Computer-aided training for risky decision making

A. Bisseret, S. Redon, P. Falzon

IRIA

CENTRE DE ROCQUENCOURT

Institut National
de Recherche
en Informatique
et en Automatique

Domaine de Voluceau
Rocquencourt
B.P.105
78153 Le Chesnay Cedex
France
Tél.:954 90 20

Rapports de Recherche

N° 95

COMPUTER-AIDED TRAINING FOR RISKY DECISION MAKING

André BISSERET
Serge REDON
Pierre FALZON

Octobre 1981

In RAPPORT DE RECHERCHE N° 95

COMPUTER-AIDED TRAINING FOR

RISKY DECISION MAKING

A. BISSERET - S. REDON - P. FALZON

ERRATUM

Page 14 read "Experimental Group" instead of "Control Group"

and vice-versa

COMPUTER-AIDED TRAINING FOR RISKY DECISION MAKING

A. BISSERET

Groupe de Psychologie Ergonomique de l'Institut National de Recherche en Informatique et en Automatique, Domaine de Voluceau - Rocquencourt - 78150 LE CHESNAY - FRANCE.

S. REDON

Ecole Nationale de l'Aviation Civile - FRANCE.

P. FALZON

Université de TOULOUSE - FRANCE. Département de Psychologie.

ACKNOWLEDGMENTS

G. NEGRE, Air Trafic Control Instructor made important contributions to this work. The authors thank L. PAILHAS, Director of the Ecole Nationale de l'Aviation Civile and J. LEVET head of the A.T.C. Training Department for their support and encouragement.

Fig. 1 is from "Application of S.D.T. to decision making in supervisory control" by A. BISSERET in ERGONOMICS, 1981. Vol. 24, n° 2 (Taylor and Francis Ltd).

Fig. 2 and 3 have been adapted from the same paper.

Reprints may be obtained from A. BISSERET.

RESUME

Jusqu'à maintenant ce sont des activités humaines qui peuvent être représentées sous forme d'algorithmes qui ont surtout fait l'objet d'études d'apprentissage assisté par ordinateur.

L'apprentissage de la résolution de problème mal défini est encore peu abordé : c'est dans cette voie qu'une méthode d'apprentissage pour une classe de ces problèmes est présentée : il s'agit de "décisions dans le risque" étudiées ici sur l'exemple d'une tâche concrète : celle du contrôleur de trafic aérien.

On insiste sur une stratégie générale pour la conception d'un système de formation assistée pour ce type de tâche :

1) Analyse expérimentale de la tâche
2) Utilisation des résultats pour définir aussi bien la méthode pédagogique que les caractéristiques de l'outil informatique
3) Evaluation pédagogique du système ainsi conçu.

Le problème, particulier à ce type de tâche, de la "correction des résultats" de l'étude par l'ordinateur est posé en conclusion.

1 - INTRODUCTION

It is known that certain human decision-making activities can be accurately analyzed and represented in the form of algorithms : in particular, these concern the tasks of solving "well defined problems". The important work of Newell and Simon (1972) dealt principally with this type of activity. In such a case it is possible, from a pedagogical point of view, to use the methods that depend upon a systematic guidance of the learner. The rules to apply, the general process to do this, and the possible exceptions to the rules, can be clearly indicated to him.

Such a pedagogical approach was taken in the work of Landa (1974). The computer can thus be used as a powerful tool, and good examples of this were given on medical diagnosis (for example B. Varet et al : 1977).

Meanwhile many human activities have depended rather on solving "ill-defined problems" : in this category, although many people exhibit competence and success, their reasoning and the implicit rules that they use can only be insufficently explained and, thus, cannot be formalized. This gives rise to great difficulty in finding an adequate training method. Usually, this type of activity is learnt empirically, by keeping in close touch, for perhaps months or even years, with experienced people.

It is most likely that the computer will allow progress in this field, and it will be shown, how research into risk decision making has brought about a system of computer aided training.

2 - RISKY DECISIONS

This is an important class of activities that can be defined as follows : in order to act upon a situation the operator must make a diagnosis of the situation ; very often there are two possible different states : one that must lead to an action on the part of the operator : the state "signal" and one that makes any action unnecessary : the state "noise".

ABSTRACT

Until nom studies into computer aided training have been mainly concerned with human activities which can be represented in the form of algorithms.

The training to resolve ill-defined problems has yet to be tackled ; a method of training for a class of these problems is presented ; it concerns "risky decisions", studied here for a concrete task ; that of the air-traffic controller.

