Initial Assessment of the Impact of Modern Taxiing Techniques on Airport Ground Control

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ABSTRACT

Project Modern Taxiing (MoTa) studies the impact of future taxiing technologies such as Datalink and autonomous taxiing tugs on airport taxiing operations and air traffic controller workload. Seven air traffic controllers were asked to manage ground traffic in two scenarios that imposed medium and high levels of workload with three different degrees of automated technology assistance: paper strips; Datalink and path suggestion; Datalink, path suggestion, and tugs. Initial results indicate that participants were able to manage more traffic when using either just the interface or interface and tugs, but the inclusion of tugs also resulted in an increase in self-reported workload. Participants were divided on technology acceptance with no one rejecting completely the new technology.

Keywords

Airport taxiing, air traffic control, Datalink, autonomous taxiing tugs

INTRODUCTION

The aircraft traffic is increasing in the air but also on the ground [1] [2] at airports that already are close to saturation. As a consequence, collision risk, time delays, pollution, and stress for the air traffic control (ATC) officer (ATCO) are rising. However, new automated techniques are being developed, aiming at saving fuel during the ground taxiing phase. Although the environmental benefit would be interesting on its own, technologies such as the TaxiBot© system [3] may also increase the number of ground movements, or the throughput. Project Modern Taxiing (MoTa) deals with providing ground ATCOs a tool that will help with managing increased traffic and taking advantage of modern aircraft taxiing techniques when available. The tool consists of an integrated ground control interface featuring the latest progress in modern taxiing methods and multi-agent algorithms for enhanced ground automation while still supporting current and conventional ground control procedures during the transition period.

In addition to the new integrated ground control interface, autonomous taxiing tugs (inspired by the TaxiBot system) were simulated. The concept is to use the tugs to continue towing the aircraft after pushback, along the taxiways until the runway holding point, thus saving fuel since aircraft engines would be lit later in the taxiing sequence. In that manner, a departure aircraft would be handled as usual by ground control, but when the tug is detached from the aircraft after depositing it at the runway, the empty tug would return to the parking areas via the same taxiways as the rest of the traffic. It was assumed that no other infrastructure would be built to support the tugs. As the taxiing tug is still a concept and deployed at only a few airports [4] [5], different hypotheses had to be made on the future operational procedures. Since one objective of the project is to ensure that proposed solutions are robust to the ATCO's workload, the most constraining hypotheses were retained.

As MoTa is a SESAR WP-E long term research project, we assumed that the empty tugs would be autonomous and manage their own routes. Route solutions determined using a multi-agent system (MAS) are presented to the ATCO. As the suggestions are based on standard paths according to aircraft type, destination, and airline, the ATCO can gain time by simply validating the suggestion instead of creating a solution. ATCOs may modify the suggested path as necessary.

The level of service that the MoTa platform is able to provide is better due to this interaction between user and machine. First, the system can monitor the situation at various levels. For example, the system can warn the ATCO when a pilot does not follow the instructed route. Additionally, the system can detect when an aircraft has

Figure 1: MoTa ground controller interface prototype, as in use for the South ground sector at CDG. The right panel is a list of all aircraft with information regarding their CTOT or arrival time and their flight status. The areas in green are potential holding points where the ATCO could send the aircraft. The physical location of the aircraft are represented by icons (those with a rectangle represent aircraft towed by an autonomous tug)

reached the end of its clearance and advise the ATCO to transfer this aircraft so that the trajectory is continuous. An interface such as this is a natural fit for technologies such as Datalink, which was also evaluated in this project. Currently Datalink on ground is not frequently used (except for engine start-up authorization), but in the near future it could be expanded especially for lengthy, non-urgent instructions.

Several observation sessions at Toulouse-Blagnac and Roissy Charles-de-Gaulle (CDG; Paris, France) airports together with workshops with ATCOs provided sufficient material for developing realistic exercises and a platform capable of supporting ground control management. The rest of this paper discusses the final interface design, the tug management algorithms, initial results with tests conducted with seven ATCOs from CDG, and concludes with a discussion of the results and future work.

HUMAN-MACHINE INTERFACE (HMI)

The interface is based on the AVISO (the ground radar image currently in use at CDG) but includes information from the paper flight strips that are still used in France, thus capable of replacing the paper strips entirely. Together, these two technologies provide the minimum information required to manage today's ground taxiing operations.

