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BALANCE TRAINING OF THE EQUILIBRIUM ORGAN AND ITS EFFECT ON FLIGHT STRATEGY

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INTRODUCTION

It is known that sailors, rope dancers, ballet dancers and astronauts have trained their sense of equilibrium.

The question is whether the glider pilot by his long-duration circling in thermals has also acquired a training of his equilibrium sense. More than the motor pilot with his long straight flights, the glider pilot's equilibrium sense is severely taxed by the simultaneously performed circling and steady observing of instruments and the aerial region.

To investigate this, an experimental program was conducted with the pendular platform of the Oto-Rhino-Laryngology Clinic, which was developed for the investigation of disturbances of the equilibrium.

EXPERIMENT 1

The test person was standing upright and free on the pendular platform which was oscillating in a sinusoidal pattern around the vertical axis with various angular accelerations from 17 to 520 degrees/sec^2.

The arms were crossed over the chest, the eyes blindfolded and the ears covered with noise protection capsules to eliminate the visual and acoustic spatial orientation (fig. 1).

The oscillation of the body, which deviates from the oscillation of the platform due to the stato-motoric counter regulation, was picked up by a potentiometer and recorded to an oscillograph, together with the signal from the oscillation of the platform.

The principle of measurement is based on the physiological and neuroanatomical process. The nervus vestibularis from the equilibrium organ cooperates with the nerves from eyes, cerebellum, tractus vestibulospinalis and reflection circuits from the muscle and ligament spindle, for instance from neck and legs (fig. 2).

RESULTS 1

The first experiment investigated short-term training. It lasted for 20 minutes with an angular acceleration of 415 degrees/sec^2. The amplitude of the body oscillation decreased in the beginning and increased again later on (fig. 3). Since the absolute height of the amplitude is different due to the different mass of inertia of the test persons, only the relative changes were correlated.

The enveloping curves of 10 glider pilots were compared by setting the minima to a base line (fig. 4).

The training's effect, which is the adaptation of the test person to the oscillating angular acceleration, can be seen from the envelope. It decreases steeply in the first minutes, flattens off later and arrives at its minimum after about 14 minutes. Thereafter it increases again steeply and the test person arrives at his fall-down threshold where he avoids falling by gripping hold with his hands.

The reason for the flattening is the overlapping of muscle and other fatigue over the training effect.

In the first minutes we see a linear decrease of the envelope which would reach a training maximum of 100% after 4,3 ± 1 minutes.

CONCLUSIONS 1

For the practice we can draw the following conclusions:

1. About 4,3 ± 1 minutes after entrance in a thermal in circling flight, the pilot has reached the maximum adaptation of his equilibrium sense to the changing accelerations.

   For 10 minutes more we see an optimal disposition to changing accelerations. During this time he should be capable of utilizing the thermal best. Later fatigue effects are superimposing and it should be recommended that he flies straight for awhile to recover.

2. The glider student with 5 minute start and landing flights does not acquire reasonable training of his equilibrium to acceleration. To give him this training, the instructor of glider students should include thermal flights at an early stage.

3. We know from accident statistics that prior to outfield landings the pilot tries to work thermals by performing steep turns in low altitude. At that

time his equilibrium sense by the long-duration straight flight is disoriented when he suddenly enters curved flight conditions, and he needs about 4 minutes again to adapt to the changing accelerations.

After he has begun circling, the pilot imagines that the speed of his straight flight still exists and he begins to pull for optimum ascent speed. In reality by turbulent air and by changing lift the critical speed is already reached.

This phenomenon can be studied in an acceleration disorientation chamber in which the pilot is moving in a circular path while he is accelerated in different directions.

EXPERIMENT 2

In the second experiment the long-term training effect was investigated on 35 glider pilots. The test person was placed on a scale, standing once on the tips of the toes and once on the heels (fig. 5). Eyes and ears were covered again. The attempts to regulate the equilibrium caused a change in force on the scale which was recorded by means of force transducers on an oscillograph (fig. 6).