Stressed is a general strategy for the conception of the training system for this sort of task :

1) Experimental analysis of the task, using the signal detection theory
2) Use of the results to define the teaching method as well as the computer tool
3) A pedagogical evaluation of the system.

The problem of the "correction of the learner's results" by the computer, peculiar to this type of task, comes in the conclusion.

However, because he lacks information on the situation the operator cannot envisage the real state of the situation with certainty. Thus the task gives rise to four possible outcomes : two correct answers, but also two possible errors : to decide "signal" when it is "noise" (false detection) or to decide "noise" when it is "signal" (omission) : the operator must choose between two risks, according to the costs he attaches to each of the four possible outcomes.

Many human activities correspond, at least in part, to this schema : medical diagnosis, fault inspection at the end of a production line, and also driving, where, for example, there are decisions on overtaking where vehicles may be approaching from the other direction, etc.

The air trafic controller's task is the subject of this paper. A system to help in the training in risky decision making was conceived according to a research plan, the stages of which will act as a plan of presentation :

- Preliminary analysis of the task
- Specification of the principal characteristics of a training methodand of an appropriate tool
- Evaluation of their efficiency.

3 - EXPERIMENTAL ANALYSIS OF DECISION MAKING BEHAVIOR

Any system in order to succeed in helping training must be well adapted to the logic of the learning processes of the operators. A detailed analysis of the behavioural characteristics of trainees compared with those of experienced operators is necessary to define the training method as well as the tool likely to help the trainee in his evolution towards becoming an experienced controller himself.

3.1. - First analysis of the task

It is necessary in the study of concrete activities to separate the essence of the task from the total work involved and to formalize it before embarking upon experiments.

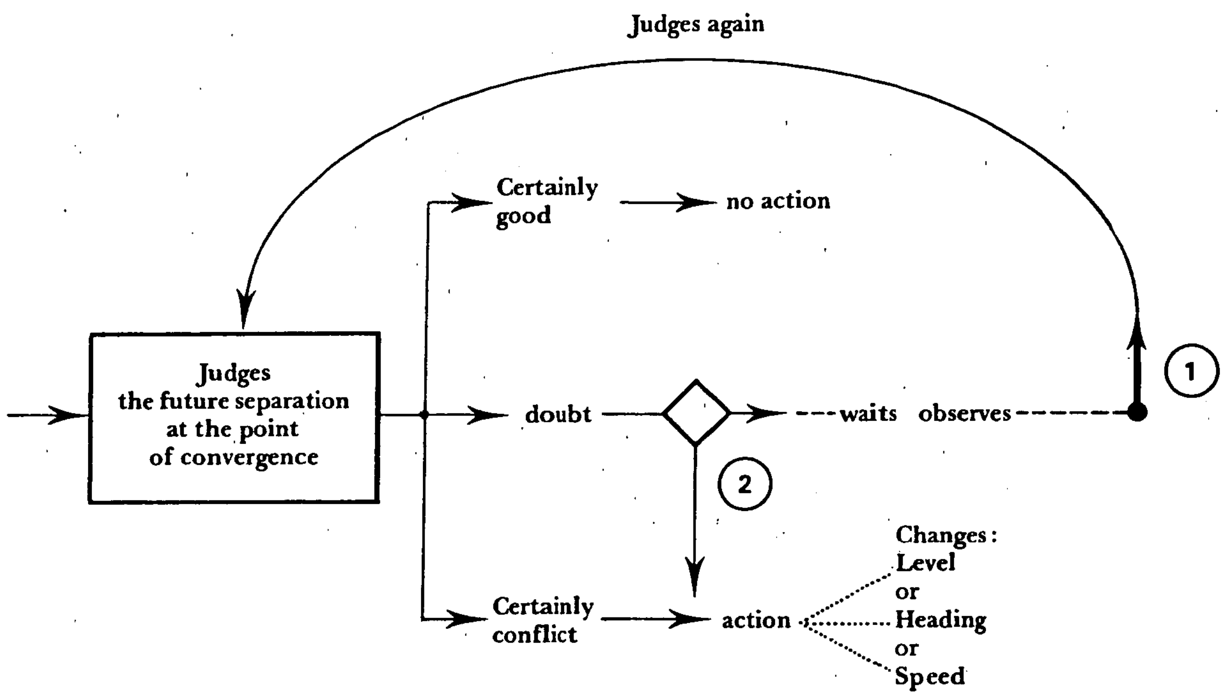

Figure 1 (from Bisseret 1981)

General model of perceptive judgements on radar screen.
(Obtained from analysis of interviews.)

Such a preliminary analysis of the work of air-traffic controllers made it possible to isolate the following central task.

