Dizziness and disorientation, sometimes accompanying flying, is not wholly preventable, but vertigo's effects can be minimized by knowing when to expect it and how to recognize it. CAMI is seeking some answers

Vertigo!

by FRANK A. TINKER / AOPA 383893

■ ■ Picture, if you will, an Air Force cadet on his first night cross-country in a T-6, thoroughly briefed on maintaining the craft straight and level, touching his three bases and getting home safely. Then picture him, barely out of sight of the airport, with no moon to tell him which is up or ground lights to tell him which is down, doing a series of slow rolls in a fit of defiance against his craven instructors.

Picture this and you'll see first a damn fool; second, a pilot completely disoriented and reeling with vertigo. You may, in fact, see the author. (It was a severe tax on the imagination to explain why I wound up in Houston instead of San Antonio.)

A pilot fortunate enough never to have been so divorced from his sense of balance will find it difficult to understand how an aircraft could so obviously be upright, yet every instrument and outside indication show that it was trying to fly at 90° to the indistinct horizon. From such knife-flight, which way is down when stars and ground lights are roughly equal, and one's built-in senses of equilibrium are feuding wildly with one another? This was an educational flight, to say the least, but the hard way to learn about vertigo.

The fact of the matter is, whether we sophisticated IFR types admit it or not, all flying is in one sense done unavoidably by the seat of the pants. That is, by means of normal human response to signals from eye, ear, and muscle, rather than from visual reference to gadgets alone. The total of these responses is, after intricate computerization by the brain, simply balance, equilibrium. Without this, the most instrument-oriented pilot in the world cannot even hold himself upright in the seat.

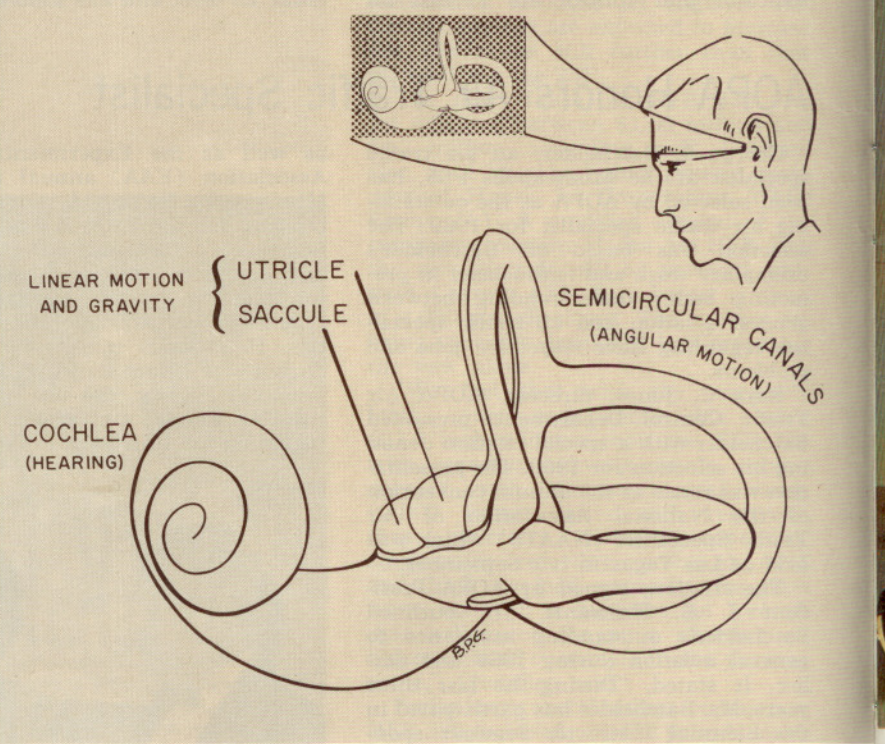
To the surprise of many, the most important of these senses keeping us from an ignominious stagger is that which emanates from the inner ear. The flight surgeon demonstrates this when he asks us to teeter on one foot with eyes closed. That foot tells us a little, of course, but divers and gymnasts still maintain precise balance while completely out of contact with solid surroundings. Let the inner ear be put out of commission, however, and the same diver, gymnast, or pilot will be unable even to stand, though his eyes and muscles are in perfect shape.

