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Uncertainty-handling assessment using nondeterministic learning tasks in pilot selection

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Context

This paper addresses selection for entry into the French commercial pilot *ab initio* training, namely the ENAC (École Nationale de l'Aviation Civile). Applicants are mainly (more than 80%) coming from scientific preparatory classes for competitive admission to the "Grandes Écoles". Therefore these applicants are hand-picked based on their school grades in mathematics and physics. To give a hint, in 2005, only 15% of the French GCE A-Level students were selected for entry into such preparatory classes. The current pilot selection process at the ENAC is composed of three steps:

1. written exams (mathematics, physic and English), with a success rate of 40%;
2. cognitive ability tests (visual perception, mechanical knowledge, sequential reasoning, quantitative reasoning, attention and psychomotor ability), with a success rate of 30%;
3. group exercises, individual interviews and an English oral exam, with a global success rate of 35%.

Each year, the ENAC hires 40 to 60 pilot trainees, selected from 1500 to 1800 applicants. Despite the low selection ratio, some pilot trainees do fail during training, especially during practical training. For the last five years, failure rates during training ranged from 6 to 10% (i.e., 3 to 5 pilot trainees per year). Considering the high cost of the practical training, efforts are made to better understand the failures' origins and to adapt the selection process to these findings if necessary. Therefore we analyzed these individual training failure cases and related them to findings of the literature.

Failure analysis

We analyzed the 12 training failures that occurred at the ENAC from 2003 to 2005, through official reports and interviews with the instructors. Ten cases were categorized as "technical problems", whereas the two others were related to "motivational problems". The "technical cases" exhibited some noteworthy descriptions:

- "insufficient speed in detecting and correcting errors";
- "impaired performance in stressful situations";
- "brilliant trainee, but difficulties in adapting to changing situations", "too much perfectionist", "difficulties to function on an intuitive mode".

The last one especially emphasized the importance for pilots to adapt to uncertain and unpredictable situations. Even if the flight is prepared, the pilot has (i) to deal with unpredictable events and (ii) to make decisions based on incomplete or imperfect information (e.g., information about the traffic given by the controller, weather information, navigational information, etc.)

Piloting requires adaptation to uncertain and unpredictable situations

A review of the literature confirmed the intuitive idea that pilots need to adapt to real world situations that are by essence not perfectly predictable.

Pulakos et al. (2000) studied *adaptability*, the capacity to adapt in operational settings. They reviewed more than 1000 incidents from different work settings, and showed that 22% of incidents reported by aircraft commanders were related to a lack of adaptability. The authors also defined a taxonomy of adaptability with eight dimensions, among which "dealing with uncertain and unpredictable work situations" represented the second most frequent attributable cause of the reported aviation adaptability-incidents. Moreover, Pulakos et al. (2002) showed a small, although significant, correlation between general cognitive ability and adaptability in work situations, therefore justifying to study adaptability on its own.

Sarter and Woods (1992, 1994, 1997) studied the pilot interaction with cockpit automation and showed that automated systems are often opaque for pilots and that pilots have to cope with this incomplete comprehension.

Hypothesis

The hypothesis of the present study is that performance in well-defined problems (e.g., mathematics, physics written exams and traditional cognitive ability tests of the ENAC current pilot selection system) does not guarantee adaptation to uncertain situations. In other words, when confronted to an uncertain situation, pilot applicants might more or less rapidly adapt their behaviour.

A paradigm for testing adaptation to uncertainty

We chose to confront the applicants with a widely studied experimental paradigm in cognitive psychology, namely *Multiple Cue Probability Learning* (MCPL, Brunswik, 1952), which emphasized the unpredictable character of real-life environments. Brunswik stressed that human beings have to learn to adapt their behaviour to imperfectly predictable environments. For example variations in the environment can often be predicted from the observation of proximal cues, as cooling can be predicted from the arrival of clouds. But no real life cue-environment relationship is perfectly deterministic. Sometimes warming can follow clouds. Rather, these relationships are probabilistic in general, and correlational in particular (when the relationship between cues and criteria is linear). As an example in the domain of piloting, Rees (1995) showed that during training, the pilot trainee has to learn to correlate flight control manipulations to aircraft reactions.