The controller observes pairs of planes represented by the movement of plots in a radar screen. He must adhere to a norm of minimal separation. Thus for each two planes, the controller must predict if there will be a "conflict" (future separation < norm) : that is to say "signal" ; or if there will be no conflict (future separation > norm), that is to say "noise".

Experienced controllers, during a series of interviews were asked to express their reasoning orally : the general outline of their decision making has been represented in fig. 1. The possible response "doubt" can be noted ; in this connection an important first result was found : an experiment of simulation comparing a sample of trainees and a sample of experienced controllers confirmed the existence of this response "doubt" in a relatively important number of cases for the experienced controllers but was hardly ever present for the trainees.

3.2. - Formalization of the task

Obviously this response "doubt" is momentary. In all events the controller must either act or not ; and thus his process always results in a two fold decision which can be represented in the four case table, with two correct answers and two errors.

Thus a model can be made of the task due to the signal detection theory of Swets et al (1961) : actually this theory can be extended to deal with tasks of discrimination between complex stimuli (Bresson, 1973 ; Gaussin, 1972).

Without detailed reference to the model here, the following are the important points. The hypothesis is taken that the controller's observation of two planes results in a representation in the form of the value of a variable x which is continuous and unidimensional.

On this variable are supposed 2 probability density functions :

- The one for pairs of planes in "non-conflict" of mean $\mu_{\bar{c}}$
- The other for pairs in "conflict" of mean μ_c such that $\mu_c > \mu_{\bar{c}}$.

For each observation the controller must decide whether the pair of planes arises from the one or the other of these two functions.

The interest of the model is that it makes it possible to distinguish two processes in the task :

i) The extracting information process itself : this is represented by the parameter d', the difference between the means of the two functions : d' is therefore an index of discrimination. The easier it is to distinguish "conflict" from "non-conflict", the more the two functions are separated from one another and greater d' is.

ii) A process of decision making : the operator uses a criterion of decision : this criterion, named β is a certain value of the variable x such that if an observation x_1 is greater than β , the operator decides "conflict", and if x_1 is less than β he decides "non-conflict".
The value of the criterion is determined by the a priori probabilities of conflict and non-conflict and by the balance allowed by the operator between the costs of the 4 possible outcomes.
Thus β is an index of the attitude of the subject vis a vis the task : for the controller β indicates his degree of "caution", as regards the risk of omission for a conflict. The more cautious the controller is, the weaker β is.

3.3. - Experimental results

i) Differences between the trainees' decisions and the experienced controllers' decisions.
Several experiments were carried out in order to study these differences (Bisseret, 1979 ; 1981) : their principle being to bring out problems of simulated pairs of planes to two samples of subjects differing in their levels of experience. Their decisions were then recorded.
Having constructed a priori the problems, the experimenter knows the real issue of the situation : he can then calculate