After this test the pilot was placed on the pendular platform for 24 minutes. The eyes had to be opened and closed according to a predetermined scheme (fig. 7). The angular acceleration was raised step by step with breaks of the oscillations between each change. After this oscillating test the pilot was placed on the scale again.

RESULTS 2

It can be seen that amplitude and frequency have decreased compared to the test before the training on the pendulum (fig. 8).

The effect of training correlates with the number of flight hours. All test persons (glider pilots and non-pilots) had a training effect of 20% (fig. 9). After 30 hours a steep increase begins which reaches 70% at 60 hours. Thereafter saturation begins which reaches 95% after 160 hours.

Including the flight experience by plotting the training effect against the total flight hours/years of flying changes the effect. Again the increase starts after 30 hours/year but is much steeper, reaching 80% after 60 hours/year (fig. 10). It can be deduced from these results that a glider pilot who does not fly more than 30 hours per year does not add any gain to his training. Before starting cross country flight at the beginning of the season it would be useful to build up training with 30 flight hours as soon as possible.

After 16 ± 4 years the pilot has arrived at his maximum training. In the investigated group the pilots began their instruction in flying with 19 ± 4 years of age. The effect of training decreases again after 35 ± 4 years of age (figs. 11 and 12). Similar results are known from other disciplines of sports.

CONCLUSIONS 2

The question to be answered after knowing these results was whether it is possible to train the glider pilot on the pendular platform prior to beginning a season. This would be advantageous for the improvement of safety for everybody and of success for the contestants.

Up to now we have only subjective reports from pilots, who felt a positive influence of such a training.

In the summary we can conclude from the second experiment that the effect of training is dependant upon

1. Age
2. Number of years flying
3. Flight hours

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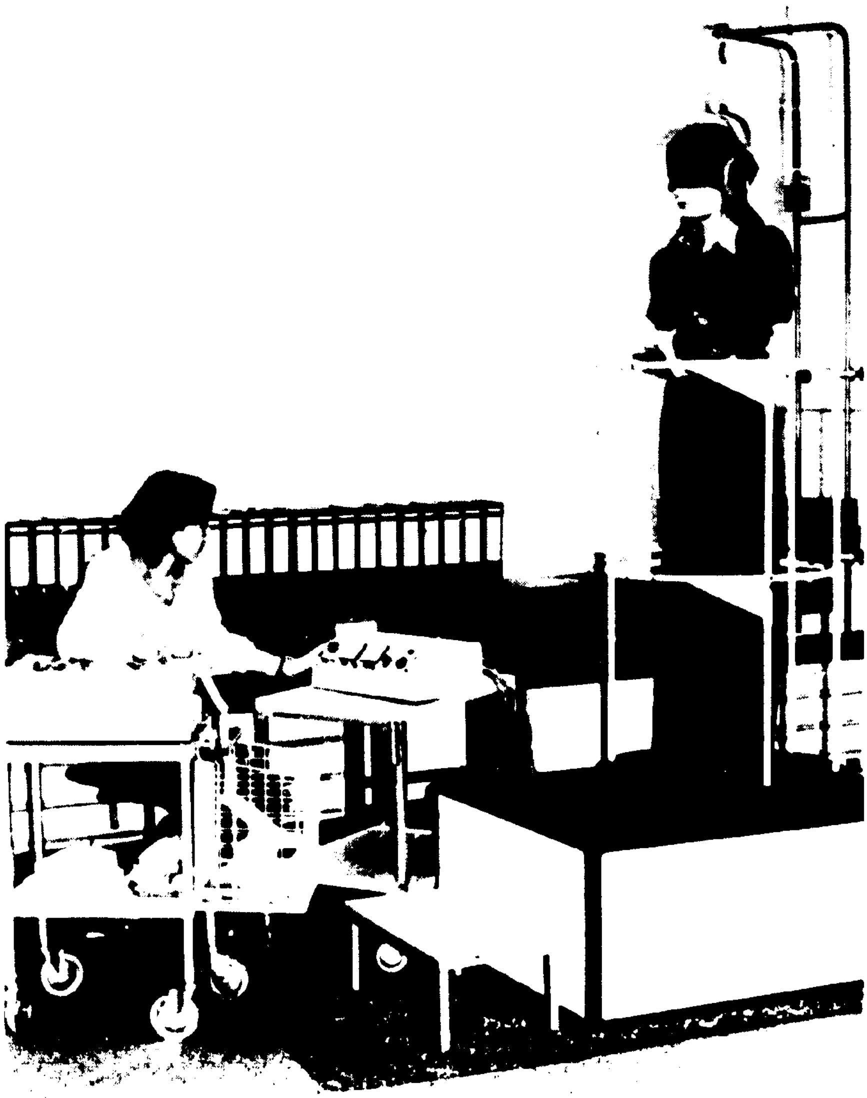