In two exploratory studies, we investigated the MCPL learning profiles of pilot applicants ($N = 401$ and $N = 448$) who took an experimental probabilistic learning test during selection for entry in the ENAC. The purpose of these studies was to investigate individual differences of a homogeneous population of mathematically proficient students with regard to their adaptation to a non-deterministic environment.

Study 1

Participants. The sample comprised 475 pilot applicants of the 2006-session of the ENAC pilot trainee selection (91% male), all coming from preparatory years, all pre-selected with the written exams, aged from 18 to 22.

Task, apparatus and procedure. The task was inserted in the battery of cognitive ability tests, without informing that the results would not be used for selection decisions. The task consisted of 60 successive trials. On each trial, two cues were presented on a computer screen. Each cue was represented as a vertical bar of continuously varying height. Participants were instructed that a probabilistic relationship existed between the two cues and a criterion. They had to learn to predict the criterion level from the cues levels. They were warned that it was impossible to give perfectly correct responses due to the influence of some random factors. They gave their response by setting the height of a third bar. Finally they received the feedback (*i.e.* the criterion). The task was time limited, and only the $N = 401$ applicants who completed all trials were included in further analyses. One cue was positively related to the criterion ($r = .63$) and the other negatively ($r = -.72$). The global cue-criterion correlation was high ($R_e = .96$). Therefore the rule that had to be learnt was a simple subtraction between both cues with a small part of randomness (8% of the total variance).

Analysis. Performance was assessed through correlations between criteria and participant's responses. Individual learning curves were provided by rolling correlations computed on 20-trial moving windows. Individual differences in learning profiles were investigated through a hierarchical clustering method. The dendrogram suggested a four-class clustering. Thus a 4-class *K*-Means was processed.

Results. The four learning profiles (Figure 1) were "Fast-Learners" (FL), "Medium-Learners" (ML), "Slow-Learners" (SL), "Non-learners" (NL). The latter group represented 12% of the participants who exhibited no significant progress throughout the test. NL and SL groups both started with low learning

levels, but only slow participants finally learned the target relationship. The SL pattern demonstrates that a poor start did not prevent final learning. Moreover, individual multiple linear regressions of the responses on the cues showed that differences in global performance of the four classes were related to cue-utilizations. Finally, response times showed that Non-learners responded on average 700ms faster than the three other learner groups ($p_s < .05$ for all post-hoc tests).

In summary, the results highlight large individual differences in a population of pilot applicants who had to deal with a partially unpredictable situation. Moreover performance differences were related to differences in cognitive processes (individual cue weightings and processing times). The question turns now to better understanding why 12% of mathematically proficient students could not achieve such a simple task.