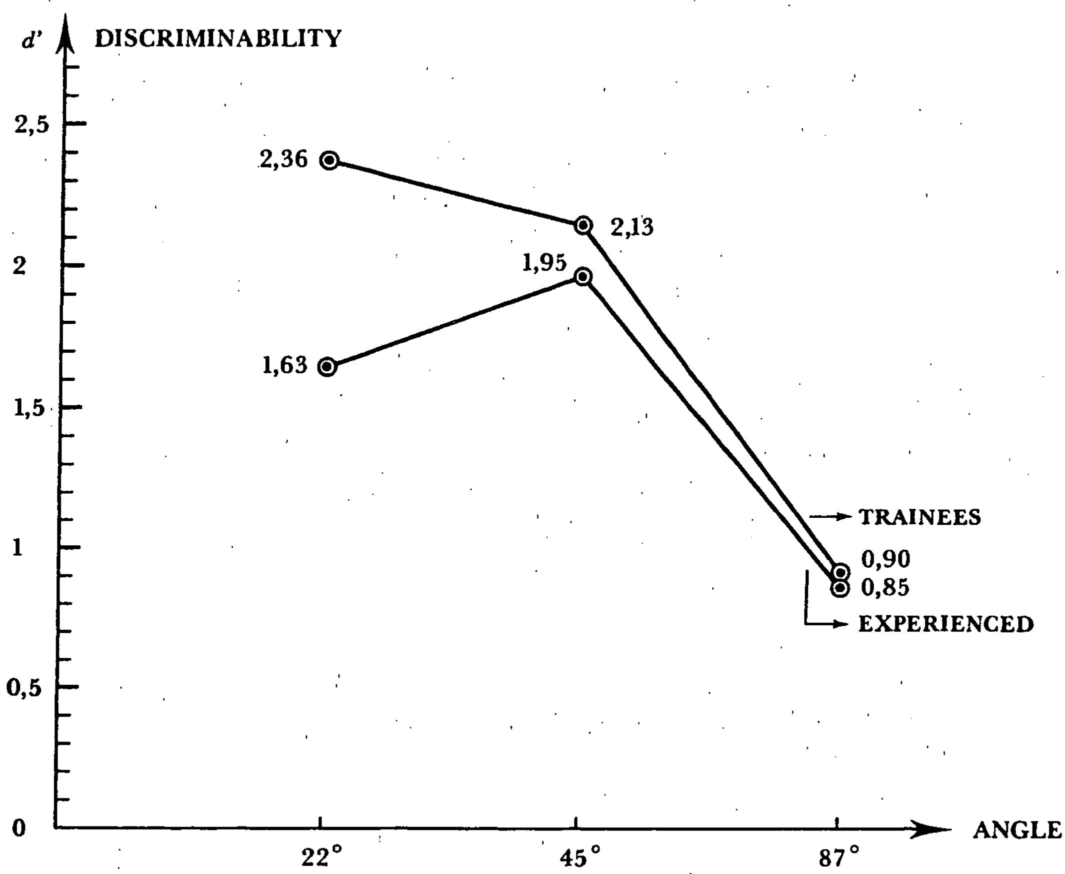

Figure 2

Variation of discriminability
according to variation of angle and experience.
(adapted from Bisseret 1981)

frequency of the four possible outcomes and estimate the indexes d' and β of the samples.
The results shown in figures 2 and 3 are those of one of the experiments in which as well as the level of experience the angle of the planes' convergence was varied. These results illustrate well the overall trend of the results found in the series of experiments carried out.
The trainees had systematically a better level of discrimination than the experienced controllers ($d'_{trainees} > d'_{experienced\ controllers}$). However the trainees were always less cautious than the experienced controllers, and sometimes considerably so ($\beta_{trainees} > \beta_{experienced}$).

ii) Interaction between the statement of the problem and the solution. Other experiments (Bisseret ; Girard, 1973) dealt with the activity of choice of solution made by the experienced controllers. One of the principal results was that of the great variability between individuals faced with the same situation ; certain operators decided not to intervene whereas others applied a solution : this shows that the decision not to intervene must be regarded as having the status of a solution.

The results can be interpreted as follows :

In this type of task, the statement of the problem is not completely external and imposed upon the operator as in the case of more classicaly studied problems. If a problem-situation is defined as a combination of the values of a set of variables then it is not possible to make a strict partition of this set according to "stated variables", the values of which are given to the operator and the "solution-variables", the values of which are chosen by the operator.

