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The Addition of Peripheral Vision to the Artificial Horizon

By

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The Addition of Peripheral Vision to the Artificial Horizon

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June, 1963

SUMMARY

This report describes an attempt to make instrument flying easier. Horizontal lines were placed on either side of the pilot at the periphery of his field of view. They moved up and down differentially as the aircraft rolled and together as it pitched, simulating the apparent motion of the real horizon. Tested in a fixed cockpit these lines or 'side-bars' did not completely succeed in creating the illusion of a stationary horizon. However, the pilot's performance as regards accuracy was much improved in tasks requiring simultaneous monitoring of roll and pitch. It is not certain that the beneficial effects of the side-bars would be found in a real aircraft because the additional clues they provide might be eclipsed by the physical effects of motion. Tests in a moving simulator are recommended to see if this possibility can be eliminated. However, even if it were not eliminated the provision of side-bars in the cockpit of a fixed simulator might extend its field of usefulness.

Introduction

When flying blind a pilot must divide his attention between several instruments. A major factor affecting the ease of control is the time required to look at all of the instruments and interpret them correctly. The shorter this time or the greater the rate of scan the less will be the individual alterations in each indication and the more accurate the picture of the flight-path built up in the pilot's mind. Any reduction of the time required to interpret even one of the flight instruments can be of major assistance. In fact in difficult circumstances, such as landing an aircraft on a carrier deck, it has been found necessary to use a different sense to detect some of the information (the aural airspeed indicator). Unfortunately, one of the pilot's most useful instruments, the artificial horizon is subject to possible misinterpretation and, quite apart from the consequences of interpreting it wrongly, this means that the average time spent studying it is increased.

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Replaces A.R.C.24 916.

This misinterpretation problem is well known and arises from the difficulty which the pilot has in associating himself with the aircraft image which appears to be stationary while the horizon bar moves. Although the instrument is truthful in that the horizon bar is always parallel to the real horizon the presentation frequently looks wrong and can easily lead to the pilot making a correction in the wrong sense. The sensation is similar to the one which accounts for the unrealistic appearance of film taken from the cockpit of an aircraft in flight or from a motorbicycle in motion. To the pilot the horizon appears to remain horizontal, while the film depicts it as moving.

Certain methods of film presentation, such as cinerama, succeed in creating the illusion of a stationary horizon to such an extent that whole audiences become quite convinced that the room in which they are seated is moving and lean over in sympathy with this imaginary movement. The technique used is to produce a picture which extends to the periphery of the audiences' vision. It was therefore suggested that if the horizon-bar could be extended so that it appeared to surround the pilot a much more powerful illusion would be produced. Obviously to provide all round coverage would be impracticable but it was thought that a similar result might be achieved by placing two oscilloscopes near the periphery of the pilot's field of vision, with a horizontal line on each moving up or down as the aircraft banked. Fig.1 shows this general arrangement diagramatically and indicates the dimensions which control the position of the two side lines. These are:-

(1) The horizontal separation of the side-bars; h.

(2) The vertical separation between the plane of the horizon and the pilot's line of sight; v.

(3) The distance from the pilot's eyes to the centre of each side-bar; d_1.

(4) The distance from the pilot's eyes to the normal artificial horizon; d_2.

The choice of these dimensions may largely be a matter for individual preference, but it is clear that the plane of the horizon must be sufficiently far beneath the pilot's line of sight to enable him to see out of the cockpit, unless 'head up' instrumentation is used, and also that the side-bars must not be located at the pilot's blind spot. In any case the practical consideration of available cockpit space would normally leave little room for choice of position*.

Experimental Installation

The experiments were based on the use of a 16 amplifier analogue computer which is described in more detail in Ref.1. It was used to build up a simple simulator.

After/

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*At the time of the experiments the writer was unaware of the phenomenon of "tunnel vision", namely, that the field of peripheral vision may become substantially reduced under conditions of stress. It now appears that for application to aircraft, as opposed to simulators, the side-bars might prove more effective in emergency if positioned nearer the central instrument. Greater knowledge of the physiology of peripheral vision is required before complete reliance can be placed in instrument presentations of this type.

After some initial study the oscilloscopes representing the normal artificial horizon and the side-bars were arranged inside a cockpit based on the use of the hood of a D-2 link trainer so that; $h = 26$ in; $v = 10\frac{1}{2}$ in; $d_1 = 17\frac{3}{4}$ in., and $d_2 = 23\frac{1}{2}$ in. These dimensions were derived largely as a result of the writer's preferences but as it would be very difficult to find optimum positions for all of the instruments this installation was used throughout the tests. The lines on all of the oscilloscopes were 4 in. long and the measurements quoted above are from the centre of each line to the point midway between the pilot's eyes. The side-bars were always geared so that they formed a continuation of the normal horizon bar and so that the angle between the line joining them and the horizontal was the true angle of bank. This was considered essential because when flying in thin cloud it would be disconcerting if the real and artificial horizons were not parallel*.