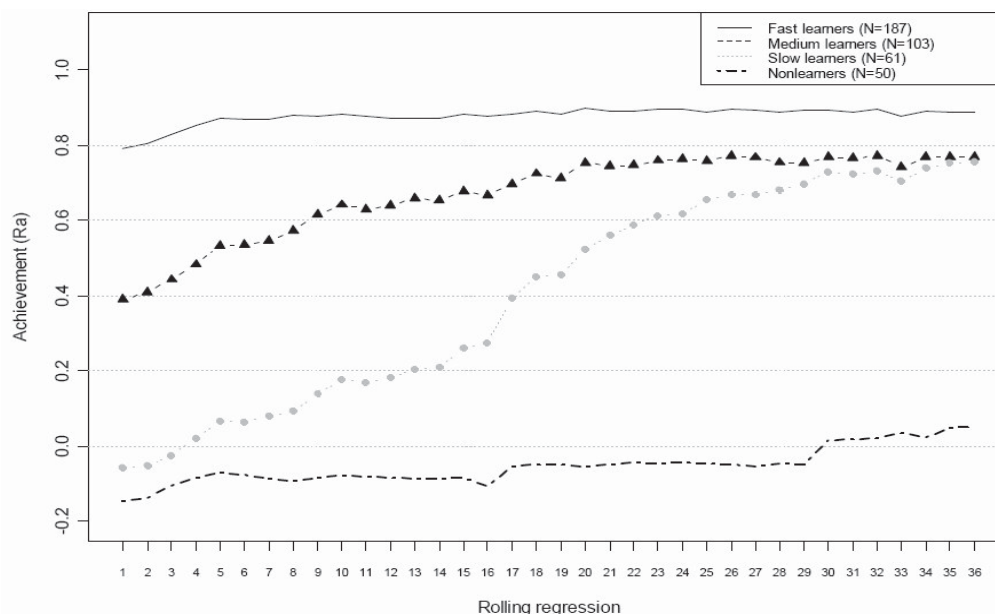


Figure 1. Learning profiles of the 4 classes - Study 1

One hypothesis could be that they would be more disturbed than learners by the presence of randomness. Therefore we conducted a second study with the addition of a third cue, almost totally irrelevant.

Study 2

Method. The method was the same as Study 1 except that three cues were used instead of two. The multiple cue-criterion correlation was identical to Study 1. Individual cue-criterion correlations were positive ($r_p = .74$), negative ($r_N = -.74$), and almost null ($r_I = .09$, I for "Irrelevant"). Participants were the 512 applicants of the 2007-session, not present in the 2006-session (i.e., they were all new to the task). Again, only the $N=448$ who completed all trials were included in further analyses. As in Study 1, cluster analyzes produced four classes.

Results. Leaving aside small differences caused by a greater difficulty of the task, the four learning profiles (Figure 2) roughly replicated those of Study 1. Again, 12% of participants were identified as Non-learners. As in Study 1, global performances were related to differential cue weightings among the four groups and Non-learners responded 700ms faster on average than Fast Learners.

General Discussion

Both studies validated the hypothesis that people highly skilled in well-defined problem-solving may have difficulties in dealing with a nondeterministic task. In particular one group of applicants (12% of

the participants in each study) failed to learn the relationship and the three others could be characterized by their pattern and speed of learning.

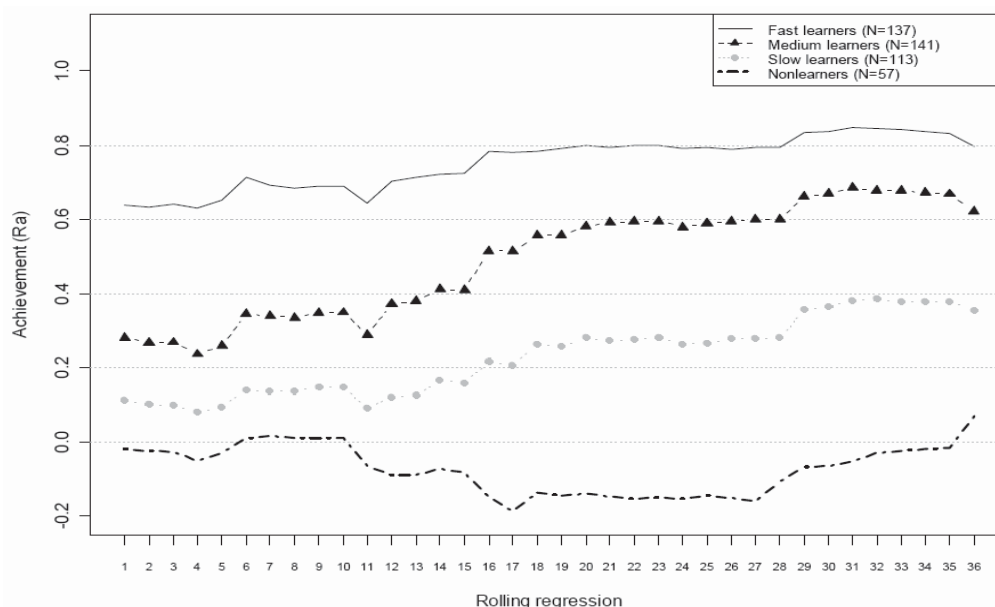


Figure 2. Learning profiles of the 4 classes - Study 2

Possible interpretations. Concerning the interpretations of these individual differences we can list some hypotheses that could be investigated in further research. Inter-individual abilities in dealing with a MCPL task could be related to general cognitive ability, ability to generate hypotheses, personality traits, resistance to frustration, dealing with change and adaptability, ability to function intuitively or stress management and emotion.