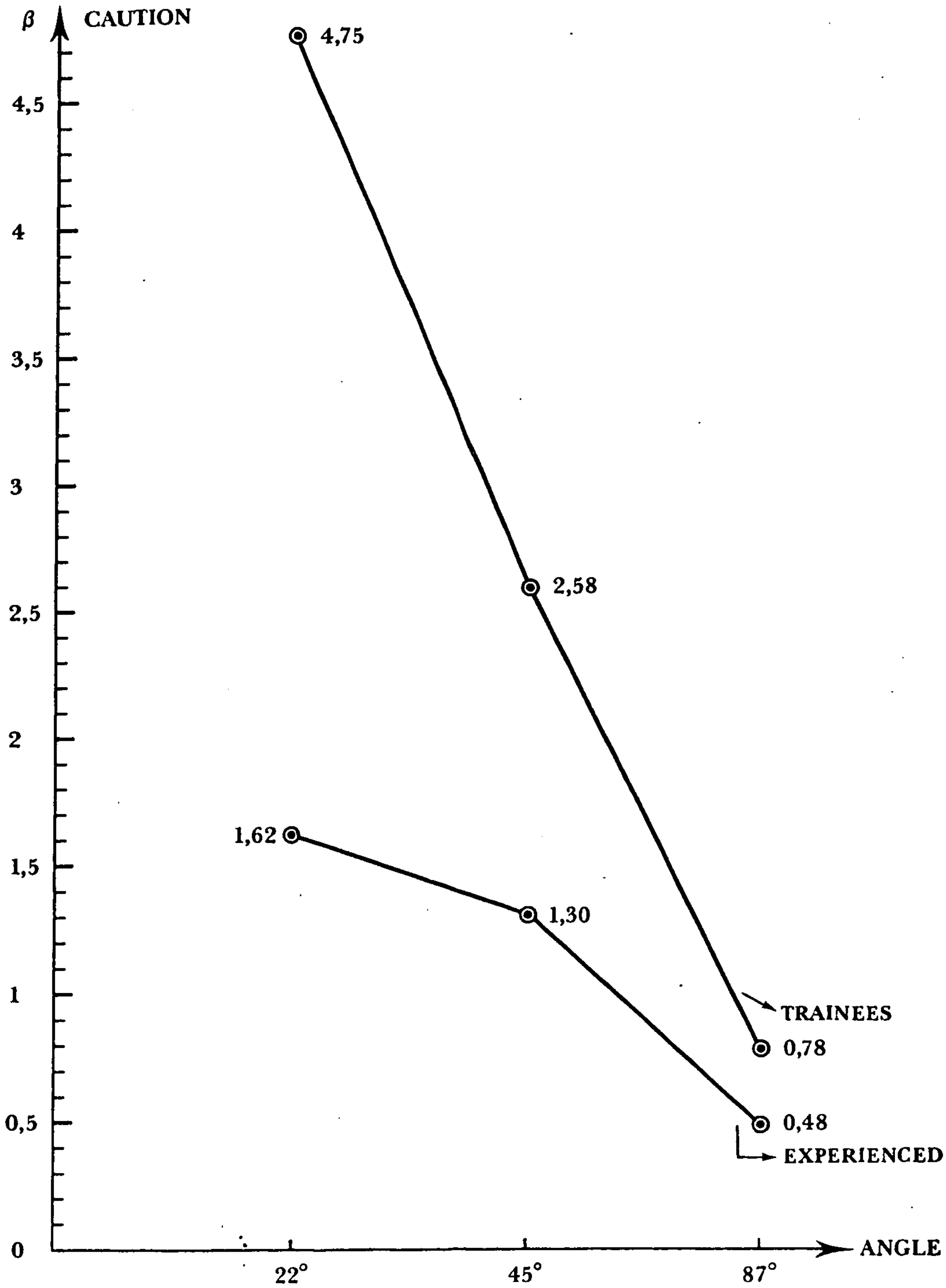

Figure 3

Variation of caution
according to variation of angle and experience.
(adapted from Bisseret 1981)

In fact, certain variables have 2 aspects : they can be decided by the operator and at the same time they contribute to the statement of the problem for him : the moment of intervention is a good illustration of this interaction between the "statement" and the "solution" of a problem. Depending on the moment of intervention, the value of the change of heading to be given to one or other of the planes in order to avoid conflict will vary. Thus the controller can fix the moment of intervention (statement) and choose the direction accordingly (solution) ; or he can do the reverse : fix the change of heading and choose the right moment.

Moreover, one realizes that the operator does not use all of the possible values in order to manipulate these variables. For each one in practice, he uses large classes of values : this in itself can be a source of difference between individuals.

Because of all these results, it seems difficult to formalize the behavior of experienced controllers into a unique model.

It can also be supposed that supplying ready-made rules to the trainee might lead him to apply them as "recipes" for a solution which will not be adaptable to new situations.

4 - RESULTING CHARACTERISTICS OF THE METHOD AND THE TOOL

These results of experimental research have made it possible to define a priori the specifications of a teaching method and a suitably adapted automatised system.

On a general level the chosen method of training does not consist of learning a series of ready-made rules : it depend upon the learner's discovery of his own rules.

On a more detailed level, here are the principal characteristics of the method and at the same time those of the computer tool.

4.1. - Condensing the time needed to gain experience

The learner is presented with a set of problem-situations representative of all the possible situations. The training relies upon the exploration of this set in a relatively short period of time compared with the many long months or even years needed to learn this type of decision in a real situation.

This exploration does not only save time : from the training point of view it encourages comparison between problem situations. To do this the learner has at his disposal a simulated work place comprising of the following :

- A simulated radar screen on which the computer plays out problems between pairs of planes
- A command terminal, of the "touch display type" : the learner can,by means of "menu" type dialogue :
  - choose the problem-situations he wishes
  - and, in order to solve the problems, pilot the plots (changing the altitude, flight speed, heading, etc.).

4.2. - Exploration of the Set by the Experimental Method

As a pedagogical method, the learner is given the opportunity to explore the set of situations by using the experimental method ; he is able to study the effect of each variable that defines a problem-situation keeping "all other things equal".

To do this the tool does not contain a bank of ready-made problem-situations : it is programmed in such a way that it allows all combination of the principal values of the variables which define the situations. The learner can thus choose :

- An angle of convergence, and for each plane
- The type of plane and therefore its speed
- The attitude of the plane (climbing, descending, or stable).

In fact, the system presents first an exercise "by default". It consists of two planes of the same type (B747) both of which are stable and facing each other head on (180° angle). To produce a different exércice the learner only has to change one, several, or all the characteristics of this exercise.