Figure 1.- Pendular platform. The test person is oscillated around the vertical axis with angular accelerations between 17 and 520 deg/sec. Ears and eyes are covered.

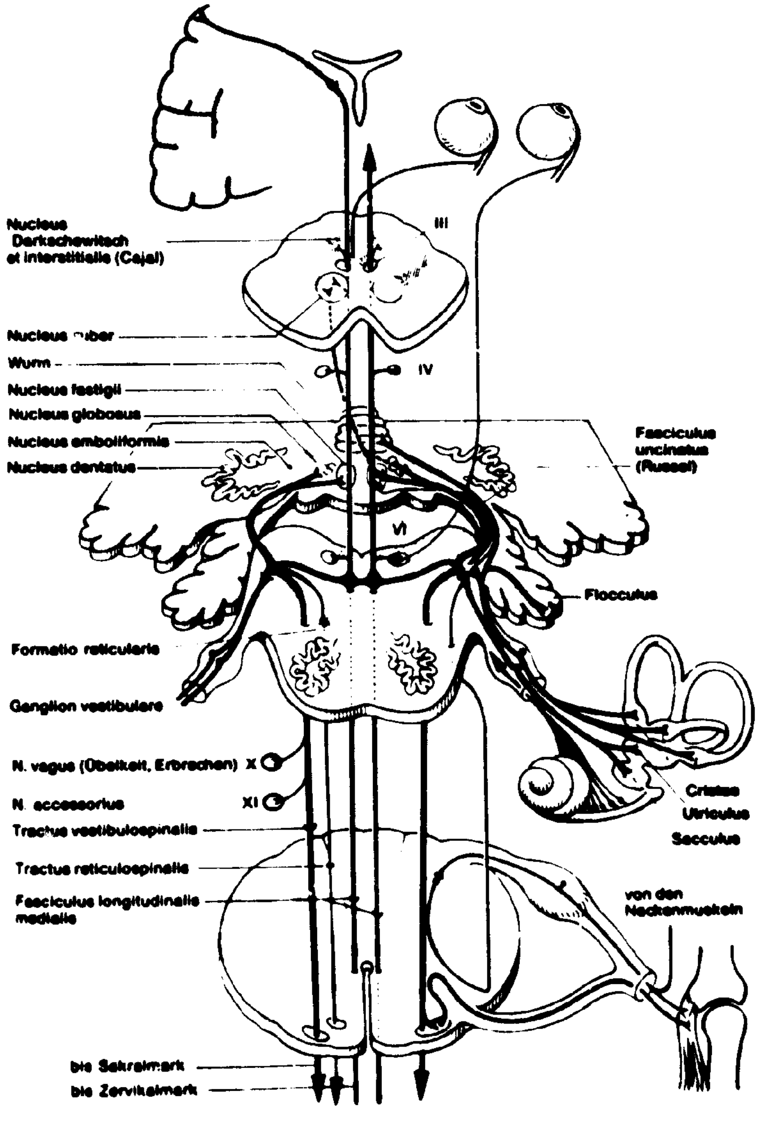

Figure 2.- Combined action of the equilibrium sense nerves.