It is this sense which is most often affected when an airman experiences vertigo, a somewhat inaccurate term meaning dizziness. Actually, a person in this state may not feel dizzy at all; his perception of up and down or his bodily motion is simply awry. To understand why, a glance at the mechanism of this inner ear is worthwhile.

Beyond the outer trumpet of this organ and the eardrum lie the essential and intricate instruments of human balance. They consist primarily of three small half-circles of tubing, positioned roughly at right angles to each other and encased in the large bone of the skull which ends just above the jaw. Within these tubes, or canals, rests a liquid. When the head is tipped or turned, this liquid flows. Its movement past tiny whiskers in the canals, called "receptors," causes these to transmit signals which the brain interprets as "left turn," "right turn," or some form of angular motion.

In addition, two small pouches in this inner ear, or "vestibule," contain a jelly interspersed with small granules of calcium carbonate dubbed "gravity stones." These pouches apparently send information on linear acceleration and deceleration. This whole process is incredibly sensitive, being able to tell not only the direction of motion, but the rate of motion and even subtle changes in that rate.

On the other hand, its exact nature remains largely unknown—and if this sounds strange it might be remembered that even the method by which the ear transmits sounds is not precisely understood either. Certainly the almost motionless mechanism which manages to perform an almost gyroscopic function for man is even more complex. The astounding fact is that it works, most of the time remarkably well.



CAMI's illustration of "where the action is," the inner ear. The vestibular system (semicircular canals, utricle and saccule) controls balance, spatial orientation, detection of motion, motion sickness, and some types of eye movement. In-flight vertigo can be caused by this tiny but powerful system which is located in the inner ear very near the sensory hearing center.
FAA Aeronautical Center photo

But it can be compromised. According to toebones recently discovered in Africa, with the aid of this deluxe carpenter's level, mankind has been walking erect about 1.75 million years. (Or, at least, something resembling man was slouching around the jungles then without dropping to his knuckles.) By comparison, certain of his species have been flying for roughly 60 years—not long enough for evolution to take much of a hold. Without reviving ancient arguments about whether or not he was meant to fly (he doesn't have feathers, does he?) it is true that being aloft in a mechanical device can sometimes impose rigorous and unnatural demands on his equilibrium system.

Factors other than odd motion can also cause a malfunction in this system. Drugs like quinine and some antibiotics, particularly if one is at all allergic to them, can bring on vertigo. So can chemicals: fumes from paint, DDT, or formaldehyde. An inadequate supply of blood to the inner ear, perhaps caused by anemia or aging, reduces its ability. Infections of the ear, teeth, or tonsils can do the same. One specific disease of the ear's vestibule is called Ménière's syndrome; a person afflicted with this mysterious malady may suddenly be unable to stand or even sit upright, then as suddenly return to apparent normalcy.

Blows to this area of the skull, too often paraded as somewhat comical, temporarily disabling affairs in TV battles, can actually have serious and lasting effects. When astronaut John Glenn spun in and clipped a bathtub, his budding political career was ended by the resulting inner ear injury. For weeks Glenn could not move about for any length of time without experiencing severe vertigo.

Likewise, our first space traveler, Alan Shepard, was knocked out of the initial Gemini flight when he developed a wobble and ringing sensation in his ears. Ménière's disease was suspected, but, as with Glenn and other victims, surgical examination could not be attempted due to the risk of damaging such a delicate area. Some medical authorities suspected that both astronauts might have been made more susceptible to ear troubles by their being tumbled unmercifully in a training contraption. This part of the training was subsequently eliminated—and there may be a lesson for pilots here: avoid mistreating such an important and fragile control.

But what has all this physical detail to do with flying straight and level? For one thing, just by knowing what may be going wrong within his body when vertigo strikes, a pilot may avoid some of the accompanying natural panic. Also, by knowing how his signal mechanism can be upset, he may either avoid placing himself in jeopardy or learn—to the small extent possible—how to overcome his own malfunction.