As seen in Figure 1, flight information is displayed on the plane label and in a flight list in a concealable side panel. The standard path suggestion for an aircraft can be retrieved by selecting its icon or ticket (i.e. a stylus touch). As seen in the Figure 1 inset, ACA1609 is departing on runway 26R and the ATCO can validate the suggested path (marked in yellow) by clicking on one of the 3 holding points to the runway (represented by the large green zones).

The aircraft context menu can also be opened when clicking on the label in addition to the icon. This helps in selecting the correct aircraft in dense traffic. The ATCO can manage the frequency status by assuming or transferring the vehicle, to inputting a non-standard route using the "*Automatic* [path completion]" or "*Manual* [path completion]" options, or using path input shortcuts such as "*Follow* [another aircraft]" which keeps the ATCO from having to input the same route again.

A non-standard route can be defined by adding waypoints on the path. In Figure 2, a point has been added to force the aircraft to avoid AF626BV which is stopped on the taxiway. The difference between the automatic and manual modes is the completion of the route. The automatic mode will complete the suggestion until destination whereas the manual mode stops the route on the last added waypoint, hence allowing definition of partial routes that stop at any point along the taxiway.

Figure 3 shows the conflict and warning visualizations. On the left, two aircraft are highlighted because of a potential crossover. AF626BV has been instructed to turn right while

Figure 2: Standard route modification using waypoints.

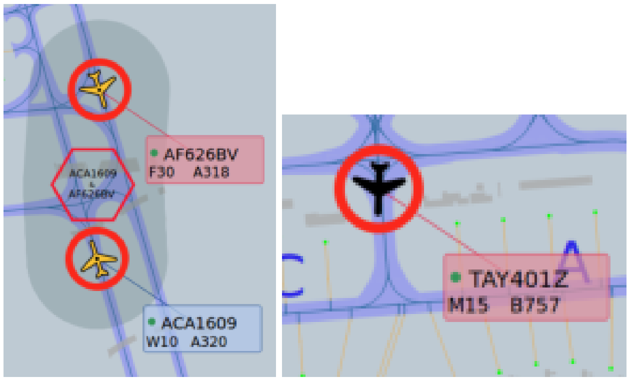

Figure 3: Conflict and Warning representations.

ACA1609 is going straight ahead and neither of them has been told to give way to the other. On the right, TAY401Z is circled in red to alert the ATCO that it has stopped for more than 10 seconds. The ATCO must determine if the aircraft has broken down, momentarily paused, or requires transfer to the next sector.

AUTONOMOUS TUG MANAGEMENT

The developed MAS optimizes aircraft ground trajectories in a decentralized manner and also manages autonomous tugs movements. Taxiways and vehicles (autonomous, service, and aircraft) are represented in this environment as agents. A taxiway agent manages resource usage (whether it is employed or not by another vehicle) and maintains a schedule of future aircraft passages. Vehicle agents asynchronously explore (i.e., independently of the others) and express their intention with respect to resource usage by communicating with the taxiways every second. These vehicles 'schedule' their usage of the taxiways as needed.

The MAS provides to the HMI path suggestions (which in return are presented to the ATCO) that dynamically take into account taxiway closures, vehicle breakdowns, and the occupancy of detaching areas or runway ramps. Each time the ATCO validates a vehicle trajectory or a new holding point, the vehicle agent fixes its intention for it. The vehicle agent is always able to continue exploring other possible paths. It alerts the controller if a better solution (i.e., less taxiing time) is found. When the ATCO closes a taxiway (by clicking on the interface), it causes that specific taxiway agent to update its schedule. Vehicles which are continuously checking their current intention to use this taxiway will detect the change of state and change their intention appropriately.

The MAS also exchanges orders (follow trajectory, stop, detach, attach) with the simulator to control the autonomous vehicles. The MAS consists of two layers, anticipative and reactive, that handle short-term and real-time operations, respectively. The anticipative layer which projects into the future to analyze potential solutions using "what if" questions and the reactive layer bases its decisions on present data. Each autonomous tug is represented by two agents: one in the anticipative layer and one in the reactive layer. The two agents from each layer communicate to each other. The one in the reactive layer can ask the one in the anticipative layer to get the best trajectory when it needs to reach a new destination. The vehicle agent in the anticipative layer informs the vehicle agent in the reactive layer when it needs to yield or the yield is completed.

