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IMPACT OF ATCO TRAINING AND EXPERTISE ON DYNAMIC SPATIAL ABILITIES

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Dynamic spatial ability is supposed to be involved in a critical process of air traffic controllers, namely conflict detection. The present paper aims at testing whether dynamic spatial ability improves with air traffic control training and/or experience. We designed a laboratory task to assess the performance in predicting if two moving disks would collide or not. We conducted a cross-sectional study with four groups of participants : ATCO trainees at the beginning (*N*=129), middle (*N*=80) or end of training (*N*=66) and experienced ATCOs (*N*=14). Results suggested on one hand that air traffic control training leads to a decrease in the number of extremely high proportions of undetected collisions from the middle of the training. On the other hand, air traffic control operational experience leads to a decrease in the number of extremely high proportions of falsely detected collisions.

Spatial ability has been identified as one of the core abilities required for air traffic control (e.g., Durso & Manning, 2008). Indeed, an important part of air traffic controllers' job consists in understanding and manipulating visual and spatial information. A review of research on spatial abilities (Hegarty & Waller, 2005) revealed that spatial ability is composed of several separate abilities such as spatial visualization (supposed to be involved in a paper folding test for example) or spatial relations (supposed to be involved in a mental rotation test for example). Dynamic spatial abilities have been studied with the possibilities offered by computer testing to investigate the reasoning about motion and the integration of spatial information over time (Hegarty & Waller, 205, p.135). An early study highlighted that dynamic spatial ability could be interpreted as a distinct factor from static spatial ability (Hunt, Pellegrino, Frick, Farr & Alderton, 1988). Later, D'Oliveira (2004) confirmed the specificity of dynamic spatial ability within the spatial domain. However, dynamic spatial ability has been less studied than other components of spatial ability like mental rotation. Besides, among the "worker requirements" identified by Morath, Quartetti, Bayless and Archambault (2001, cited by Durso & Manning, 2008) for the job of air traffic control, four were grouped under the "spatial" label and comprised "visualisation" and "projection". Thus, the projection of trajectories of moving elements was highlighted as a central process for air traffic controllers (ATCOs).

As air traffic controllers are supposed to frequently use cognitive processes aimed at predicting whether two moving elements would collide, one question that arose was whether the performance at such tasks would improve during training and with experience. Thus, the present paper adresses the question of the potential improvement of the performance at a dynamic spatial ability task with air traffic control training and professional experience. Indeed, air traffic control training confronts learners to many dynamic visual problem solving situations. Therefore, their performance in extrapolating trajectories from dynamic visual data should be higher at the end of their training compared to the beginning. Similarly, after several years of air traffic control experience, ATCOs should have better performances at such tasks compared to ATCO students at the beginning of their training.

Method

Participants

Two hundred and eighty nine participants were recruited for the present study. They comprised 275 ATCO trainees at three stages of their air traffic control training (129 at the beginning, 80 at the middle and 66 at the end of their training) at ENAC (Ecole Nationale de l'Aviation Civile) as well as a group of professional ATCOs (n=14, with a mean experience in a control center of M=10,6 (SD=4,2) years).

Measures and Procedure

The TwoBalls test. A specific dynamic spatial ability test has been designed in order to measure the performance at predicting whether two moving disks would collide or not (see Figure 1). After three familiarisation trials with feedback on the correctness of their answer, participants were confronted to 50 test trials which varied in the heading and speed of each moving disk. Both disks had a diameter of 64 pixels (participants sat in front of a 24-inch, 1920 x 1200 resolution computer screen, thus the disk measured approximately 1.7 cm) and moved in a window of 640 pixels. The angles of the disk trajectories varied from 16° to 323° and the speeds varied from 10 to 40 pixels/s. At each trial, participants had to decide, as quickly as possible, whether the two disks would collide or not. No feedback was prodived for the test trials. Among the 50 situations, 19 involved colliding disks (the distance between the centers of the disks ranged from 6 to 46 pixels) and 31 non-colliding disks (the distance between the centers of the disks ranged from 78 to 222 pixels). Instructions explained that the scoring rule would take the response latency into account, so that the score would be higher if the response was given quickly. However, participants were also informed that in case of wrong answer their score on that item would be negative. Each trial ended automatically two seconds after the minimum distance between the disks was reached. On average, the minimum distance was reached after 9s. At each item the answer of the participant as well as its response latency were recorded.