By seeing how vertigo is induced in the medical laboratory, anyone can better understand how it might happen to him aloft. Actually, medical interest in the exact operation of human equilibrium does not have a long history, comparatively speaking, so that much of the work being done now still falls into the experimental category. Also, modern findings contradict earlier assumptions. The FAA's Civil Aeromedical Institute (CAMI) at Oklahoma City has dug into the phenomenon of vertigo at length, spinning volunteers scientifically in barbers' chairs and measuring the reactions of whirling ice-skaters. Although its work could be expected to point directly toward aviation eventually, by the very lack of firm background information, much of this effort has approached pure research, widely applicable.

So sensitive are the mechanisms of the inner ear that severe vertigo can be caused merely by changing its temperature rapidly. This is done by irrigating the ears with warm and/or cold fluids. As the victim—pardon, the subject—responds to the sensations thus produced, his eyes show the typical signs of vertigo—drifting to the side, returning jerkily. Such eye movement, nystagmus, is used as a measurement of vertigo.

Again, the precise reason for this reaction is not known, but it appears that as the inner ear gives signals of motion or tilt, the brain and the eyes try to accompany or compensate for such reported motion. Since there actually is none, however, the eye betrays the malfunction within the balance system.

Most commonly used to induce vertigo is the rotating chair, of which several types have been devised by the

David Schroeder of the FAA Psychology Laboratory is seated in the CAMI disorientation device, which has been used in a number of research projects. Among studies currently in progress are those examining the effects of alcohol on blurring eye movements and the sensations of vertigo.

FAA Aeronautical Center photo

Ann Margreth Frei, an Ice Capades star, attempts to maneuver with eyes closed after completing a spin. Without fixed visual references, even such a highly trained figure skater will become disoriented and fall to the ice. Electrodes taped by her eyes lead into a telemetry transmitter strapped to her chest. The telemetry receiver and eye-movement recording equipment were located at rink-side for this CAMI study.

Photo by W. Geyer

medical inquisitioners. A child induces dizziness by spinning so fast that he apparently exceeds that capability of his ear to keep up with the motion. The chair can be used similarly or in a more subtle fashion. Many of the CAMI tests are performed at r.p.m.s from only one to 15, with accompanying acceleration or deceleration. As different situations are imposed on a person in the chair, his reactions, particularly any nystagmus, are recorded. This can be done either visually or through electrodes attached to the outer parts of the eyelid.

During some longer tests, the person's equilibrium system adjusts to the motion in rather spectacular ways. The fluids in the ear come to rest after a few seconds of motion at a constant velocity. Then, as movement ceases or a different motion is begun, an entirely erroneous and vigorous sensation results. This is vertigo, a refusal to believe that the ceiling is up, the floor is down, or the walls are standing still. The twitching eyes, of course, accompany the sensation of apparent motion.

the humor from a drunk's wobble.

An intriguing confusion of the equilibrium is obtained by accustoming its owner to a particular turning motion, then having him alter the position of his head. This, of course, changes the flow of inner ear fluids and, since the brain has apparently already compensated for the pressures of the established movement, causes an entirely disconnected sensation.

By now most AOPAers have heard of the Vertigon, a simple turning contraption inspired by and developed from the Oklahoma City experiments. Members of Flight Products, Inc., specialists in training devices, were so impressed at CAMI with the weird sensations produced by these simple head manipulations during motion that they set about to bring the experience to the flying world at large.

Passengers in the Vertigon, as in the CAMI lab, tilt their heads 30° from the vertical while their seats are rotated gently. This placement of the head in varying positions has the effect of aligning the vestibular canals differently with the plane of motion and the force of gravity, thus eliciting unusual movements of the fluids within.