As such, conflict detection was integrated in the platform. When a potential conflict is detected, the yield order is sent to the lesser priority vehicle's reactive layer. By default, empty tugs have less priority than other aircraft. The controller is also able to dynamically assign priority.

The vehicle trajectories follow a certain set of constraints that are based on airport operations (e.g. the A380 cannot traverse taxiway E). Aircraft towed by tugs must follow an additional constraint of passing through a detachment area near the runway. For this project, the detaching areas were assumed to be the de-icing stands. The detachment operation takes about 90 seconds.

Autonomous tugs have a high level of autonomy, as to minimize the additional workload of the ATCO. It was assumed that the assignment of vehicles would not be part of the responsibility of the ground ATCO. Rather, the airport or the airline would assign or command the tugs as fit.

Once a call is received, these tugs autonomously drive to the aircraft and attach to it (90s). This attaching period is still outside of the ground sector and occurs in the parking area. The tug will conduct pushback and will taxi the aircraft through the parking area. As mentioned previously, when attached to an aircraft, the assembly interacts with the ground ATCO in the same manner as a traditional aircraft.

After the detaching operation, they drive to a nearby parking area and wait for new requests. They send a message to the ATCO confirming their movement in the ground area but no ground clearance is required. The ATCO can stop or restart them as necessary. These operational procedures were assumptions made based on potential tug management in the future. They were made to minimize the additional workload of the ATCO.

EXPERIMENT DESIGN

The Project MoTa validation campaign consisted of evaluating the platform at different stages under a range of work scenario difficulties in order to understand the impact of such technologies on ATCO performance and workload. Three human-in-the-loop experiments were conducted during the course of almost two years, each centered on a specific technology level, with both scenarios simulated in each experiment. All experiments were conducted in the ATC simulator of the Aeronautical Human-Computer Interaction Laboratory at Ecole Nationale de l'Aviation Civile (ENAC; Toulouse, France; Figure 4). The platform simulates the ground controller position at CDG. In brief (for details, please refer to [6]), there are three pseudopilots to displace aircraft around the airport with respect to ATCO commands. A 225 deg external view from the tower is provided to the participant.

Figure 4: MoTa platform in the ATC simulator at ENAC, from the perspective of the user.

Seven ATCOs (one female) from CDG participated in this study with three ATCOs participating in all three experiments. The average age of participants was 38.5 years (std = 2.89) and the average years of experience working as a ground controller was 12.3 (std = 1.89 years). Each experiment lasted about 3 hours and consisted of a 30-40 minute training session, installation and calibration of neurophysiological equipment, the two 35-minute scenarios (with questions in-between scenarios) and a short debriefing period.

At the end of each of the last two experiments (where new technology was introduced), participants were debriefed regarding their interactions with the interface, the use of Datalink, and management of the tugs. This debriefing was a semi-structured interview and adapted to participant observations. There were five ATCOs that participated in both experiments 2 and 3.

Two independent variables were chosen: level of automated technology assistance or experiment (XP; baseline, interface, and interface with tug system) and scenario difficulty (SC; medium and hard). The XP factor was of three levels. The baseline level of technology assistance (1) was equivalent to that currently employed in the French ATC domain, that is, paper strips and a ground radar map. The interface level (2) was a reflection of future technology, with about 50% of the aircraft equipped with Datalink and the ATCO using the tactile interface described in Section 2. The interface + tug level (3) used the same tactile interface, but featured a fleet of autonomous tugs that towed a portion of the aircraft and about 80% of the aircraft equipped with Datalink. The SC factor had two levels and was defined by the number of aircraft and the number of operational events [7]. Each scenario was 35 minutes long. The medium scenario (m) had 31 aircraft, four operational events (pilot error, closed taxiway, tractor, restricted zone), and was representative of an average day at CDG. The hard scenario (h) reflected future traffic loads that could be experienced by a single ATCO and had 51 aircraft, the same four operational events, and a change in runway configuration occurring half way through the scenario. For XP2, the Datalink usage was of 17 and 27 aircraft for SCm and SCh, respectively. For XP3, this usage was 24 and 40 (counting aircraft non-equipped with Datalink, but towed by a tug). In XP3, there were 7 tugs and 10 tug-towed aircraft in SCm; 10 and 20 in SCh.