When he has thus composed a situation, the corresponding plots are shown on the radar and it begins to evolve.

Example exercise :

- The learner composes : /180°/ an airbus/climbing/a Boeing 747/ stable/
- The learner can then make a diagnosis : if he decides "conflict" he can, for example, try a change in heading of 5° by either of the planes at the moment he judges correct, and state, a few moment later "that won't work"
- He can then ask for a replay of the same situation and subsequently try several degrees of change in heading, until he finds the one that will, in fact, allow a suitable separation
- Then he can modify one variable of the original situation ; keeping the same 2 planes, still face to face, but for example, both of them climbing ; he will then try to discover how this change of one variable makes him change the solution
- He could then change the speeds, etc.

4.3. - The learning of Caution

The results of research have shown that the trainees had a tendency to be too discriminating and not sufficiently cautious.

To avoid an attitude of overprecision and to encourage caution, the system was supplied with an alea. When the trainee plays back a situation it closely resembles the first situation but has been slightly modified. The future separation of the planes can either be improved or worsened, and this within variable proportions. This is to make the learner doubt the stability of objective situations, and thus, to gradually adopt a lower criterion of decision : in other words it tries to make the trainee more often decide "conflict" unnecessarily, to reduce the risk, than to decide "non-conflict" incorrectly.

Type of problem	Control Group			Experimental Group	
	1st test	2nd test		1st test	2nd test
2 planes at the same level 1) 40° angle of convergence	0	6.0		13.0	10.0
2) 90° angle of convergence	7.0	17.5		12.5	15.0
2 planes climbing or descending 3) head on (180°)	26.5	36.5		53.0	61.0

Table 1 : Percentage of "non-conflict" responses when conflict according to the type of problem, and for the two tests for each group

5. EVALUATION OF THE METHOD

A first evaluation was made through the following experiment (Falzon, 1979). A set of pupils on a practical course of 12 sessions (1) was divided into 2 groups, each of 12 members.

The "control" group did the usual practical work which also consisted of exercises on a simulator, but with an imposed progression and under the supervision of an instructor who commented and corrected throughout each session.

The experimental group had the same number of sessions but used the self-teaching method described above. The functioning of the tool was explained at the first session, but once this had been done, no rules were given concerning its use. The pupils were free to construct whatever exercises they wished. Both groups took two evaluation tests, after the 7th and 12th sessions.

The following are the main results

5.1. - Comparison of the results of the two groups

Because the number of measures was insufficient the values of the parameters d' and β had very little signification. However, it is interesting to compare the frequencies of the appearance of "omissions", i.e. the "non-conflict" response when there was one (Cf. Table 1).

It can be seen that as concerns the risk of omission, the self-teaching group tended to be more cautious than the control group. This is an encouraging result in that the acquisition of this caution is one of the essential objectives of the method.

Nevertheless, it can also be seen that both groups tended to increase this type of response from one test to the other, so it could be that this is a phenomenon which is characteristic of the first phase of training. It would be necessary to follow the

---

(1) It was an initiation course for graduate engineers.