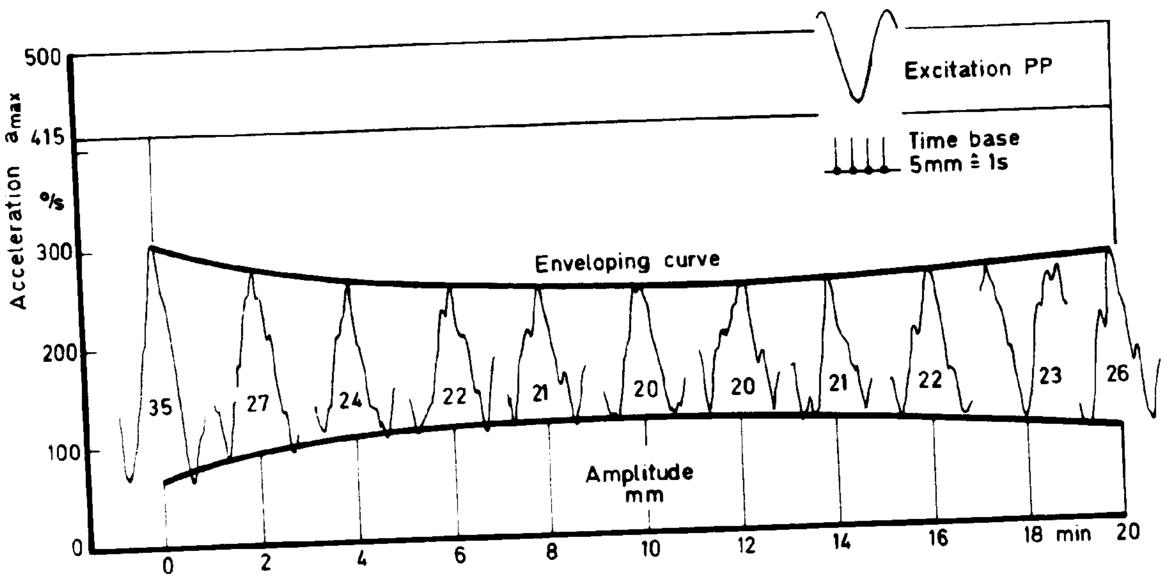

Figure 3.- Time history of amplitude of body oscillation. After a decrease in the beginning it increases again later.

