Glider Pilot Physiology:

Clues You Can Use

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Physiology: Clues You Can Use

This manuscript describes the essential physiologic requirements for safe glider (or powerplane) operation, and provides clues for the pilot to aid recognition of one's physiologic status.

1. *We're Soup*

Though Scripture does not point this out, when the Lord God formed Man out of the dust of the earth, He added water, most likely before breathing the Breath of Life into his nostrils, as the nostrils would otherwise not have held together. Since then, the American Heart Association has wrapped its hands tightly around jurisdiction of mouth-to-mouth resuscitation, but has not required of God that He annually re-certify to maintain His competence.

Hundreds of eminent Biologists have devoted entire careers to working in windowless laboratories to prove in tiny detail the exact manner in which we are constructed of various solutes in a water solvent, combined in an elaborate framework of enzymatically-controlled reactants. While we are thankful for their detail, which makes modern medicine possible, among other blessings like chicken soup and fried eggs, we can boil down the requirements for optimal functioning of the organism to just a few elements:

- Solvent: Water, in the right amount.
- Solute: Electrolytes, in proper proportion.
- Reactants: Fuel in various forms, ideally delicious.
- Electrons: Oxygen is our electron donor, for oxidative metabolism.
- Temperature: The proper ambient temperature is maintained, subject to foolish interference, by oxidation of fuel, homeostatic mechanisms, insulation, and a nice fireplace.

2. *Performance*

Of the many factors affecting competent performance, we will limit ourselves to biological ones. When the Lord God made Man a living spirit, He created psychological, ethical, social, and spiritual factors; but we will assume that you and your mom pretty much worked the basics out several years ago, and you have become a competent, effective human being and pilot. Some of the biological factors are:

- fatigue,
- hydration status,
- oxygenation,
- nutritional status,

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- core temperature,
- emission-control plan,
- cardiovascular conditioning & stress response,
- and others.

3. Fatigue

Rest, as you already know, takes several forms. You may come home from your sedentary job exhausted and rest by going for a long run. That is, physical and mental effort seem to produce separate types of exhaustion. Each person has a different capacity for mental or physical work, which varies over time depending on many factors. The most pervasive and subtle collection of factors is called "jet lag," and amounts to disturbed biorhythms.

Ideally, one should arise at the same time every day, and go to bed within about 30 minutes before and up to 1 hour after a given time (depending on your need for sleep), in order to entrain biorhythms most effectively. Changing your sleep cycle will shatter your biorhythms promptly. If you stay up most of one night, you will be sleepy the next (second) day, but on the following day you will lack mental and physical resilience and feel "tired" (but not sleepy), even if you sleep on your normal schedule. This third-day fatigue is "jet lag," and is likely to occur during any trip if the sleeping conditions are unfavorable to satisfying rest.

Chronic "jet lag" does affect longevity: About 40 years ago Northwest Airlines studied its pilots, and found that the life expectancy of their trans-pacific pilots was several years shorter than that of pilots flying only domestic routes. And a study about 15 years ago of physicians showed that those specialists such as ophthalmologists and pathologists, with no night call, lived on the average into their 80's, while those whose specialties required night call, such as general or family practice or internal medicine, died about 10 years younger.

With travel involving any significant shift of time zones, adaptation of your biorhythms requires several days, as you've noticed. Traveling west is easier than traveling east: research has demonstrated that we can cope well with a delay in bedtime, and time of arising, of up to three hours; but to "back up" only half an hour presents a similar difficulty to our systems. So our bodies adjust most smoothly if we (in traveling west) go to bed and get up three hours later each day, and if in traveling east we go to bed and get up 1/2 hour earlier each day. Ironically, this means that if we travel more than 4 time zones east, it's actually easier to adapt by going to bed three hours later each day.

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Actually to follow such a schedule rigidly is usually impossible while traveling, but understanding this principle and approximately following it can make it easier for you to adapt during and after your next trans-continental trip.

And the important lesson for the pilot is that *if you are able to continue "living in your home time zone" during a trip by arising at the usual zulu time daily, you will have less mental fatigue and avoid the performance degradation that comes with jet lag.*

Regarding the nature of mental fatigue, little is known physiologically due to the unseemly reluctance of people to let biologists put fine metal probes into the depths of their brains. Despite this general lack of commitment to scientific progress, everyone except young children in need of a nap and college students understand that mental fatigue impairs intellectual performance. And piloting a glider is obviously an intellectual performance, if only because so little gross physical activity can take place in such a small cockpit.