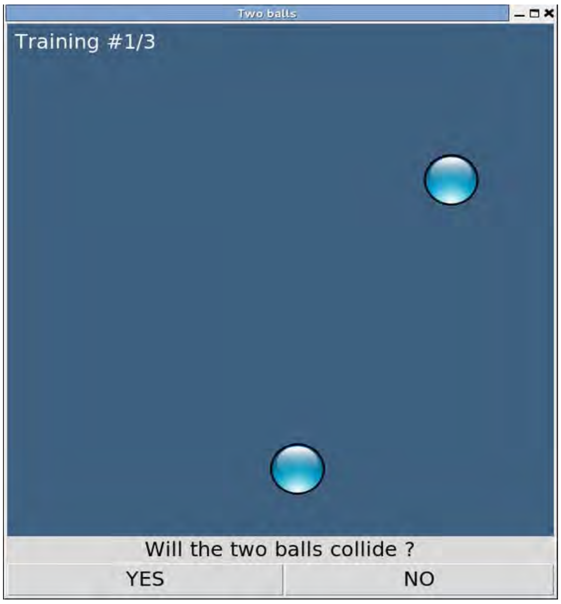

Figure 1. Screenshot of one item of the TwoBalls test. Both disks were moving towards each other and the participant had to click on “yes” or “no”.

Procedure. Participants completed the computer-based TwoBalls test by groups of nine and interacted through a mouse. The whole test took maximum 10 minutes to be completed.

Results

The internal consistency of the TwoBalls test was satisfactory as corresponding Cronbach’s alpha was 0.75. Globally, performances were high, even for ATCO trainees at the beginning of their training (see Table 1). Indeed, the mean rate of correct responses exceeded 87% for each category of participants. However, large individual differences were observed, specifically for ATCO trainees. For example, rates of correct responses of ATCO trainees at the beginning of their training ranged from 60 to 100%. As two types of errors could be committed by the participants, we investigated the miss rates and false alarm rates. These two variables were not normally distributed, thus we used non-parametric statistical inference tests: the Kruskal-Wallis test for the comparison of the four categories of participants, and the Mann-Whitney test for the comparison between two categories of participants.

Miss rate. Globally, miss rates were only marginally significantly different across the four categories of participants (Kruskal-Wallis rank sum statistic = 7.4, $p = .06$). More precisely, the mean miss rate of ATCO trainees at the beginning of their training (6.6%) was significantly higher than the one of ATCO trainees at the end of their training (3.3%), Mann-Whitney statistic = 3356.5, $p = .009$. Moreover, inspection of the variability of the miss rates of ATCO trainees at the beginning of their training revealed that 6% of them had a miss rate superior to 25%, whereas in the three other categories of participants, none of them had such a miss rate (see Figure 2).

Table 1.
Mean (and standard deviation) correct response rate, miss rate and false alarm rate of performances at the TwoBalls test for each category of participants.

	Correct response rate (%)	Miss rate (%)	False alarm rate (%)
Status	*Mean (SD)*	*Mean (SD)*	*Mean (SD)*
Trainee start	87.3 (8.9)	6.7 (9.0)	16.4 (11.0)
Trainee middle	88.9 (7.4)	5.5 (6.4)	14.4 (10.9)
Trainee end	89.3 (8.0)	3.3 (5.0)	15.1 (11.8)
Expert	90.4 (5.0)	4.9 (6.7)	12.2 (5.8)

Note. Correct responses correspond to correct answers "yes" when the disks would collide and "no" when they would not collide.