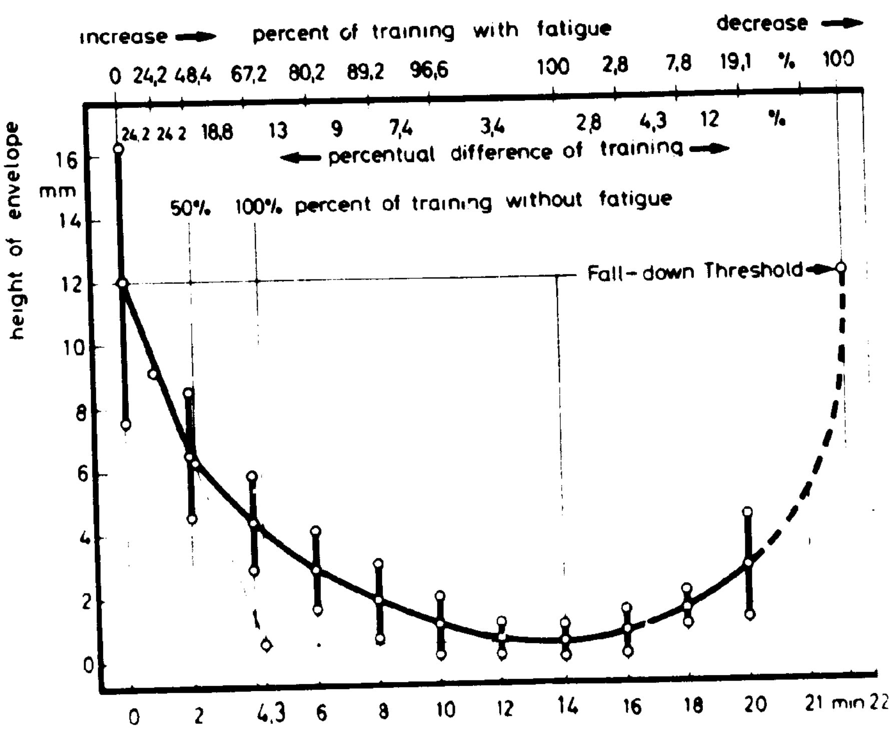

Figure 4.- Envelope of short-term training. It shows 100% effect of training after 4,3 minutes, lasting for 10 more minutes.

Figure 5.- Test person on the scales. She is balancing on toes or heels with covered eyes and ears.

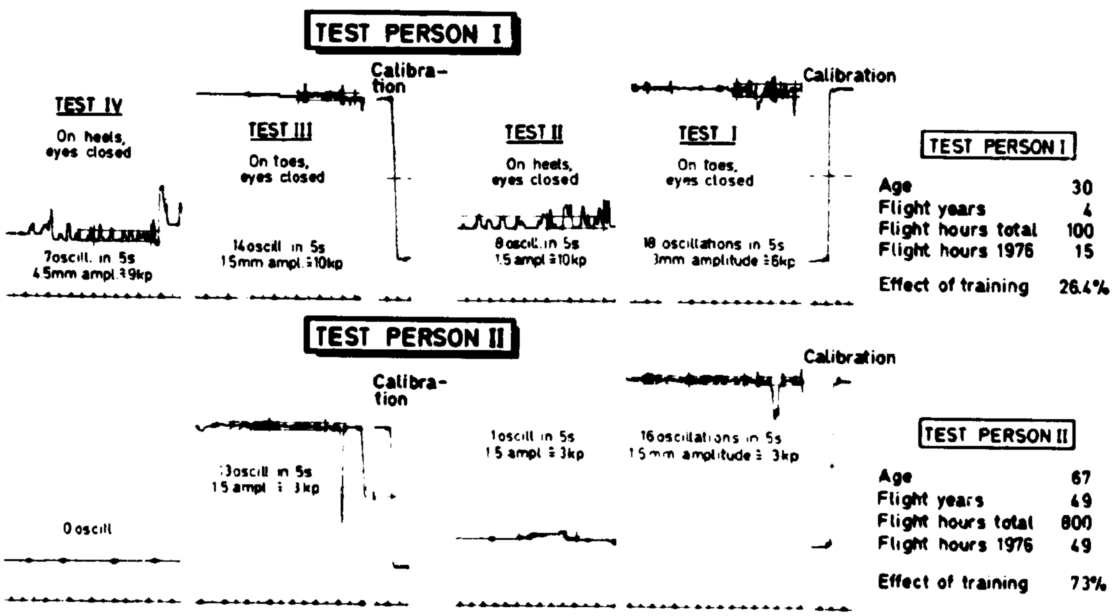

Figure 6.- Long-term training. Original recordings for two different test persons. 1 kilopond (kp) = 9.8 newtons.