There were several primary dependent variables collected during the experiment, but only three are discussed in this paper due to the fact that the analysis is currently in treatment: the percentage of aircraft successfully treated (PAC), the NASA Task Load Index (TLX) score, and the SHAPE Trust in Automation Index (SATI). The PAC variable is equivalent to throughput. An aircraft is considered as correctly treated if it has been successfully transferred to the consequent sector (local or apron) by the participant. This transfer point is the last point of contact with an aircraft, after the initial call and any follow-up commands. The PAC is calculated by taking the number of correctly treated aircraft within the 35 minute scenario and dividing by the maximum possible. Aircraft that are in mid-route at the 35 minute mark are counted as correctly treated, as we assumed that a transfer would occur at the end of this route. This variable was measured after every run.NASA TLX is a standard self-reported workload framework that has been frequently employed [8]. The simplified version of this test was used in this study. The questionnaire was distributed after each run. SATI is a questionnaire developed by Eurocontrol [9] to determine a user's trust in a new automation system. There are six questions that ask the user to grade his or her perception on measures such as whether the system is precise, reliable, and comprehensive. This questionnaire was applied at the very end of the experiment.

RESULTS

Out of the seven individuals that participated in this experiment, five participants took part of the first experiment, three for the second, and five for the third.

Figures 5, 6, and 7 show the mean and 95% confidence intervals of the data for each of the groups. Although the current sample size and the non-normal distribution of the data does not lend to the use of parametric statistics such as ANOVA, one can draw some initial conclusions on these measures and the usefulness of the MoTa platform.

Percentage of Aircraft Successfully Treated (PAC)

In general, participants had a higher PAC in the medium scenario than the hard scenario, with an average of 0.99 compared to 0.79. Similarly, participants had a higher PAC in XP2 than in XP1 or XP3 (0.94 and 0.87, 0.88 respectively). Based on this plot, it is clear that both SC and XP have a discernable effect on the PAC, in particular, the use of XP2 in the hard scenario. Indeed, participants were able to achieve a PAC of 0.89 in XP2:SCh compared to 0.75 in XP1:SCm. In operational terms, participants were able to correctly treat seven more aircraft thanks to the interface level of automated technological assistance. However, the addition of the tug does not seem to provide any operational advantage in neither the hard nor medium scenario, with performance in XP3 equaling that of XP1.

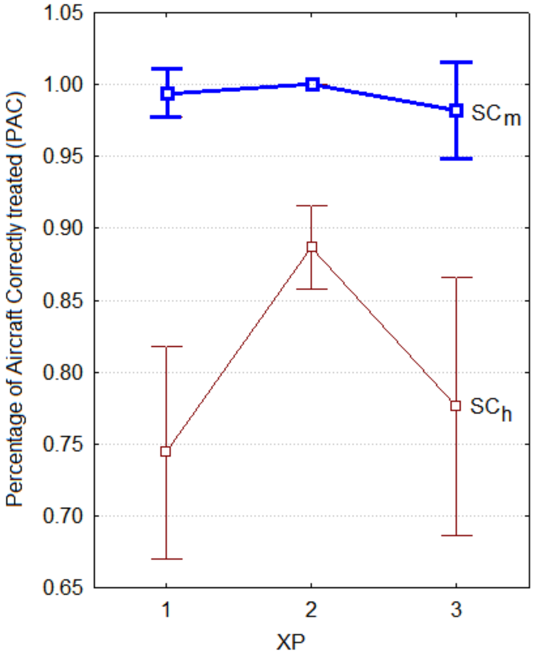

Figure 5: Changes in PAC with respect to Scenario (Sc) and Technology Level (XP)

NASA Task Load Index (TLX) Score

Participants reported having less workload in the medium difficulty scenario with average scores of 3.42 (out of a maximum of 7, high workload) and 4.74, respectively. The average workload across technology levels also varied (3.97, 3.03, and 4.83 for XP1, XP2, and XP3 respectively). Participants experienced the least amount of workload in XP2:SCm (most representative of current work technology) and the most amount of workload in XP3:SCh (most representative of future work technology).