Initial Tests on the Side-Bars

Although the presentation was greatly enlivened by the side-bars so that small changes in bank angle were detected much more quickly there was still no illusion of motion about a fixed horizon. The pilot still had to make a conscious effort to interpret what he saw. Part of the difficulty lay in the fact that the pilot terded to associate the side-bars with the aircraft's wing tips rather than the horizon and thus correct in the opposite sense. An attempt to overcome this was made. The side-bars were altered so that they appeared to be a continuous wave moving steadily towards the pilot so simulating the motion of the aeroplane. This actually proved confusing as the bars appeared to move up and down as well as backwards due to the pilot's rather distorted view of them. Finally, the bars were made to move in sympathy with the pitch of the aircraft. This was done so that as the aircraft pitched up the bars went down which altered the apparent perspective of the horizon and gave the impression that the aircraft had climbed rather than simply that it was climbing. Because the illusion produced was of a change in height and not a change in pitch the gearing appeared to be quite arbitrary in this case. It had to be kept reasonably low or else the bars disappeared from view too easily. This alteration brought a lot more life to the presentation, although the original hope that a complete illusion of aircraft motion relative to a stationary horizon, as is achieved by cinerama, was still not fulfilled. Despite this the side-bars seemed to ease the pilot's task considerably, chiefly by drawing his attention to small changes in bank angle, and it was therefore decided to attempt comparative tests in order to determine their effect upon his performance.

The Nature of the Tests used to evaluate the Side-Bars

The tests were so devised that it was necessary to look at two instruments thus ensuring that the rate of scan was important. Using approximate equations of motion for a Viscount series 800 (the short period, constant speed, pitch equation and a roll equation which gave the correct

initial/

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*Throughout the experiments the cockpit was in darkness except for normal instrument lighting. The pilot had no outside view and no attempt was made to simulate the effect of superimposing the side-bars on the normal view out of the cockpit.

initial angular acceleration and final angular velocity) a simulated aircraft was produced which the pilot had to control in pitch and roll using the artificial horizon as a reference. Control was by means of a small centre stick, 6 in. long with a movement of 3 in. in any direction at the pilot's hand. It was spring-loaded with a rate of 1·45 oz/in. In roll he was merely required to keep the wings level in the face of disturbances. The integral of the flightpath angle was displayed to the pilot on the horizontal needle of an ILS cross-pointer instrument to such a scale that full deflection represented approximately ±100 ft at 120 knots. His task in pitch was to keep the needle in the centre position, thus holding the height constant. This required reference to the ILS meter together with a certain amount of cross-reference to the artificial horizon. In principle therefore the two tasks were completely independent. A function generator was used to provide an arbitrary disturbance lasting for a period of 80 secs. It was used directly to provide the roll disturbance and its integral was used to provide a varying disturbance in pitch. The magnitude of either could, of course, be varied independently. Fig.2 shows one magnitude of the roll disturbance which became known as the easy roll task.

The integral of the modulus of the error in either bank or pitch was measured electrically so that a comparative score could be given immediately after each run which lasted for exactly 80 secs, that is the time taken for one complete cycle of the disturbance, when pitch and roll tasks were performed separately; and for 160 secs when they were performed together because pitch and roll scores could not be measured simultaneously so that it was necessary to continue for two complete cycles.

Standardization of Roll and Pitch Tasks

Before any comparative tests could be attempted it was felt desirable to relate the difficulties of the roll and pitch tasks on their own. A standard roll task, consisting of a disturbance with a peak to peak amplitude of 30° was chosen and 12 runs were made giving a mean score of 24·6 (this corresponded to a mean error of 0·61°).

Five different magnitudes of pitch disturbance were then taken and five runs completed for each. The scores in these tests are shown in Table I and plotted in Fig.3. Within reasonable limits of scatter the results show a gratifying degree of linearity between score and magnitude of disturbance; it was thus possible to pick a magnitude of pitch disturbance which produced approximately the same numerical score as the standard roll task already mentioned. This disturbance was used as the standard pitch task. The method used to determine it does not imply that it had precisely the same degree of difficulty as the standard roll task but simply that a pilot trying equally hard at each task would think that he had done equally well in each. In all subsequent tests the magnitudes of the pitch and roll tasks were varied without altering this ratio.