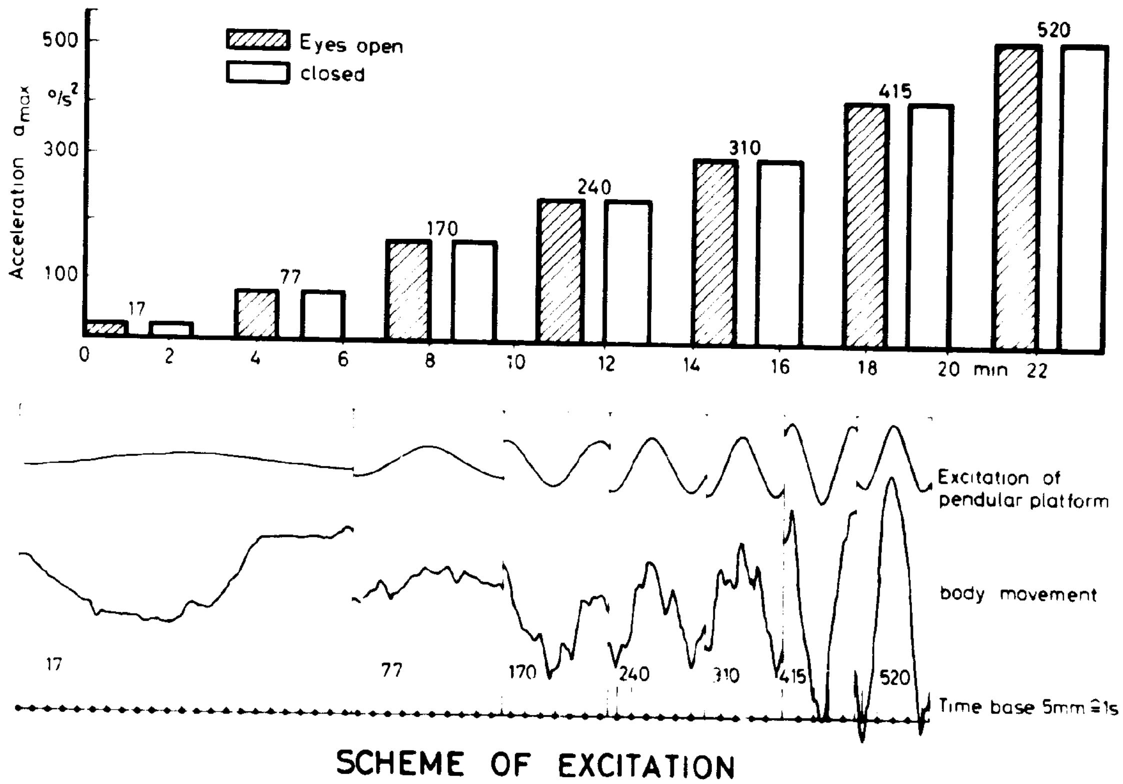

Figure 7.- Excitation scheme. The equilibrium sense is excited according to this scheme. The eyes are open or closed, the acceleration is raised step by step with breaks between.

FORMULAS

(1) $\left[1 - \frac{\Delta G_{III}}{\Delta G_{I}}\right] \cdot 100 = TE\ [\%]$ $\frac{III}{I}$ valid for toes

(2) $\left[1 - \frac{\eta_{III}}{\eta_{I}}\right] \cdot 100 = TE\ [\%]$

TE = Effect of training

Δ_G = Average amplitude of oscillations during 5 sec (difference in weight on scale)

η = number of oscillations during 5 sec

For the heels divide $\frac{\Delta G_{IV}}{\Delta G_{II}}$ and $\frac{\eta_{IV}}{\eta_{II}}$ accordingly

EXAMPLES

Test-person	TOES				HEELS				
	ΔG_I	ΔG_{III}	η_I	η_{III}	ηG_{II}	ηG_{IV}	η_{II}	η_{IV}	
I	2,5	1,8	9	12	12	5,4	7	3	
	28 %		~~- 33 %~~ *		55 %		58 %		TE from (1)or(2)
II	0	0	1	0	10	0	5	1	
	100 %		100 %		100 %		80 %		TE from (1)or(2)

* measurement error eliminated

Average TE from I = $\frac{28 + 55 + 58}{3} = 47\ \%$

Average TE from II = $\frac{100 + 100 + 100 + 80}{4} = 95\ \%$

Figure 8.- Calculations, formulas, and examples.