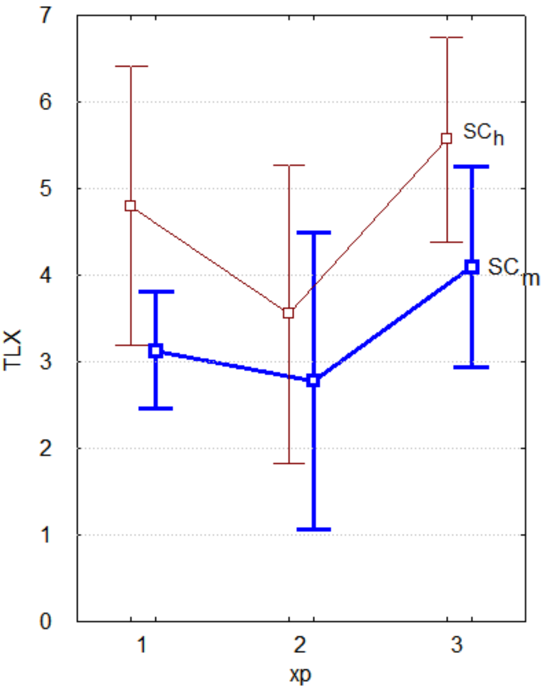

Figure 6: Changes in NASA TLX with respect to Scenario (Sc) and Technology Level (XP)

Trust in Automation (SATI) Score

Participants marked that they had less trust in the new automated technology assistance systems than their current technology at CDG, with average scores of 5.07, 4.61, and 2.90 respectively for experiments 1, 2, and 3. It appears that participants trust the autonomous tug system less than the interface system. Not surprisingly, neither of the two technology levels scored higher than the baseline technology. Nevertheless, no system received a score of 0, meaning that the systems are not detrimental to the task of managing ground operations.

Observations and Subjective Feedback

Overall, participants were receptive to the introduction of the new technology assistance, with all participants completing the task and no large degradation in performance nor a rejection of the system. The principal

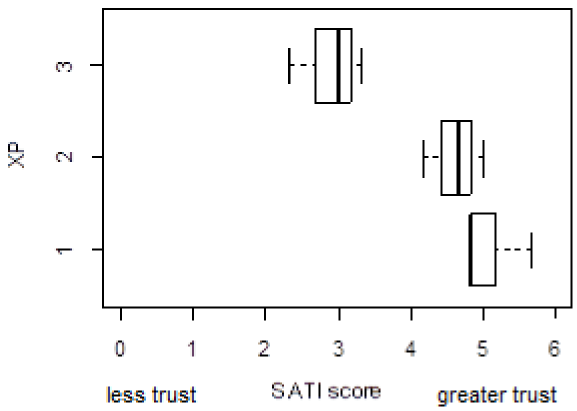

Figure 7: Changes in SATI score due to Technology Level (XP)

usage of the interface was interacting with the path suggestion and decision support system elements of the interface, either for aircraft equipped with or without Datalink. The main difference between the two types of aircraft was simply a question of whether commands could be transmitted via interface or needed to be communicated via radio. In general, participants found the path suggestion useful, but limited in its ability to adapt to non-standard paths. The modification of trajectories posed significant problems to participants, particularly in engaging the manual mode and creating the modification.

Several participants were unable to place a trajectory waypoint, either due to the interface not registering the stylus or the participant misclicking on the taxiway (accidentally clicking on a ticket, another aircraft icon, not on the taxiway itself; an unintentional hand touch placed a waypoint). The sequence and number of waypoints to incite a specific trajectory deviation was not immediately apparent to the participants. Since the trajectory visualization reacted in real-time with each trajectory click, several participants were perturbed once this trajectory visualization did not meet their expectations. Extra waypoints were placed to correct this (temporary) trajectory, often creating more problems, and resulting in greater user frustration (and ultimately leading to a trajectory reset or tool abandonment). However, many of these problems seem to be the result of familiarity with the interface. Two participants reported relative mastery of the interface in later trials.