Random Tests covering Wide Range of Variables

Three magnitudes of task were chosen, being one half, equal to, and double those of the standard roll and pitch tasks. These correspond to tasks which were easy, medium and difficult respectively. Three values of pitch gearing were used, with one degree of pitch change producing either 0, 0·125 or 0·625 in. of movement of the side-bars. The mean scores for three runs with the side-bars in use and for three without them were evaluated for each combination of task and gearing in three circumstances:-

(a)/

(a) Roll task alone

(b) Pitch task alone

(c) Roll and pitch tasks combined

The test runs were made in random order and the pilot was told his score after each one. They were made in batches of thirty minutes duration which was the maximum the pilot could do without becoming over-tired. After each break he was allowed to repeat the last three runs as practice before proceeding to the next batch. After overnight breaks a complete half hour practice session was given. The results from these tests are summarised in Tables (II-IV). Despite the precautions taken to guard against scatter, no real pattern emerged from the results. The reason for this lay in the fact that the task was so difficult. It required three runs to get into practice after each break and that occupied about 10 mins. By the time another three runs were completed the pilot was already showing signs of tiredness so that in practice there was virtually no time when the results were not affected by either learning or tiredness. Even if many more runs had been made it is doubtful if adequately consistent results would have been obtained because direct comparisons between tests with and without side-bars under otherwise identical conditions were frequently separated by long intervals as a result of the random distribution of the tests.

Demonstration of a Different Comparison Technique

The only way to get consistent results appeared to be to keep all the variables constant and then investigate the effect of the side-bars in those particular conditions. At this stage the writer decided to do the flying himself in order to avoid the continual use of another person. Of course the writer could easily be biassed but a large amount of time was saved by this decision enabling many more runs to be made. If any significant results emerged they could be checked with another pilot.

Firstly, so as to find a pattern of testing which would give consistent results 30 consecutive runs were made with the easiest roll task followed by 30 runs with the most difficult roll task. They were completed in batches of ten and the scores are tabulated in Table V. It can be seen that the scores vary over a wide range and so demonstrate the inadequacy of using only three runs as a basis of comparison. The scores of the 30 runs were then divided into two groups consisting of the 1, 3, 5 ..... runs and the 2, 4, 6 ..... runs. The successive means of these groups were evaluated and are included in Table V. It will be seen that when the means of each group are based on about 10 runs they are very similar and when plotted in Fig.4 it is clear that both groups were the same test. Furthermore, since both groups contain readings taken at the beginning, middle and end of the sequence these means are independent of learning, tiredness and other extraneous factors. This system can be used for comparison purposes by making the alternate runs with and without the side-bars and comparing mean results. From the above results it was expected that any improvement of more than 2 to 3% would be shown up.

Initial Comparison for the Roll Task

Table VI and Fig.5 show such a comparison for the most difficult roll task alone. It is clear that the side-bars did not significantly improve the results. This is not surprising because the pilot was free to

concentrate/

concentrate on the artificial horizon all the time. As already mentioned it was necessary to take the scores for the pitch and roll tasks separately when both were being performed together and this was not altogether satisfactory as the pilot could hazard a guess at which particular task was being scored and so concentrate upon it. Therefore, before serious comparisons were for both tasks together a new scorer was developed which enabled the tasks to be scored simultaneously.

Comparison for Roll and Pitch Tasks Together

A comparison was now made for the most difficult roll task compared with the medium pitch task, tasks which for the pilot performing the tests, produced similar scores; in fact this pilot actually produced lower scores with the most difficult roll task than with the medium pitch task. Fig.6 shows that the improvement in score was about 22% with the side-bars in use. To illustrate this improvement further the mean score for the pitch task alone (25 runs) was 36·0 and for the roll task alone (15 runs) was 26·3. Added together these indicate that the minimum possible score for the combined task would be 62·3. Without side-bars the score was in fact 65% worse than this while with them in use it was only 33% worse, clearly a most significant improvement. A quick check over 20 runs showed that the improvement in score brought about by the introduction of side-bars was nearly equally divided between the pitch and roll scores. The improvement was undoubtedly due to the fact that the pilot was alerted to bank angle changes even when he was concentrating on the ILS meter. The effectiveness of the device springs from the fact that changes in attitude are easily corrected if action is taken at once; and that the nervous system of the human being is such that he responds quickly to any sudden movement seen out of the corner of his eye.

With another pilot the improvement in score due to the side-bars was only 14% as compared with 22% for the previous pilot but this is still appreciable and there was no doubt that he was under less strain with the side-bars in use. All of these tests were done with a pitch gearing of 0·125 in. per degree. An increase of even 0·312 in. per degree made the display confusing because of an undesirable tendency for one or other of the bars to disappear. Probably the results would have been just as good without the pitch gearing but even a little gearing did seem to enliven the display considerably especially when large pitch changes were being made.