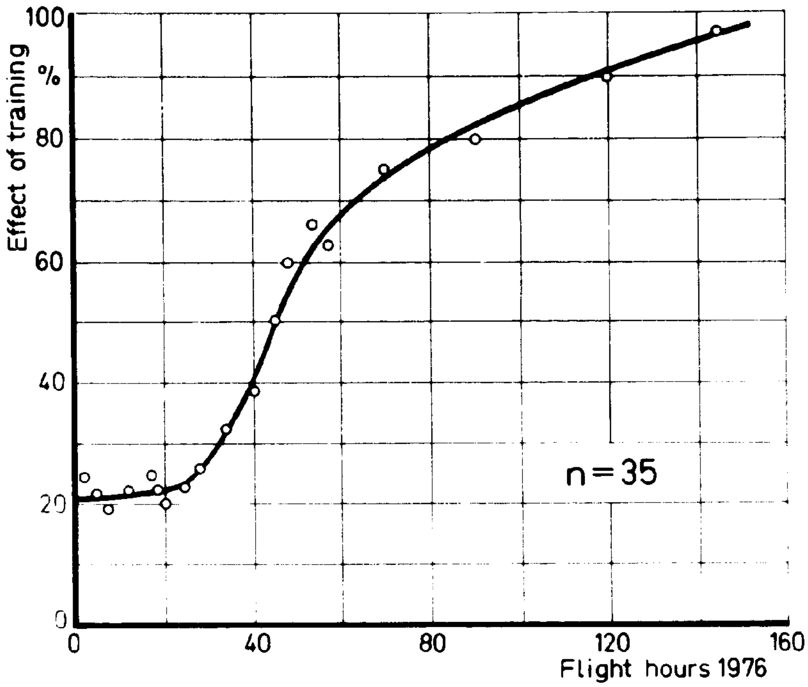

Figure 9.- Effect of training versus flight hours.

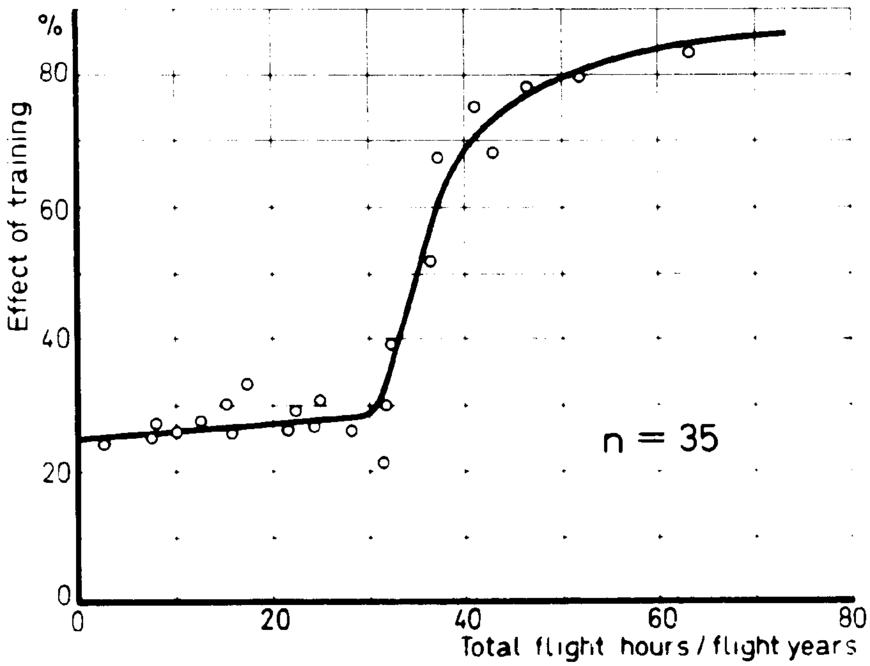

Figure 10.- Effect of training versus average flight hours per year.