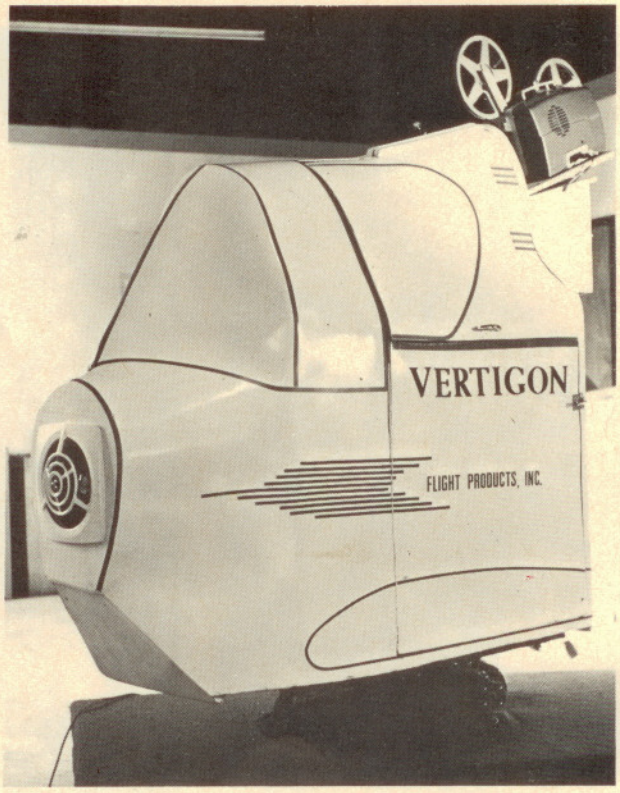
When apparent motion has ceased, the pilot of this earthbound craft moves his head upright—then grabs for the stick, for his chair has obviously gone into a steep dive!

"I have flown fighter planes under almost every situation possible, but I don't believe I have ever felt a more violent maneuver," testified one pilot.

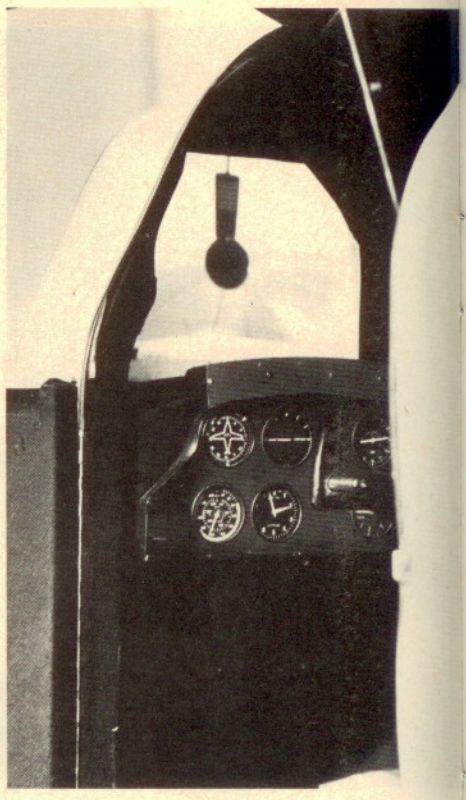
The actual angle of this imaginary dive may be as much as 90°—a vertical plunge. Leaning the head forward can produce an acceptable barrel roll to the right; returning it to normal inspires a left roll. The CAMI doctors point out that such cockpit movements as leaning to retrieve a pencil or change a gas selector switch could cause a similar reaction under adverse conditions. No wonder some participants in this strange but simple exercise ask to be excused to avoid embarrassing themselves. The illusions produced by the Vertigon are heightened by the addition of an instrument panel and a motion picture (actually taken from a cockpit) showing a flight from engine warmup to a bank into clouds—when the fun begins.

All very interesting, but what is its application to safe flying? The adapters of the Vertigon, and the FAA scientists, point out that such a device, by showing what can happen under certain conditions, will generate a respect for vertigo in the aviation community. Persons who have used the simulator seem to agree with this premise and urge anyone who flies to share the experience. Such an ordeal may also, by accustoming pilots to the sensation, help to lower the fright level if vertigo is ever subsequently encountered while aloft. It may also encourage pilots to obtain instrument ratings and maintain them in good work-

First production model of the specialized Vertigon simulator was installed at the FAA Civil Aeromedical Institute (CAMI) at Oklahoma City to be used in pilot training and research. The two principals involved in a study of spatial disorientation at CAMI are Dr. William Collins (center), chief of the Psychology Laboratory, and Dr. Harry Gibbons (left), head of CAMI research. Delivery was made by Louis Ziegler, president of Flight Products, Inc., manufacturers of the Vertigon.