Discussion and Conclusions

These tests have shown clearly that when performing two tasks simultaneously a marked improvement in accuracy was obtained by extending the artificial horizon by means of two lines positioned near the limits of the pilot's field of vision. However, the results, which were obtained from a fixed base simulator, should not be applied directly to a real aircraft, because the side-bars mainly provide an angular velocity stimulus which may merely duplicate cues already available to the pilot of an actual aircraft due to its motion. However, even if this were so the use of side-bars could extend the field of usefulness of fixed simulators by providing cues similar to those of a moving cockpit. It would therefore be very interesting to compare results obtained in a moving simulator with those obtained from a fixed simulator, both with and without the side-bars in use, for a problem in which a moving simulator is usually considered essential: only if such tests indicated that the side-bars are still helpful to the occupant of a moving cockpit would it be worthwhile to tackle the practical problems of

developing/

developing a blind flying installation on this principle. In particular, the side-bars would have to be very bright to attract the pilot's attention in a real aircraft flying in cloud. Possibly it would prove desirable to use some form of "head-up" presentation.

There remains the possibility that the use of side-bars in a real aircraft where the physical cues of motion are already present would create the "grand illusion" of a stationary horizon which was sought originally. However, even if the only use for the side-bars proved to be to increase the field of usefulness of fixed base simulators the idea would have proved extremely valuable.

References

No.	Author(s)	Title, etc.
1	K. J. Holden	Investigation of some piloting problems by analogue techniques. Ph.D. Thesis, The Queen's University of Belfast. March, 1963.
2	G. A. Rathert, B. Y. Creer and J. G. Douvillier	The use of flight simulators for pilot control problems. NASA Memo 3-6-59A. February, 1959. A.R.C.21 046. June, 1959.

Table I /

Table I

Variation of Score with Magnitude of Task
(Pitch alone)

Relative Magnitude	Scores in Volts					
	1	2	3	4	5	Mean
0·2	9·7	8·9	5·6	7·3	10·0	8·3
0·5	12·7	13·6	8·0	11·1	8·9	10·8
1·0	21·6	17·0	19·8	15·0	11·6	17·0
2·0	26·9	20·9	24·0	23·3	25·9	24·2
4·0	42·0	50·0	31·5	40·1	53·0	43·3

Table II

Initial Tests: Pitch Gearing = Zero

Task	Side-bars	Roll score (Roll alone)	Pitch score (Pitch alone)	Total score (Both together)
Easy	IN	13·6	15·9	50·2
	OUT	15·8	11·8	49·8
Medium	IN	20·7	22·9	73·0
	OUT	22·1	24·3	59·8
Difficult	IN	31·0	31·9	135·6
	OUT	18·4	39·4	116·6

Table III /

Table III

Initial Tests: Pitch Gearing = 0·125 in./degree

Task	Side-bars	Roll Score (Roll alone)	Pitch score (Pitch alone)	Total score (Both together)
Easy	IN	12·0	12·9	52·8
	OUT	15·1	12·5	54·0
Medium	IN	18·9	19·2	87·2
	OUT	22·0	23·1	80·0
Difficult	IN	58·2	51·6	122·4
	OUT	57·3	63·2	118·8

Table IV

Initial Tests: Pitch Gearing = 0·625 in./degree

Task	Side-bars	Roll score (Roll alone)	Pitch score (Pitch alone)	Total score (Both together)
Easy	IN	15·1	18·4	57·4
	OUT	14·8	15·0	62·2
Medium	IN	18·7	14·4	77·2
	OUT	24·6	17·4	62·6
Difficult	IN	31·9	33·3	126·4
	OUT	27·0	28·9	118·4

Table V /

Table V

Demonstration of Comparison Technique

Easy Roll Task				Difficult Roll Task			
1,3,5,7... Runs		2,4,6,8... Runs		1,3,5,7... Runs		2,4,6,8... Runs	
Score	Mean	Score	Mean	Score	Mean	Score	Mean
12·8	12·80	13·6	13·60	20·8	20·80	18·8	18·80
11·5	12·15	10·0	11·80	22·0	21·40	21·5	20·15
10·4	11·57	9·5	11·03	20·0	20·93	20·5	20·27
11·5	11·55	13·0	11·52	24·5	21·82	24·5	21·32
13·0	11·84	12·8	11·78	22·8	22·02	20·8	21·22
7·8	11·16	8·5	11·23	23·5	22·23	25·5	21·93
10·0	11·00	10·3	11·10	15·7	21·33	24·3	22·27
9·4	10·80	8·8	10·81	20·0	21·16	19·0	21·86
10·1	10·72	13·6	11·12	23·0	21·37	20·0	21·66
13·5	11·00	14·7	11·48	18·0	21·03	21·0	21·59
6·7	10·61	8·8	11·24	17·3	20·69	18·0	21·26
11·0	10·64	8·5	11·01	17·3	20·41	19·0	21·07
12·1	10·75	11·8	11·07	18·0	20·22	18·6	20·88
11·7	10·82	9·0	10·92	20·3	20·23	22·3	20·99
11·5	10·87	10·6	10·90	23·4	20·44	18·3	20·81