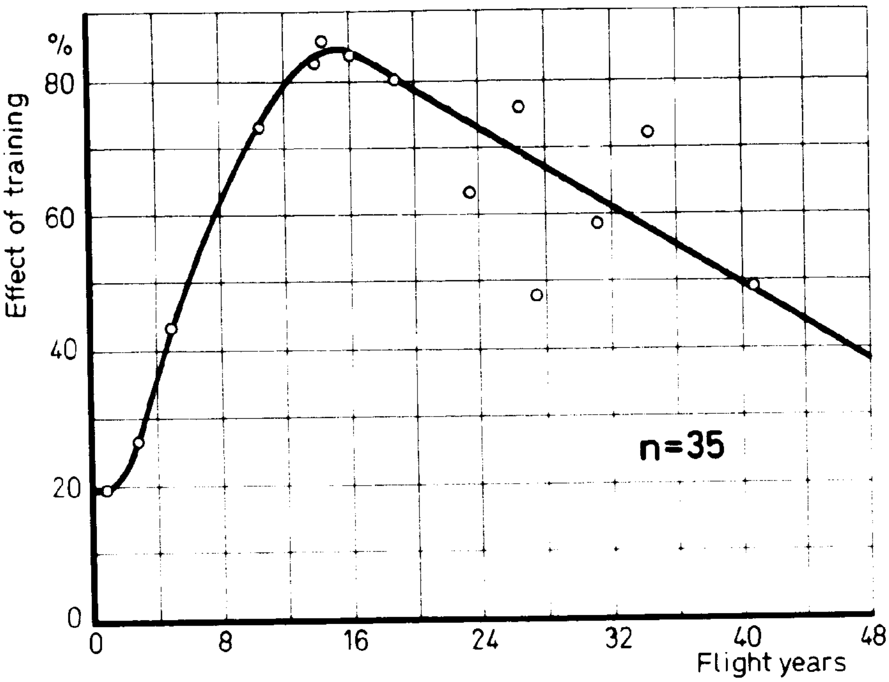

Figure 11.- Effect of training versus flight years.

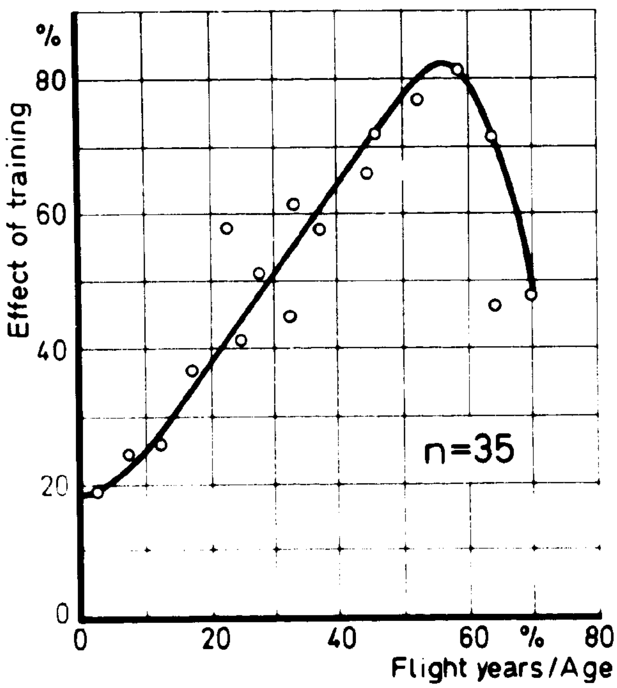

Figure 12.- Effect of training versus age related flight years.

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A MONTE CARLO APPROACH TO COMPETITION STRATEGY

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The classic MacCready approach to maximize cross-country soaring speeds has many drawbacks. Pilots race to get maximum scores, not to maximize speed over a short length of a course. Maximum scores require a consistently high average cross-country speed, but absolutely no landouts in a typical contest. If a pilot refuses to accept weak lift, he will have a good time almost regardless of the speed at which he flies. This presumes that he will make it around the course, however. Real strategy is not so simple. Variables which must be taken into account other than the strength of the next thermal are the following:

1) Height of clouds
2) Distance between thermals
3) Time of day
4) Water ballast
5) Present altitude
6) Weather changes
7) Lift organization
8) Distance to goal

This list is neither complete nor arranged in order of importance. Most competition pilots recognize these factors and attempt to take them into account in their decision making. The biggest problem, however, is how to quantitatively make trade-offs between these factors.