The use of Datalink was also well accepted by the participants. Three participants were observed to use Datalink when available, with one explicitly stating that it provided a temporal advantage to verbally transmitting commands via radio. The other two participants stated that they did not have a habit of using Datalink and thus forgot that it was available to them during the scenarios. One other participant did not find Datalink input to be faster than radio and felt that it complicated his task and thus used Datalink only in lower workload situations.

Two participants stated that the alerts provided by interface were useful, but could be improved upon. The 10s stopped aircraft alert was most useful, with several stating that it helped remind them of aircraft that required a sector transfer. Participants felt that there were too many alerts, especially those that were irrelevant (e.g. between tug and aircraft when tug will stop automatically) or not well-defined. For example, the algorithm defines a conflict as a physical proximity of two vehicles that are in the ground sector (a physical definition of the area around the airport) within a time horizon of 90 seconds. However, in practice, the ground sector is not strictly defined in the physical sense, but in terms of call to the tower or acknowledgment from the ATCO. Therefore, the participant should receive notification of a conflict even if one of the vehicles is physically outside of the ground sector, if this vehicle has already called the tower.

The use of tugs solicited a range of responses from the participants. Two participants in experience 3 were comfortable with the level of control over the tugs, whereas the other three preferred to have more control. Two participants stated that the tugs should call the tower and demand clearance like other aircraft. In general, participants regarded a tug-towed aircraft similarly to a regular aircraft, meaning that little to no additional resources were necessary. However, one participant did state that having to remember to give a separate holding point (for detaching) was difficult to recall.

DISCUSSION AND FUTURE WORK

The initial results of this study show three main results. First, automated taxiing technology assistance (e.g. Datalink, path suggestion, autonomous tugs) can help improve ATCO taxiing performance. Second, more technology may increase the overall workload. Third, the MoTa system is promising but is not currently mature enough to replace current systems. The tendencies in percentage of aircraft correctly treated show that the addition of the tactile interface with Datalink and path suggestion improved overall throughput. However, the inclusion of the tugs and increase in datalink usage reduces these gains, thus implying that a) tugs do not provide a significant performance advantage; b) too much Datalink may contribute to the workload; or c) a combination of both may overall throughput. While participant comments suggest that just the tugs are the culprit, the experimental design does not allow for isolation of this effect. Indeed, while the use of both technologies seems to improve performance, there is not enough statistical power to state whether the improvement is attributable to the effect. In general, the MoTa platform seems to be the most effective in the hard scenario, with performance fairly regular across all technology levels in the medium scenario. Additional development to account for participant comments should improve the user acceptance of the technology.

Similar trends were seen in workload, with decreases in workload when using only the interface and an increase when using the interface with the tugs. Globally, the hard scenario imposed greater workload than the medium scenario. There is not enough statistical power to determine whether the changes in workload are due to the technology itself.

Observations of and remarks from the participants showed that acceptance of the automated technology assistance was mixed, with half of the participants finding it to be useful and the other half reporting no gains in performance. The SATI scores confirm this thinking, with a score of 5 but also another score below 3. The current MoTa platform performs well in nominal conditions but is less robust to off-nominal behavior (e.g. misplacement of hands, stylus, or misclicks; major trajectory modifications), which may explain the lack of confidence in the system. Interface usage was observed to have improved with respect to experience, with participants reporting greater usability in later trials. Indeed, participants were trained on the interface for only 30-40 minutes prior to starting experiments 2 or 3. More time for training was not possible due to participant schedules.

The regressive trends in workload, performance, and trust in automation suggest that they are due to the inclusion of the tugs. This association is supported by participant comments collected at the end of each session. However, it is unclear as to the specific aspect - the tug-towing aircraft or the non-servicing tugs themselves? While participants reported treating tug-towing aircraft like other aircraft, the use of another holding point and the necessity to detach the tug from the aircraft does increase the overall time spent in the ground sector (as noted previously, detaching is a 90s procedure) and increase the number of vehicles in the same area. Similarly, non-traversing tugs travel on the same runways as aircraft, thus theoretically reducing the taxiway resources, that is to say, increasing potential conflict. Further investigation is warranted to better understand the source of the complexity for both performance and for workload. As for trust, there may be a more direct explanation. Participants did state there was a general mistrust of the autonomous tugs and how they functioned when not towing an aircraft, particularly their lack of calls to tower for taxiing clearance. The number of conflict alerts, especially those that were between two tugs (and thus resolved automatically without ATCO interference) may have led to a diminishing effect on the importance of the system alerts. It is clear that newer versions of the MoTa platform should carefully divert the ATCO's attention only when their intervention is necessary.