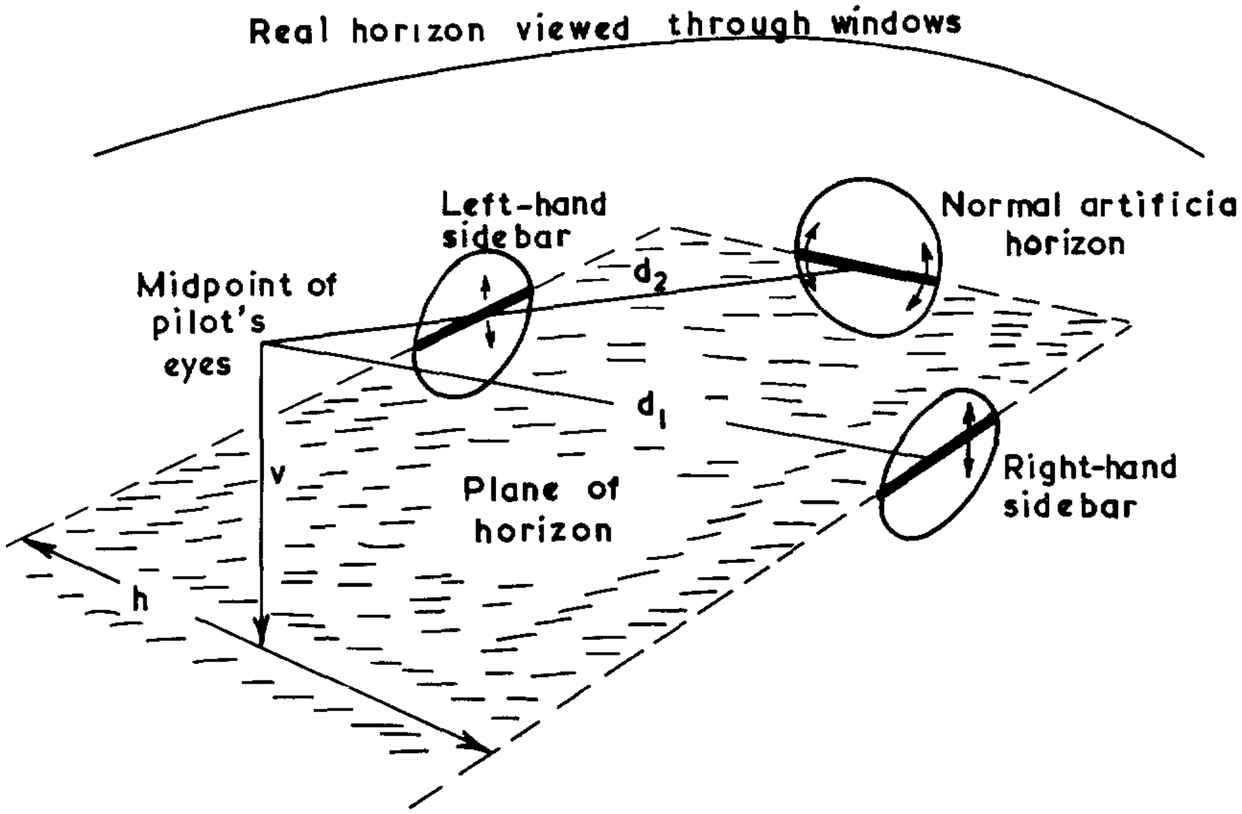
Table VI

The Effect of Side-bars

Difficult Roll Task				Difficult Roll Task Medium Pitch Task (new scorer)			
Without Side-bars		With Side-bars		Without Side-bars		With Side-bars	
Score	Mean	Score	Mean	Score	Mean	Score	Mean
16·8	16·80	14·2	14·20	99·8	99·8	118·0	118·0
14·0	15·40	17·3	15·75	69·3	84·5	91·8	104·9
16·5	15·77	14·8	15·43	76·2	81·8	106·0	105·3
15·3	15·65	16·0	15·57	76·8	80·5	94·0	102·4
16·8	15·88	14·2	15·30	87·8	82·0	99·2	101·8
16·6	16·00	16·7	15·54	80·5	81·7	93·0	100·3
17·4	16·20	16·8	15·71	81·7	81·7	113·0	102·1
17·0	16·30	15·8	15·72	81·5	81·7	101·0	102·0
14·4	16·09	14·9	15·63	74·3	80·9	97·8	101·5
15·2	10·00	16·8	15·75	78·2	80·6	85·8	100·0
15·0	15·91	13·4	15·54	75·2	80·1	113·0	101·1
15·0	15·83	17·0	15·66	82·8	80·3	110·0	101·9
16·5	15·88	15·5	15·65	84·8	80·7	104·0	102·0
21·6	16·29	17·6	15·79	85·3	81·0	103·0	102·1
17·8	16·39	15·0	15·73	-	-	-	-