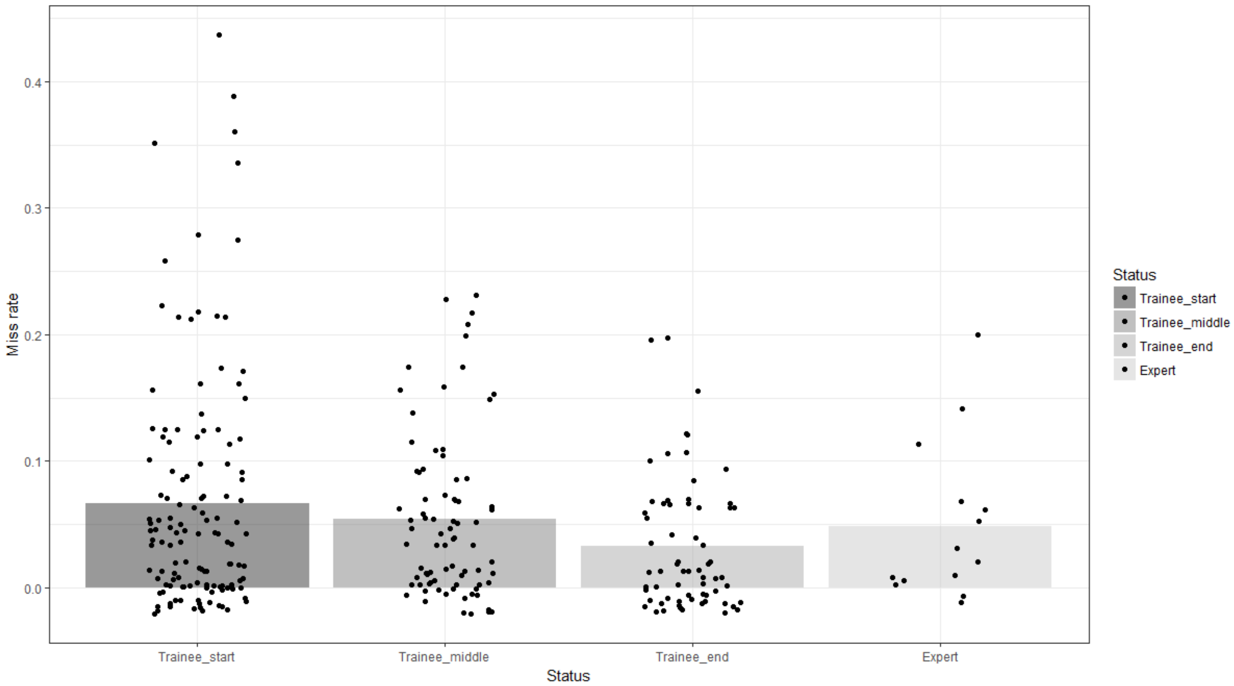

Figure 2. Mean miss rate and individual data (dots) for each category of participants (ATCO trainees at the start, middle or end of training and ATCO experts).

False alarm rate. Globally, false alarm rates were not significantly different across the four categories of participants (Kruskal-Wallis rank sum statistic = 3.0, p = .39). Even if we focus on ATCO trainees at the beginning and the end of their training, the difference is not significant, Mann-Whitney statistic = 3891.5, p = .32. The mean false alarm rate is lower for ATCO experts (12.2%) compared to ATCO trainees (between 14.4 and 16.4%). However, the difference is not significant, Mann-Whitney statistic = 723.5, p = .22. Nevertheless, inspection of the dispersion of the false alarm rates highlighted that none of the experts had a false alarm rate superior to 23%, whereas for ATCO trainees at the beginning, middle and end of their training respectively 21%, 19% and 20% of them had a false alarm rate superior to the maximum of those of ATCO experts (see Figure 3).

