no FAA requirements for ATC communications simulation in flight simulators or flight training devices. Thus, there exists no justification for ATC communications simulation technology based on the regulatory compliance that exists in other areas of flight simulation, such as visual scene generation and motion cueing. Finally, while there is little disagreement with the need for providing realistic ATC communications simulation in flight simulation, the training benefit of this aspect of flight simulation is less clear.

Two studies have recently been conducted which provide some evidence of training value that may be associated with improved ATC simulation fidelity. The first study (Lee, 2001) examined the effects of realistic ATC communications simulation in a line-oriented simulation using an FAA-approved flight simulator and crews currently flying the simulated aircraft (a B747-400). Crew performance was evaluated under both low and high fidelity ATC communications simulation in a line-oriented simulation. In the low fidelity condition, I/Es provided all ATC ownship communications, but no frequency chatter simulation was provided. In the high fidelity ATC condition, ownship communications and frequency chatter was simulated by professional controllers. Significant differences were revealed in communications management, crew workload, and perceived realism. Increased crew-initiated ATC communications were evident in crews exposed to the high fidelity ATC condition. The crews also rated their workload as more comparable to actual flight operations and the simulation as generally more realistic. While this study was carried out in the confines of a research environment, a subsequent study (Lee, 2003) was conducted in an airline training environment with crews undergoing Captain upgrade training. As with the earlier study, crew communications management was affected by increased ATC simulation fidelity. More crew-initiated ATC communications and less communication between the cockpit crew and between the cockpit crew and the simulated cabin crew were evident. Higher workload ratings and higher perceived realism were also found with higher ATC fidelity.

In the above studies, ATC communications fidelity was defined as low when an I/E provided ATC ownship communications and no frequency chatter was simulated. When a professional controller provided all ownship communications and frequency chatter was simulated, ATC fidelity was considered high. The low ATC fidelity condition in these studies was intended to simulate the level of ATC fidelity currently provided by airline training organizations. The high fidelity ATC condition was designed to approximate real-world ATC communications, a belief supported by crew comments and ratings in both studies. However, neither of these two studies addressed the independent contributions of either ownship communications or frequency chatter simulation. Identifying the relative contributions of each to crew training and evaluation is important if a cost-effective ATC simulation is to be achieved.

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chatter must also incorporate real-world changes in ATC procedures, ATC facility names, and airport related information such as runway and taxiway closures.

The present study was conducted in order to isolate the influence, if any, of one of the two key elements of ATC communications simulation – frequency chatter. The choice of this element for evaluation was based on the likelihood that, for technical and cost reasons, it is most likely to be the first element of ATC communications simulation implemented in airline simulators. While the provision of frequency chatter in flight simulators is not without technical challenges, these are more likely to be overcome within the near future than those facing ownship communications simulations (see Lee, 1999). Secondly, frequency chatter simulations are amenable to alternative, lower cost implementations which make it a much more attractive to training organization in meeting ATC communications simulation needs. For example, some training organizations have experimented with frequency chatter simulation using pre-recorded, real-world radio frequency transmissions. Finally, the absence of frequency in flight simulations, particularly line-oriented simulations, is an obvious shortcoming in simulator design given the high density communications traffic typical of air carrier operations. Both aircrews and instructors are aware of the lack of ATC realism when frequency chatter simulation is absent. The reasons cited above makes the provision of frequency chatter simulation an attractive candidate for any proposed improvements to ATC communications realism in flight simulators.

This study was designed to assess the effects, if any, of realistic frequency chatter simulation on aircrew performance in a line-oriented simulation. Of particular interest was the effect frequency chatter simulation might have on crew workload since frequency monitoring by aircrews is a common secondary task in real-world operations. The presence of realistic frequency chatter simulation may increase workload which, in turn, might affect other aspects of crew performance.

Method

Participants

Twelve instrument-rated pilots holding commercial licenses participated in the study. Pilot ages ranged from 21 to 51 yrs. (Mdn=26 yrs.). Eleven of the twelve pilots were Certified Flight Instructors. Pilot flying experience ranged from a total of 265 to 14,000 hrs (Mdn=1,100 hrs.) with total instrument pilot-in-command hours ranging from 15 to 2,174 hrs (Mdn=72 hrs.). The pilots were randomly assigned to one of six two-person crews with the constraint that age and experience differences between the pilot-flying (PF) and the pilot-not-flying (PF) were minimized within each crew. In order to allow for a comparison between PF and PNF pilots, assignments to these positions were made so that the average age and experience of pilot crew position were similar. Participants were instructed to perform crew functions, including crew briefings and checklists, as they would in actual flight operations.