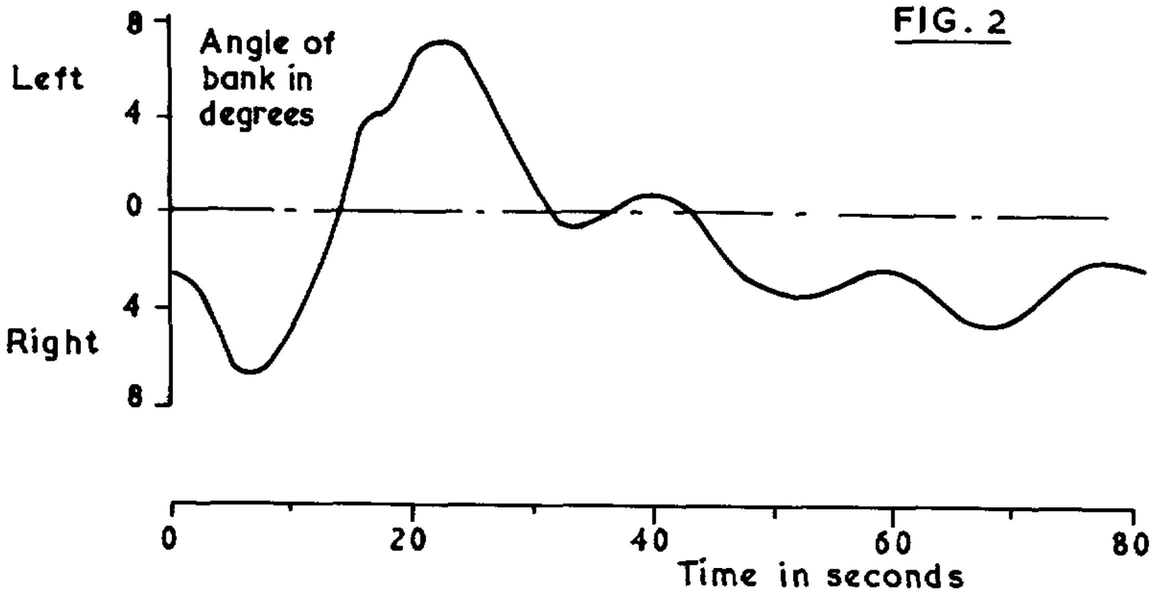
FIGS. 1 & 2

FIG. 1

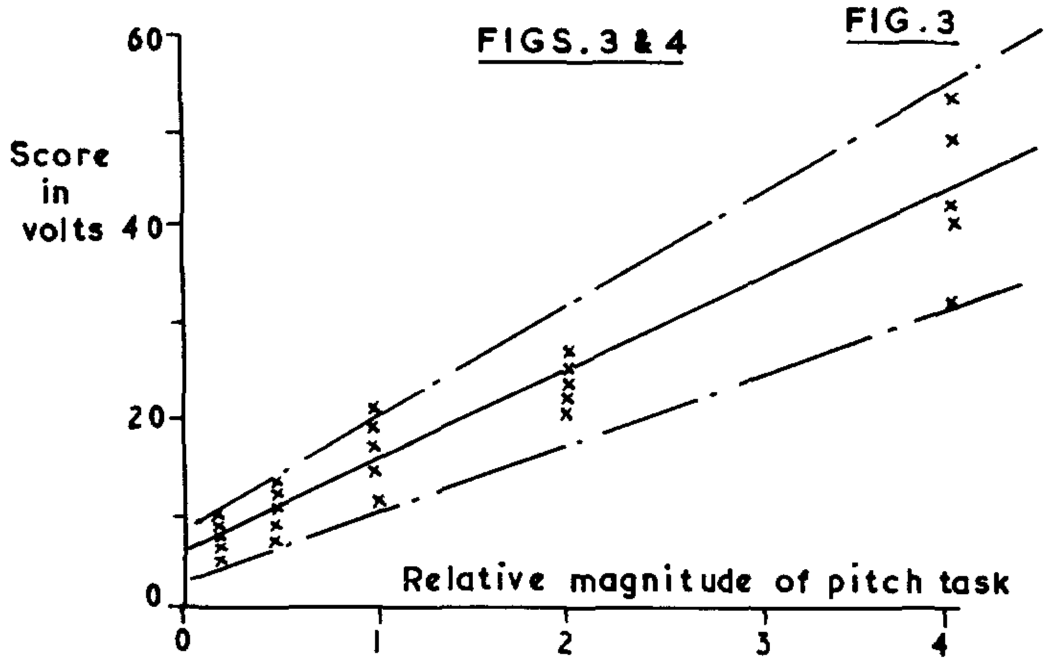


The layout of the sidebars