Cognitive ability. Our data collection allowed us to test the possible overlap of the MCPL ability with general cognitive ability. A factor analysis showed that the individual differences captured by the MCPL performance are different from those captured by the traditional cognitive ability tests.

Predictive validity. As of the moment of this writing, out of the 48 trainees hired in the 2006-session, only two, case#1 and case#2, had failed during training. Their individual profiles suggest that they had difficulties to cope with the MCPL task (Figure 3): For case#1, despite a good start, his performance decreased all the task long and case#2 performed almost perfectly but she took enormous time to respond at each trial (she was the only applicant who completed only 22 trials out of 60).

Conclusion

This study constitutes a first exploratory investigation of the possibility to include the ability to cope with uncertain environments as a new tool for pilot selection. The present findings raise important questions with regard to selection methods that give considerable weight to analytical processing skills when recruiting people who will have to cope with intrinsically uncertain situations.

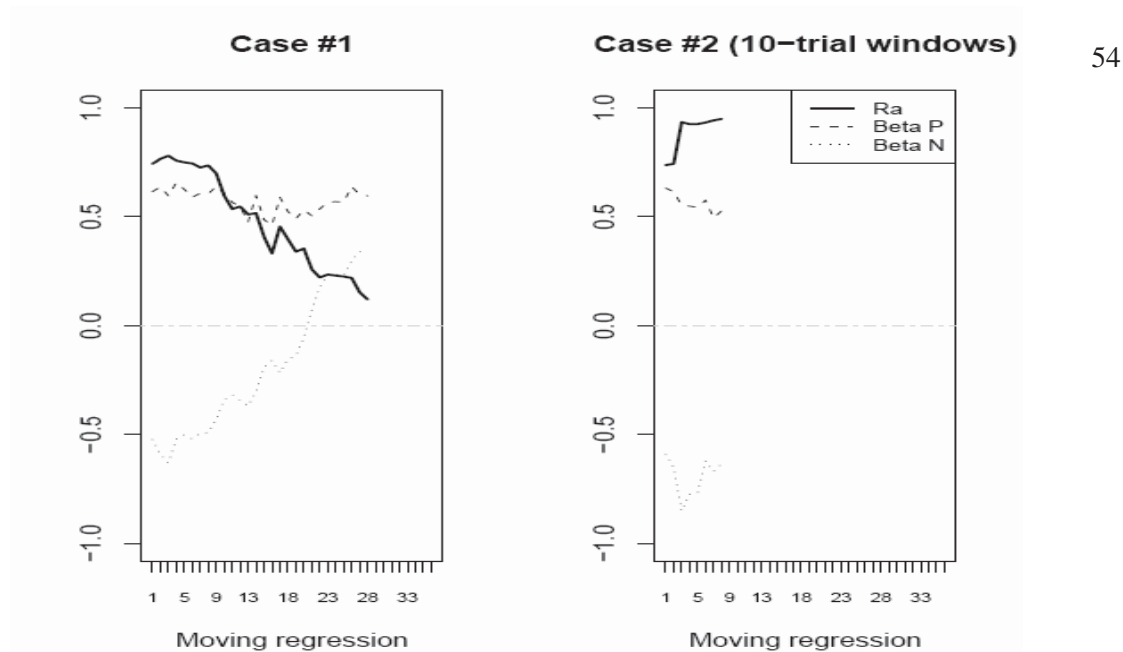


Figure 3. Individual MCPL profiles for the two trainees who failed.

As the tendency is to shorten training programs to achieve cost reductions, pilot students should be able to learn dealing with complex environments and systems even more efficiently. Further research will be needed, in particular to evaluate the predictive validity of such a task.

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