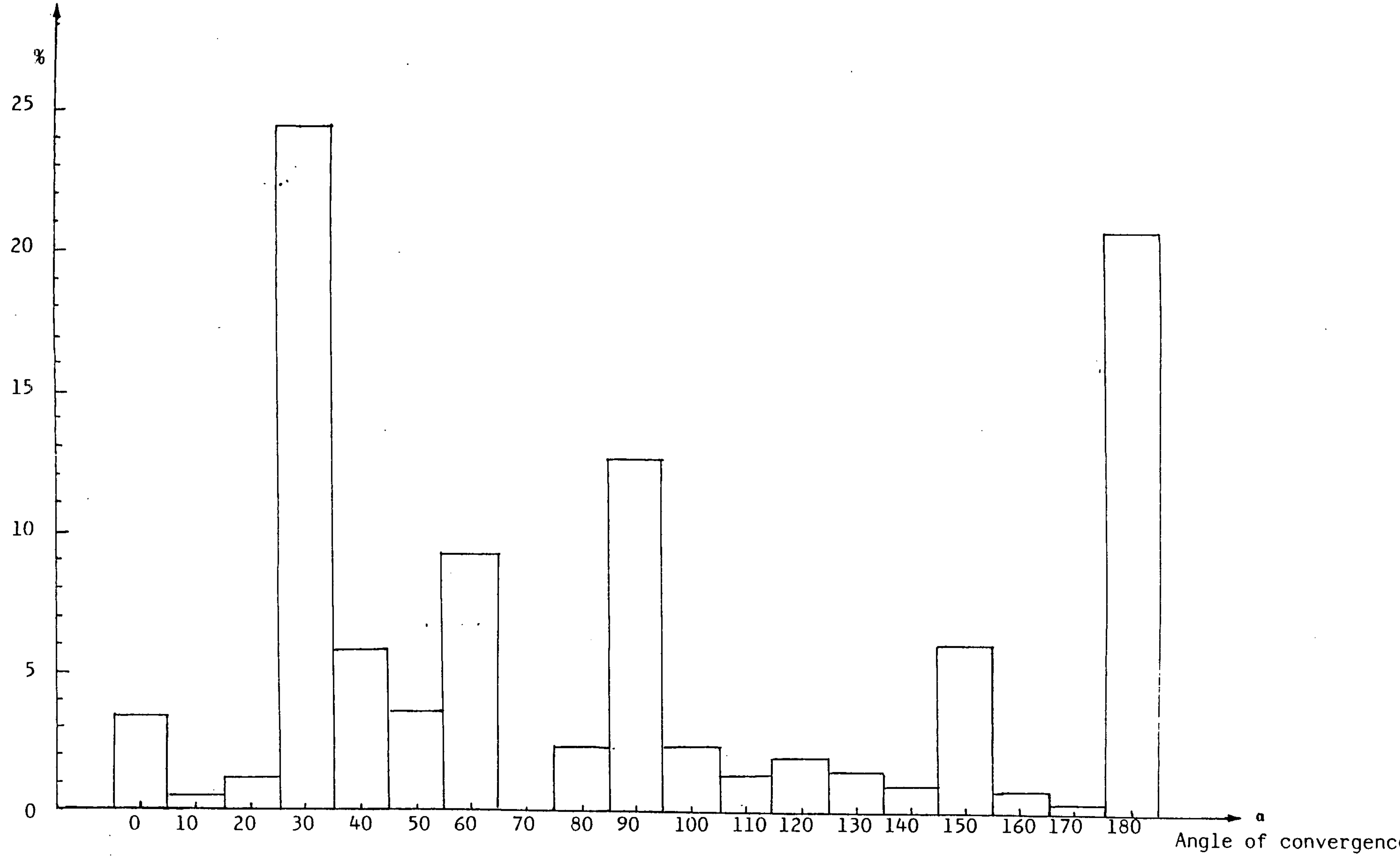

Fig. 4 : The frequencies of the pupils' use of the 19 possible angles

training over a longer period to know if it is a temporary or lasting phenomenon, and if proving to be the latter, the method should be modified.

5.2. - Qualitative analysis of the training process

The pupils were entirely free to program their own exercises ; which gave rise to a fear (expressed by certain instructors) that they might treat the tool more "like a game" than a training method ; or else, even if they treated it as the latter, they would be unable to organise their sessions in an efficient manner. The risk was that the pupils would explore the universe of situations in a disorderly way.

In fact, it has been established that this was not the case, despite the large number of possible situations and the small number of sessions.

Without going into too much detail here and giving a too specific analysis of the air-traffic controller's problems, we will underline 3 characteristics of the pupils' activities that show the organisation towards a systematic training.

- A representative sample

This behaviour of selecting a representative sample was shown particularly clearly by the choice of the angles of convergence (Cf. fig 4) ; among the 19 angles permitted by the tool, the pupils favoured certain ones (multiples of 30°) but at the same time covered the range quite well.

	2 jets	1 jet & 1 B 747	2 B 747 s	1 B 747 & 1 propeller	1 jet & 1 propeller	2 propeller aircraft
Sessions 1, 2 and 3	21.6	22.0	32.9	13.5	8.0	1.9
Sessions 5, 6 and 7	41.0	28.6	7.5	2.5	16.6	3.67

Table 2 : Frequency of choice of aircraft type and evolution from the first to subsequent sessions

	2 stable planes	1 stable + 1 climbing or descending	2 climbing and/or descending	2 climbing and/or descending then stable
Sessions 1, 2, 3	59.5	25.0	7.5	7.5
Sessions 5, 6, 7	23.5	28.5	27.0	20.5

Table 3 : Frequency of choice of the classes of vertical trajectories and evolution from the first to subsequent sessions

- Realistic choices

The pupils had a clear tendency to train using the situations that are the most frequent in real life - which can be considered as an intelligent choice bearing in mind that this was an introductory course.

This attitude is especially shown by the "type of aircraft" variable (Cf. Table 2). The pupils trained mostly with jet aircraft keeping only a small number of their exercises for propeller aircraft, and when this was the case, the situation usually comprised of one jet and one propeller aircraft.