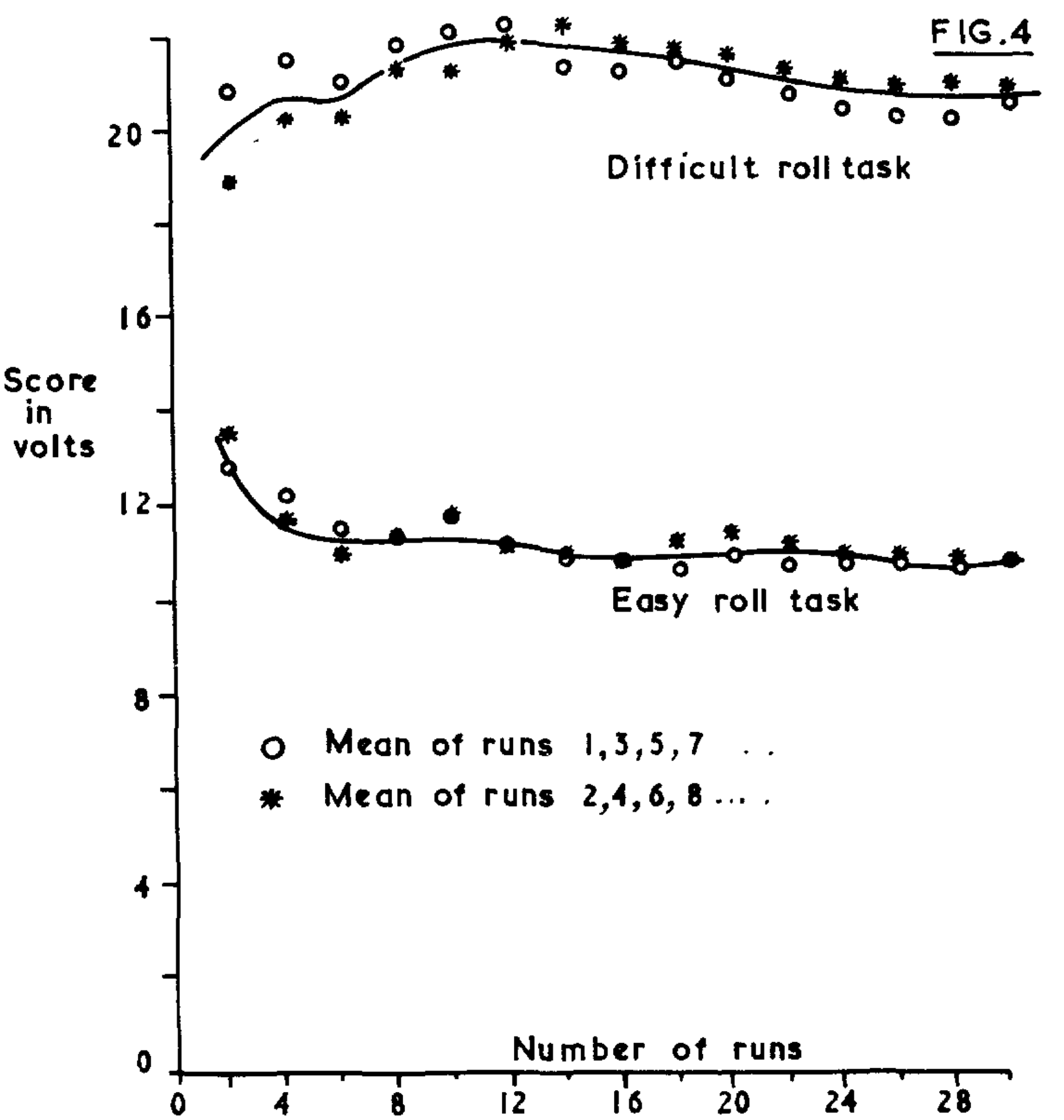
FIG. 2



The easy roll task



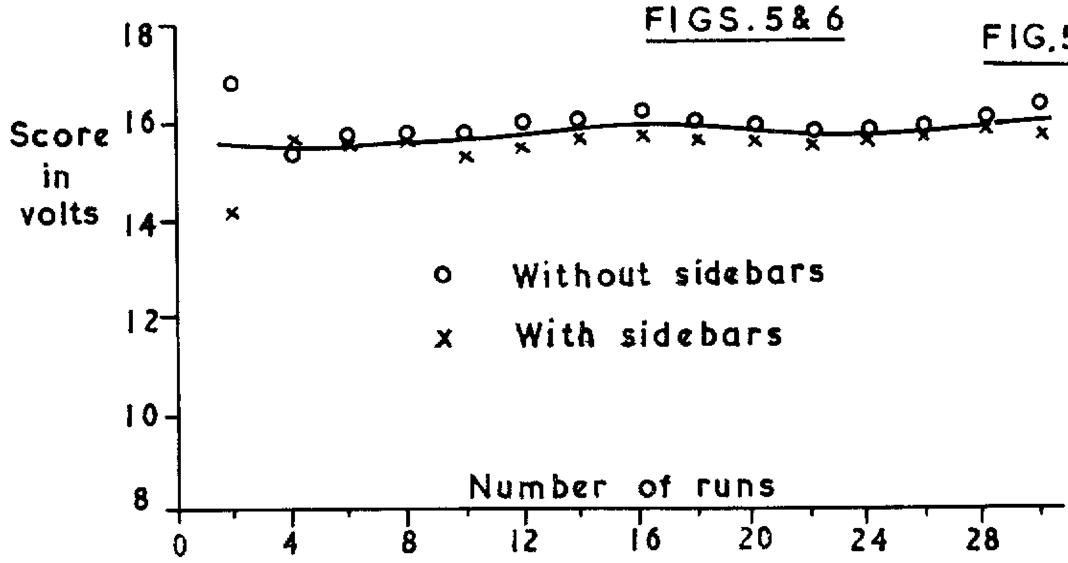
Variation of score with magnitude of task (pitch alone)