Front view of Flight Products' Vertigon. A four-minute ride in the Vertigon produces almost all sensations of vertigo which will occur in actual flight.



Movies projected on the "windshield" in front of the pilot in the Vertigon simulate flight from engine start to flight in cloud, at which point vertigo is induced. While experiencing the false sensations of diving, steep climbs, rolls and tumbling, the pilot actually is turning only on one axis with no change in pitch.

Parenthetically, if similar results are obtained with 100-proof spirits, they may be due to alcohol's effect on different portions of the mechanism, either the nerves or the brain itself. Understanding this may remove some of

ing order.

The FAA has gone much deeper in its investigations than merely producing odd sensations. The various methods of encouraging and resisting vertigo have been explored, with findings that may become more useful as the catalog of knowledge expands. A specially instrumented T-34 has been used to study eye movement and other reactions of pilots in flight. In one important lab experiment, subjects were found to respond more vigorously to angular motion when they were mentally alert, while showing few signs of its effects when completely relaxed.

Dr. William E. Collins, head of CAMI's psychological laboratory, demonstrated this by feeding arithmetic problems to persons in the rotating chair. With the resultant increase in their mental effort, more vigorous signs of vertigo—involuntary movement of the eyes principally—immediately appeared.

This demonstrates, according to Dr. Stanley R. Mohler (AOPA 167639), former director of civil aeromedical research and now with the Office of Aviation Medicine in Washington, "the important factor (little emphasized or known) that when one is attempting to accomplish mental arithmetic or other mental tasks—such as is the case with a newly trained or 'rusty' instrument pilot flying in IFR weather—one is much more susceptible to nystagmus and subsequent vertigo. This helps explain why pilots when under the hood and not under the intense mental stress of real IFR conditions are not so susceptible to vertigo."

Why does this nystagmus occur, and, again, what is the practical meaning of its irregular occurrence here?

"The semicircular canals are tied in with the eye muscles through a servo 'feed-back' mechanism," explains Dr. Mohler, "which is in part responsible for the nystagmus which results from rotary motions of the body. This servo mechanism works by reflex, and it is this reflex that is heightened by 'mental arousal' tasks during motion and may thereby aggravate vertigo. Dream states (reverie) have the opposite effect. *This means that the more skilled and proficient a pilot is at instrument flight, the less demanding a mental task IFR flying is for him, and the less susceptible to vertigo he may be.*" [Italics are supplied.]

Why not simply accustom pilots to vertigo and thus build up an immunity to its effects? Investigators who first dug into the phenomenon of vertigo were intrigued by the apparent ability of dancers and skaters to maintain their balance after prolonged rapid whirling. Actually, however, ballet dancers do not whirl indiscriminately; rather, they 'spot' by fixing their gaze on a particular point while their body spins, keeping their head pointed toward that spot as long as possible, then returning to it with a rapid whip of the head. In effect, they see only this spot during the entire spin. Remarkably, much the same techniques are used by professional aerobatic pilots doing a series of rolls or controlled spins. "Roll Around A Point" is the title of Duane Cole's guidebook on primary aerobatics.

This is not so simple with a professional ice skater whose spins may approach a peak velocity of 300 r.p.m. It had been assumed—and even stated by some medical authorities—that such performers "habituated," or adapted, themselves to violent turning and thus overcame the effects of vertigo.

"We know ballet dangers and ice skaters actually strengthen their inner ear mechanisms," said a Harvard professor of otology a few years ago.