Apparatus

An FAA-Approved, Level 1 Flight Training Device (FTD) was used in the study[3]. The FTD simulated a light, twin-engine, piston-powered aircraft comparable in performance to a Piper Seminole. In order to provide realistic, radio frequency chatter (FC), recordings were obtained of actual frequency chatter corresponding to the planned scenario routes. The recordings were then edited to remove communications which did not conform to weather conditions within the flight simulation scenario. Additional editing of the recordings was performed in order that the number of transmissions per minute[4] was comparable to that of high density terminal areas. All ownship communications (communications directly to the simulated aircraft) were provided by a professional air traffic controller. While FC was provided only on airport approach and departure frequencies in this study, ATC ownship communications were provided on all communications frequencies including Clearance Delivery.

Procedure

Prior to the beginning of each simulator test session, pilots were provided with route clearance, weather, fuel available and other information pertinent to the simulated flight scenario. Each crew was also provided with a 30-min. simulator familiarization period to acquaint them with simulated aircraft operations, controls and displays. This familiarization period included a takeoff and an ILS approach. The test session consisted of two legs between three local airports, each leg was approximately 35 min. in duration. Both legs were flown in Instrument Meteorological Conditions (IMC) with occasional mist and rain showers. (There were no aircraft system malfunctions or unusual weather phenomenon, such as icing, in the simulation scenario). One of the two legs contained frequency chatter on airport departure and arrival frequencies in addition to the ownship communications provided by the controller. The other leg provided only ownship communications and no frequency chatter. Order of the legs was counterbalanced across crews so that half of the crews flew the leg containing the frequency chatter first while the remaining crews flew the frequency chatter leg second. The counterbalancing was intended to minimize order effects. Following the completion of each leg, crews were required to complete the NASA-TLX workload rating scale (Hart and Staveland, 1988). The scale contains six individual rating categories with an accompanying description of what each category is intended to measure. Each pilot completed the rating scales independently. Following the completion of the test session, each pilot was required to complete a questionnaire which solicited ratings, comments and suggestion of the value of ATC communications simulation for pilot training.

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[3] An AST-300 manufactured by Aviation Simulation Technologies

[4] Combined air-to-ground and ground-to-air transmissions averaged approximately 11 per minute. A 10-second period was added within each minute where no frequency chatter occurred to allow for ownship communications.

Results

Data from this study were organized into three separate categories for analyses: 1) pilot workload rating data from the NASA-TLX workload index, 2) communications and instrument procedure errors committed by pilots during the simulation, and 3) pilot responses to the post-study questionnaire on the value and realism of ATC communications simulation.

NASA-TLX Workload Ratings

The NASA-TLX is a workload index consisting of six separate rating scales. Each scale is accompanied by a description of the workload category to which it refers. The six rating scales are: Mental Demand, Physical Demand, Temporal Demand, Effort (physical and mental), Performance and Frustration. For the purpose of analyses, the original scale was converted to a 10-pt scale.

Mean workload ratings are shown in Figure 1 as a function of frequency chatter condition collapsed across pilot position (PF, PNF). While differences appear in every rating category, the only statistically reliable differences were found in the Mental Demand ($t=2.12$, $p<.057$) and in the Effort ($t=2.77$, $p<.018$) categories. In both categories, the presence of frequency chatter increased the pilots' required mental demand and effort. The increase in rated workload for the Effort command is likely due to increases in mental effort from the frequency monitoring task as actual radio communications operations (e.g., changing a radio frequency) are the same in both FC and No-FC conditions.