Demonstration of comparison technique

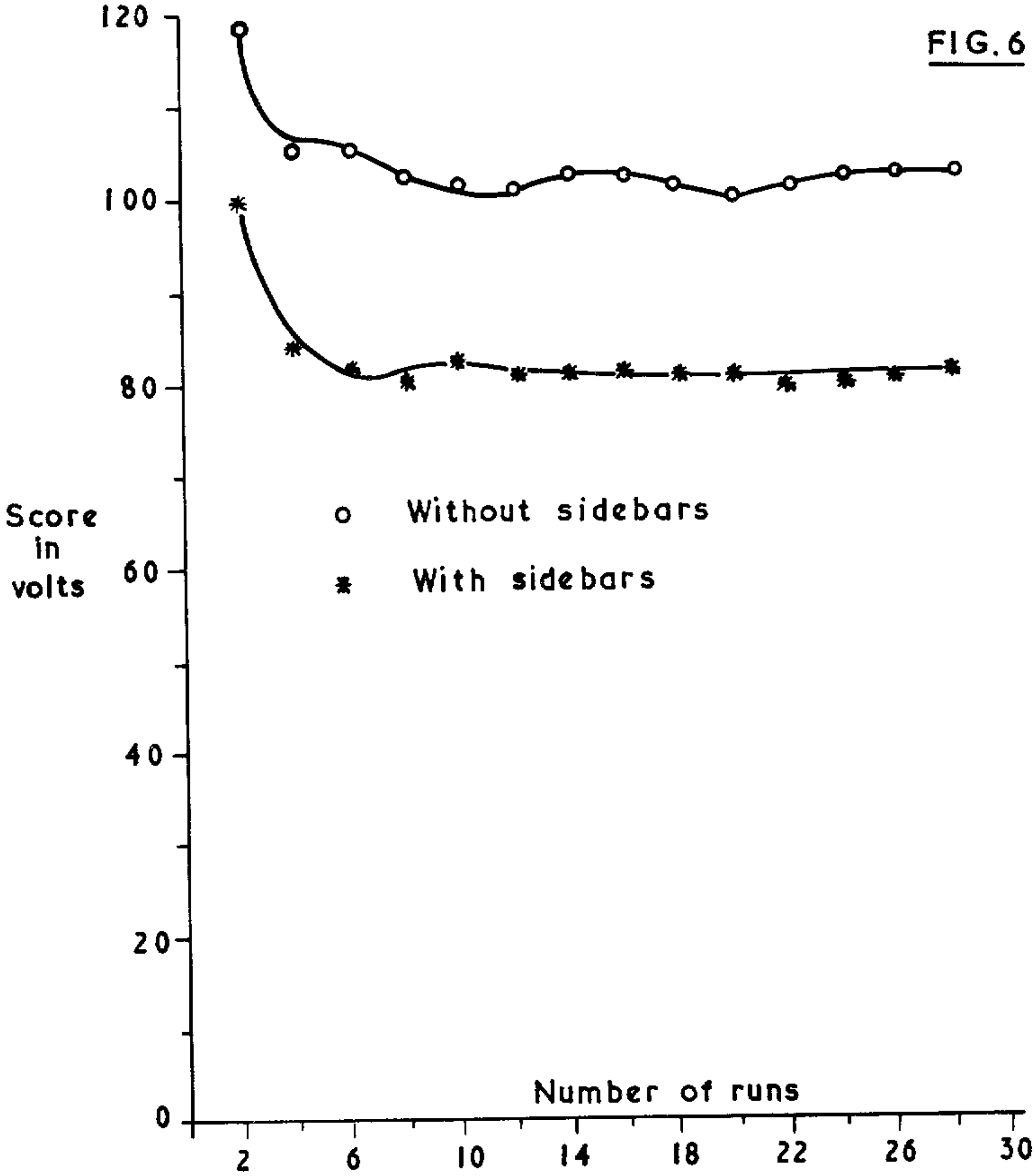
FIGS. 5 & 6

FIG.5



Effect of sidebars:- difficult roll task

FIG.6



Effect of sidebars:- combined pitch and roll task

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DETACHABLE ABSTRACT CARDS

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