- A progression in difficulty

The adoption of a spontaneous pedagogical strategy was particularly shown concerning the pupils' choice of the relative trajectories in the vertical plane. Table 3 shows that they started over the first few sessions with easier problems (stable aircraft) leaving until later the more difficult problems of convergence with climbing and/or descending aircraft.

5.3. - Evaluation of the tool itself

The tool proved easy to use : from the first session the composition of the situation and the piloting of the plots using the touch display were mastered by the pupils.

However, one shortcoming is worth drawing attention to : the exercise "by default" seems to have overinfluenced the pupils - that is the situation of 2 B. 747s, converging at 180° (head on) and both stable.

As can be seen in fig. 4 and Tables 2 and 3, the particular values of the variables defining this by default situation were chosen often abnormally. The pupils had a tendency at the beginning of each session, to start with the "by default" situation, or partial modifications of it.

Faced with this fact, we would recommend withdrawing the "by default" exercise and replacing it with a neutral choice from the start.

All in all, this is only a preliminary evaluation and should be completed by other studies, on a greater number of pupils and over a longer period of training.

Moreover, only the diagnostic activity could be tested here, and it would be interesting to evaluate the help offered by this tool for the training of problem-solving by the pupil.

However, these first results are encouraging : in the absence of any rules, the pupils organised their training themselves, starting with a limited number of well-chosen situations and following a progression in difficulty.

Also, the comparison with the classic method makes it possible to conclude that, for the practical side, the self-teaching method produces results that are at least as good.

It should be pointed out that the self-teaching method is already in use in the Control School and in Control Centres.

6. CONCLUSION

To conclude, it is interesting to underline a difficult problem that arises from aided training for this type of decision making. It concerns the participation of the computer in the evaluation of the learner's performances : it is known that the immediate correction is very effective pedagogically. In many tasks it is possible to clearly distinguish between a correct answer and a wrong one and it is thus easy to inform the learner.

But for tasks of risky decision making, this is not the case. In reality, the "correct answer" (or the natural outcome) is often not known ; in a real situation, the air-traffic controller never knows if two planes were actually going to fly too close to one another, in the same way that a doctor seldom has the a posteriori possibility of verifying his diagnosis independantly from the treatment he has prescribed, etc.

Now, in a simulated situation the "natural" outcome is known since one is in full control of the construction of the situation ; the problem relies upon knowing whether or not one ought to inform the learner of this real outcome. A plausible hypothesis is that pedagogically this would not be good, as by doing so, one would risk leading the learner into seeing the task as being relevant to an algorithmic process of decision, whereas he must, as has been shown, learn to choose between 2 errors.

Thus, rather than have the computer evaluate each exercise in terms of success or failure, one must work towards a system of evaluation which would provide the trainee, at regular intervals, an estimation of his powers of discrimination (d') and his crite-tion of caution (β).

It is the correct evolution of these two measures towards the values of the experienced operators that would give the learner, the feedback necessary for him to progress.

REFERENCES

Bisseret,A. ; Girard Y. (1973) - Une expérience sur le choix des solutions dans le contrôle du trafic aérien - Research Report of IRIA, n° CO R35.

Bisseret, A. (1979) - Utilisation de la théorie de la détection du signal pour l'étude de décisions opératives : effet de l'expérience des opérateurs - Research Report of IRIA, n° CO R60.

Bisseret A. (1981) - Application of signal detection theory to decision making in supervisory control : the effect of the operator's experience - Ergonomics - 1981 - Vol. 24 - n° 2, 81-94.

Bresson F. (1963) - La place des processus de décision dans l'activité perceptive - Journal de Psychologie Normale et Pathologique, vol. 60, 37-61.

Gaussin J. (1972) - Un essai d'extension de la théorie de la détection des signaux comme modèle de décision sous risque. Bulletin du CERP, vol. 21, n°4, 145-156.

Landa L.N. (1974) - Algorithmization in Learning and Instruction. Educational Technology Publications.

Newell A. ; Simon H.A. (1972) - Human Problem Solving. Prentice Hall, LONDON.

Swets J.A. ; Tanner W.P. ; Birdsall T.G. (1961) - Decision Processes in Perception. Psychological Review, vol. 68, n° 5, 301-340.

Varet B. ; Allorent F. ; Levy J.P. ; Salame N. ; Blondel F.M. ; Boyer J.F. (1977) - Comparison between a prescribed and a permissive process in computer assisted training in decision making. Information Processing 77. B. Gilchrist Editor. IFIP, North-Holland Publishing Company, 343-346.