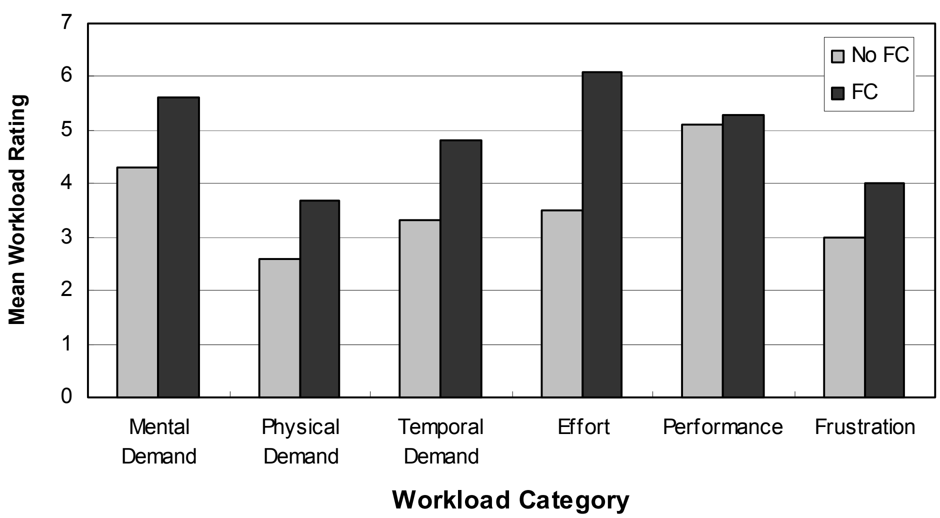

Figure 1. Mean workload ratings as a function of Frequency Chatter (FC) and No Frequency Chatter (No FC) conditions. (n=12 pilots).

Procedural Errors

Analyses of the flight simulator test session videotapes were conducted to determine whether the presence or absence of frequency chatter affected procedural errors either in air-ground communications (e.g., readback errors) or in instrument flying (e.g., failure to identify a navigation aid). Overall, very few errors of either type were found in either the FC or No-FC conditions in this study and the average number of errors did not differ reliably between the two conditions. The provision of high levels of frequency chatter simulation in this study did not appear to affect the aircrew's execution of routine communications and instrument procedures in this study.

Post-test Questionnaire

A post-test questionnaire was completed by all pilots individually following the completion of the flight simulation test session. The first question asked each pilot to rate the importance of adding ATC communication simulation to pilot simulator training. Figure 2 shows the frequency distribution of ratings given by the pilots to each importance rating category. Nine of the twelve pilots (75%) rated the addition of realistic ATC communications simulation as very important or essential. None of the pilots rated the addition of ATC communications simulation to pilot simulator training as not important.

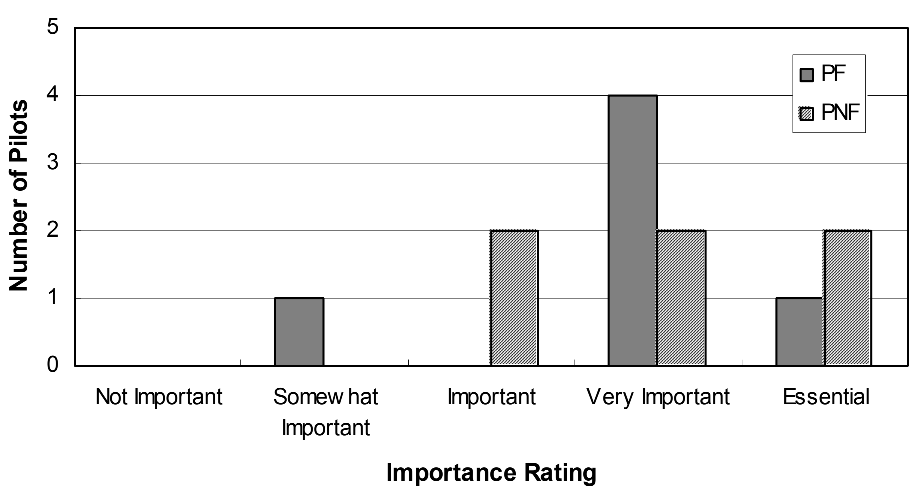

Figure 2. Pilot ratings of the importance of adding realistic ATC communications simulation to pilot simulator training. (n=12 pilots).

The questionnaire also required pilots to evaluate the relative importance to pilot simulator training of the two keys elements of realistic ATC communications: ownship communications and frequency chatter. Of the 12 pilots responding, ten (83%) indicated that *both* elements were import in simulator training. One of the pilots (8%) regarded ownship communications as solely import and one regarded frequency chatter as the important element.

A third item on the questionnaire asked participating pilots when, in the instrument and advanced flight training regimen of pilots, realistic ATC communications simulation is needed. Four of the twelve pilots (33%) indicated that it should be provided throughout basic instrument flight training. The remaining pilots (67%) thought that realistic ATC communications simulation should be provided only at the end of instrument training or whenever the trainee has achieved instrument flight skill proficiency. None of the pilots interviewed thought that it should be provided only in instrument proficiency evaluations or only during simulations used for awarding advanced ratings or licenses.