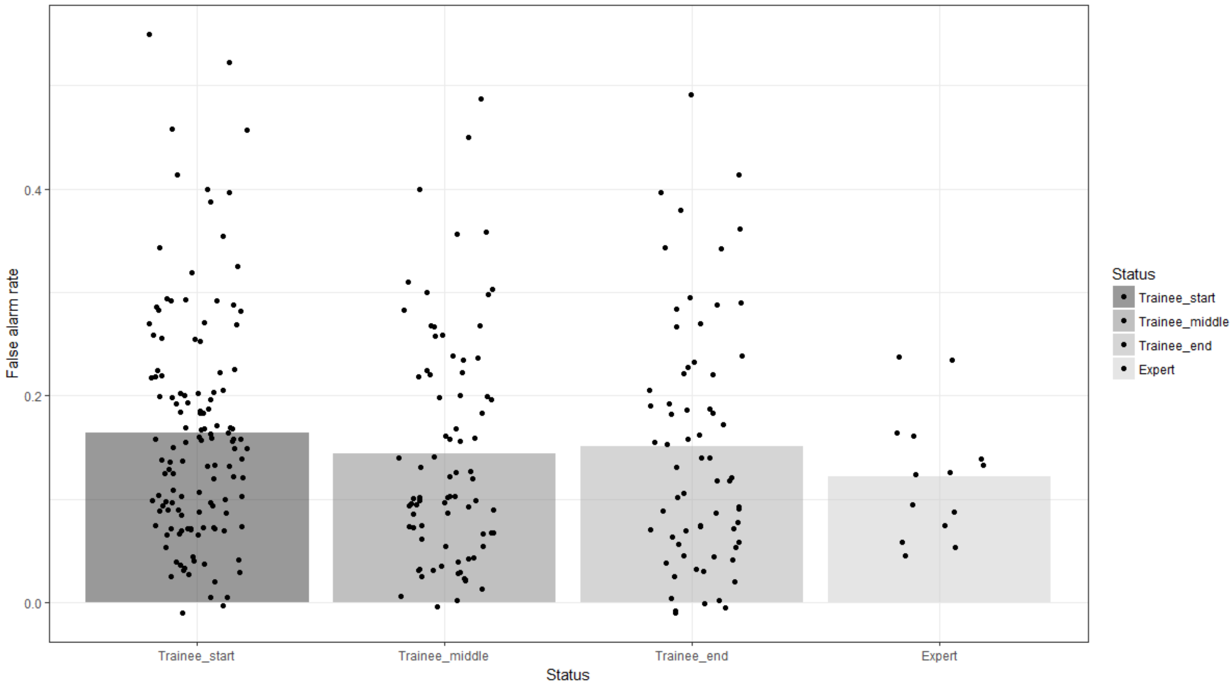

Figure 3. Mean false alarm rate and individual data (dots) for each category of participants (ATCO trainees at the start, middle or end of training and ATCO experts).

Mean response latency. We computed the mean response latency for the 50 items for each participant. Globally, the mean response latencies were not significantly different for the four categories of participants, Kruskal-Wallis rank sum statistic = 3.6, $p = .32$. Most of participants spent from 1.5 to 4.5 s at each item. This is far below the mean 9 s delay before the response was obvious, thus the instruction to answer as quiclky as possible had been followed.

Discussion

A dynamic spatial ability test has been designed to assess the skill in predicting whether two moving objects would collide or not. The present study assessed how the performance at this test would evolve during air traffic control training and experience. To that extend we compared performances at this test for different categories of participants, ATCO trainees at the beginning, middle and end of training, as well as experienced ATCO profesionnals. Firstly, the performance at this test was globally high for each category of participants. Secondly, differences appeared when we focused on the two types of errors that could be committed with such task, namely a non prediction of a future collision (miss) or a prediction of a collision that would not happen (false alarm). At the end of training, ATCO trainees had fewer misses than at the beginning of their training. Thus, ATCO training seems to help to detect conflicting situations. Concerning false alarms, ATCO training does not seem to help to reduce false detections of conflicts. However, this skill seems to be improved with ATCO professional experience.

In an early experiment, Bisseret (1981) presented experts (qualified controllers) with pairs of converging aircraft in a simulated environment. Conflicts were rarely missed (0.9%), but there was a high false alarm rate (68.4%). Thus, in a high-fidelity simulated environment ATCO experts have the tendency to adopt a cautious strategy which lead to miss few conflicts but to falsely diagnose conflicts when there is no conflict. In another experiment, Bisseret (1981) showed static images of radar screens or several successive images in order to simulate the aircraft's approach minute by minute to experienced controllers and trainees (one year at school and two months in an operational centre). In each case, experienced controllers were more cautious than trainees about the risk of saying « non-conflict ». This cautious strategy has not been reproduced in the present study, as the false alarm rate of ATCO experts was not superior to the one of ATCO trainees. Indeed, the TwoBalls test is rather different from a realistic ATC situation. In particular, the decision time was quite low (less than five seconds). Further work should investigate performances in situations where the disks are moving more slowly, like the movements on a real radar screen.

The dynamic collision prediction skill was higher after ATCO training and experience. Thus, this skill could appear as relevant to be assessed at the ATCO selection stage. However, our study was cross-sectional (with different groups of participants) and not longitudinal (with the same group of participants at various stages of the training). Now, a longitudinal study would be needed to investigate whether a poor performance at such task before the beginning of the training would predict more learning difficulties during training. Furthermore, it would be interesting to assess whether a specific training program designed to improve this skill could improve the performance at detecting conflicts in realistic simulated ATC environments.

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