But verities at Harvard sometimes turn out to be suppositions as they migrate west. The FAA specialists, enlisting the aid of Ice Capade stars, went into the matter somewhat more deeply. Attaching telemeters to the eyes of these skaters, they found that the dervishes of the rink showed much the same susceptibility to dizziness as ordinary pilots. Following violent spins on the ice, the skaters staggered and sprawled when asked to walk with eyes closed—and this to their own amazement. When subjected to the turning chair experiments, they again experienced the same sensations as persons who cannot even stand up on ice skates.

"Skaters produced significantly less primary slow-phase eye displacement than did non-skaters, but the groups did not differ in number of eye movements nor in duration of nystagmus," reports Dr. Collins.

"Habituation," or adaptation, did not properly describe the reaction of persons to whom whirling was an old story. "Rather, what occurs is a change in the form of the response," reads Dr. Collins's report. "Thus, in studies which maintained subjects in states of alertness, a simple 'dropping out of responses' did not occur even after many stimulations, whether rotatory or caloric (irrigation with water of different temperatures)."

In other words, Harvard to the contrary, these skaters' inner ears had apparently not been "strengthened" to any appreciable degree by their long practice. One thing in which these skaters did excel, and which might be of use to pilots, was controlling their balance by immediately "fixing" on a stable spot with their eyes the instant their spins ceased. As long as they could use their eyes in this manner, even if only for a few moments before they closed them again, their vertigo subsided rapidly. With this trained advantage removed by having to keep their eyes closed, or being whirled in complete darkness, however, they reacted much like the customers of their show.

So training against vertigo, it seems, is difficult if not impossible. Perhaps in the business of fixing one's gaze resolutely on a stable point he can reorient himself more rapidly after a dizzying experience, which is undoubtedly what aerobatic pilots unconsciously do. But flight-induced vertigo is not always simple dizziness.

Avoiding the conditions which may cause it are not much easier. Long spirals or circling maneuvers, violent corrections which tend to disorient a person visually in poor visibility, too frequent or abrupt transition from outside reference points to interior instruments, poor lighting or placement of instruments—these could tend to induce a confusion that would encourage vertigo.

As for the finding that mental activity increases eye nystagmus and reverie helps avoid it, certainly no one could suggest that a pilot minding a flight plan should lapse into a somnolent state just to avoid upsetting his balance. The arithmetic of flying is mandatory. Conscious relaxation, if the pilot finds himself concentrating blindly on his cockpit problems, would help, as it does in almost all aspects of instrument flying. Relaxation, however, usually comes with experience and confidence; the best way to avoid vertigo, *ergo*, is to become as proficient as possible.

If, through some violent or insidious circumstance, it should occur during VFR conditions, a pilot's recovery could be aided by remaining calm, screwing his vagabond eyes to some single point fixed with respect to the earth, and remembering that the sensation should pass within a few seconds. During that time, depending on the severity of the vertigo and his altitude, it might be advisable to let a stable aircraft fly itself. Once back on the ground, a visit to the flight surgeon to find out if there were a physical reason for the attack would be in order.

If on instruments, which is most frequently the case, a pilot's immediate temptation when things begin to tilt unreasonably is to damn and disregard those instruments. So, check the vacuum and electric power supply. Unless these show a malfunction, the flight gauges are far more apt to be accurate than one's upset vestibular receptors. Of course, if his sensation is of falling and the altimeter begins to unwind, a correction is called for, vertigo or no. But if his senses say he is turning while the needle, gyro compass, and artificial horizon say he is not, he ain't. This is kindergarten stuff, but it is also something which every transport pilot uses in some measure a dozen drowsy times a year on night flights.

Vertigo, it seems, will remain for a long while as part of a complete flying education, neither wholly preventable nor catastrophic. Like phony advertising, knowing when to expect it and how to recognize it will enable you to avoid buying its lousy product. □

THE AUTHOR

Frank A. Tinker, a frequent contributor to The PILOT, *is a long-time military and civilian pilot with a deep interest in writing about aviation. A former airline pilot, the author's most recent flying activity has been piloting a nonsked in the Alaskan petroleum operation. He resides in Ogden, Ut.*