There are several limitations to this study which may help to explain these results. The population of available ATCOs with CDG experience is limited (less than 10 ideal candidates work at ENAC, where the simulator is located). The small sample set reduces the statistical power of this analysis. Additionally, it was not possible to have technology level as a within subjects variable, meaning half of the subjects saw all conditions and the other half saw one portion. Furthermore, the run order of experiments 2 and 3 was not counterbalanced. Since the retention rate for experiment 2 appeared to be quite low, it was decided to run experiment 3 first. Otherwise, a balanced set could have been achieved, but with little to no data regarding the tug performance. This study will continue to add more participants to improve the statistical power. Lastly, the usage of autonomous tugs is a substantial change from current airport taxiing operations. A 30-40 minute training session is likely insufficient to alleviate any initial distrust biases within the participant. Therefore, it is difficult to state whether the autonomous tugs are truly insufficient for taxiing operations. Rather, participants were not convinced with this version and this level of training. The subjective results of this study indicate there are several areas of improvement to the overall design of the interface and the functionality of the algorithm. Namely, trajectory input methods need to be more clear to participants and alerts should be more specific. Furthermore, the definition of a potential conflict should be clarified to reflect actual practice. Future studies should consider evaluating different levels of control over the autonomous tugs. Additionally, it would be worth evaluating the evolution of the technology acceptance with more training and time.

CONCLUSION

A study regarding the integration of taxiing technology such as Datalink, path suggestion, and autonomous taxiing tugs was conducted with seven participants with experience working at Roissy Charles-de-Gaulle airport. Initial results indicate that the inclusion of such automated taxiing technology assistance improves overall performance and reduces workload, but only in limited cases. In particular, the use of the tugs may increase the workload and negate the performance gains achieved with the interface. This increase in workload may be due to having a separate holding point for tug-towed aircraft or the potential increase in conflict due to tugs sharing the same taxiways as aircraft. Participants have mixed feelings with regards to the technology, with about half reporting ease and noting advantages to the technology and the other half expressing discontent with its functionality or usability. As this study is currently in progress, the inclusion of more participants will improve the power of the statistical analysis and conclusions that can be drawn from the results. Future studies should also consider examining more specifically the source of complexity with respect to the autonomous tugs, whether it is the tugs moving autonomously or the tugs when attached to an aircraft.

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REFERENCES

1. Eurocontrol. Task 4 Report: European Air Traffic in 2035. Challenges of Growth, 2013.
2. IATA Association, I.A.T., Global-Annual Outlook (Passenger numbers), A.P. Forecasts, Editor. 2014: http://www.iata.org/publications/Pages/20-passenger-forecast.aspx.
3. Taxibot-International. http://www.taxibot-international.com/#!concept/c431. 2013
4. Cook, C. Trialling the Taxibot. Airports International.com. http://www.airportsinternational.com/ 2012/12/trialling-the-taxibot/13014. 4 December 2012.
5. Lufthansa Group. Innovative TaxiBot now used in real flight operations. https://www.lufthansagroup.com/en/press/news-releases/singleview/archive/2015/february/20/article/3439.html. 20 February 2015.
6. Chua, Z.K., Andre, F., Cousy, M. Development of an ATC Tower Simulator to Simulate Ground Operations. Proceedings of the 2015 AIAA Modeling and Simulation Technologies Conference (Dallas, TX, USA, June 2015).
7. Chua, Z., Causse, M., Cousy, M., Andre, F. Modulating Workload for Air Traffic Controllers during Airport Ground Operations. Proceedings of the HFES Annual Meeting 2015 (Los Angeles, CA, USA, October 2015).
8. Hart, S.G., Lowell, S.E., Development of NASA-TLX (Task Load Index): Results of empirical and theoretical research. Advances in Psychology, Vol 52, 139-183. 1988.
9. Dehn, D.M. “Assessing the Impact of Automation on the Air Traffic Controller: The SHAPE Questionnaires”, Air Traffic Control Quarterly. Vol. 16, No. 2. 127-146. 2008