Discussion

In two earlier studies assessing the impact of high fidelity ATC communications simulation, both crew communications and crew workload were significantly effected (Lee, 2001; 2003). These studies examined the combined effects of two elements of realistic ATC communications simulation, ownship communications and frequency chatter, in line-oriented simulation scenarios. The present study examined the individual contribution of one of these elements, frequency chatter, on crew performance and workload while providing realistic ownship communications throughout the test scenario.

The study found clear evidence of the impact of frequency chatter simulation on crew mental workload as evidenced by the significant increases in the NASA TLX workload ratings. The ratings indicate that the workload impact of frequency chatter is on mental demand and effort of both crewmembers. There was no indication of a larger increase in rated workload for the PNFs in the study, despite the fact that the PNF was the crewmember primarily responsible for all ATC communications. While workload ratings showed a significant effect of frequency chatter simulation, there was no evidence that it affected the crew in its execution of instrument and communications procedures. The lack of an impact on crew performance in this study is in agreement with the findings of the previous study evaluating ATC communications simulation in airline training environment. The increases in workload ratings for the FC condition in the present study suggest, however, that a more demanding task environment may well have led to more crew procedural errors. Crew comments collected following the test session supports this hypothesis (see Appendix A).

The task of monitoring radio frequencies is considered secondary to those of aircraft control and navigation. The role that simulation of frequency chatter in flight simulator training may play is to increase secondary task loading beyond that periodically provided by the occasional ownship communication. The main benefit of FC simulation may be to allow for a systematic increase in crew mental workload throughout the flight scenario.

This is possible since FC can be provided on every frequency used in the scenario (e.g., clearance delivery, ground, tower, departure, etc.). FC transmission rates can also be systematically varied from one scenario to another. Both attributes of FC might allow the I/E to increase crew mental workload systematically[5]. The increased workload would also be more realistic than the current strategy of adding equipment malfunctions or weather-related problems.

While the present study did not assess the role of realistic ownship communications, the previous studies (Lee, 2001, 2003) both showed increased use of ATC as a resource when realistic ownship communication simulation was compared to that provided by I/Es. While realistic ATC ownship communication simulation may have some effect on crew workload, it is likely that the provision of realistic ownship communications simulation elicits resource management behavior from crews comparable to that which they would exhibit in real-world operations. A potential benefit of realistic ATC ownship communications simulation, therefore, may be the ability of I/Es to more accurately assess crew use of ATC as a resource as well as reinforcing crew air-ground communications procedures (e.g., accurate readbacks).

The analyses above suggest a potential for the two primary elements of ATC communications simulation to affect crew behavior differently. Realistic simulation of frequency chatter may serve to increase crew mental workload as crew members need to devote more cognitive resources to the frequency monitoring task. Whether this increased mental workload affects crew performance will depend upon the workload demand of the particular flight simulation scenario. Realistic simulation of ownship communications, in contrast, is more likely to elicit crew use of and interaction with ATC and therefore may provide I/Es with a more valid assessment of crew behavior than would otherwise be possible. The effective use of ATC resources is an important element of crew performance. Realistic ownship communications simulation appears to be a means by which this aspect of crew resource management behavior may be assessed.

References

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[5] The effect of increasing FC transmission rate on workload is supported only by anecdotal evidence at this time.

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Appendix A – Crew Comments

R.B. (PNF). It seems to be very beneficial as any radio chatter seems to keep a pilot from becoming too relaxed on his radio performance. Much more like actual flying when ATC chatter not related to that specific pilot is used.

P.M. (PF). Add more chatter that may confuse the pilot. This helps in the concentration skills/methods for the pilots.

D.A. (PNF) Perhaps add an emergency in another aircraft to the chatter. The emergency can eat a lot of air time and delay the student's necessary communications.

E.L. (PF) Be sure to keep databases for frequency chatter current! Create various voices.

J.R. (PF) ATC simulation should be given only for the simulated aircraft until basic attitude instrument skills are at a level where the student feels comfortable. The ATC chatter should be added throughout the remainder of training.

S.F. (PNF) Equipment malfunctions of any sort would have increased the difficulty even with a two man crew. Single pilot would be almost impossible.

L.K. (PNF) I felt that when the background ATC chatter came on the whole experience became ten times more realistic and my concentration increased.