If you feel tired, you are tired: expect sub-par intellectual agility, slowed perception, and awkward judgment—and rigidly stick to the basics.

4. Hydration Status

The fact that you're about 85% solvent does not signify the extent of the problem we face in maintaining optimal hydration status. The significant facts are that our expired air is fully humidified, that we are required to make a certain amount of urine daily, and are covered with millions of pores, each containing a little water pump that is more responsive to our core temperature than to our hydration status. We are little more than elaborately leaky sponges that must be saturated with water to function well.

The bottom line is that we must steadily consume beverages in order to keep the inhabitant of the sponge happy and well coordinated; exactly what we consume and how we manage our relationship to the energy status of our environment determine how successful we are in maintaining our performance status. More simply, *dehydration hinders brain function, overhydration is inconvenient, but safer.*

5. Volume status

Hydration and fluid volume are related but different features of the water-management problem. "Hydration" refers to how much water is in the soup; "volume" refers to how much soup there is. This is important to the pilot and to the walker, because volume is what maintains blood pressure, and without blood pressure we faint. If you become dehydrated, your blood volume contracts and you will tend to grey out when pulling g's, but you can quickly restore this volume with water. If you become volume depleted, you must replace solute (salts, essentially) as well as water in order to restore blood volume. This is what made Gatorade a household word. But if Gatorade were the only way to restore electrolytes they would not have to promote it.

There are a number of things you can do to make management of your fluid balance easier and yourself a safer pilot.

First, look for and recognize the signs in your body of proper fluid balance. *Mental mistakes and incoordination are late signs, not early signs, of dehydration.*

6. Thirst

Thirst is a fairly reliable guide to dehydration, but responds late to volume depletion. An injured person who bleeds heavily becomes intensely thirsty, but we don't like to wait for this degree of volume depletion before re-hydrating. The more sensitive part of your thirst mechanism detects dehydration—the relative excess of sodium in the blood that accompanies water loss—and generates a thirst sensation.

And if you eat excess salt, you become thirsty until you take in enough water to restore a normal electrolyte balance (normal osmolality), and you are in a state of *volume excess* until your kidneys dispose of the extra salt.

Moral: *if you're thirsty, drink.* Trust your body on this.

Some sensations are interpreted by people as thirst which are not. Chief among these is dry mouth, quickly produced by mouth-breathing in a dry environment. For this reason elderly people with defective salivary secretion sometimes become seriously over-hydrated, especially in the northern states in winter. But pilots and other *physically active healthy people should respond to all thirst-like messages by drinking, especially in a hot environment.* How *much* is drunk and *what* is drunk depends on other knowledge and other clues.

7. Sudoresis, Diaphoresis, or Perspiration

Sweat is a clue to the success of your hydration efforts and the aggressiveness with which you need to hydrate. Whether you are acclimated influences what type of solution you should use to rehydrate.

Sweating is annoying and inconvenient. It runs onto our glasses down our chin. When we close the canopy, it condenses and fogs both it and our glasses. It corrodes metal. And it makes us itch. We're grateful when it stops. Unfortunately this gratitude may be misplaced, as on a hot day sweating may stop (or seem to stop because it's diminished) simply because the tank is low.

So on a hot day, *to sweat is a sign that you're well hydrated.* And *if you feel a little warm and are not sweating, take this as a danger signal.*

You see, you lose salt along with sweat, especially when sweating profusely or if you, like me, spend a lot of time in an air-conditioned office and have not become acclimated to heat. Acclimatization involves several slow adjustments of our physiology, one of which is for the sweat glands to conserve salt. On a dry, warm day, when sweat evaporates rapidly, the non-acclimated person will get a little crusty from the salt left behind, and the dog will be happier when he licks your hand.

When sweat is salty, you lose volume, not just water. You fail to get normally thirsty because the osmolality of your blood changes little, and instead you simply feel worn out. Which you might expect at the end of a long flight anyway, and fail to realize that your chief need is not sleep or rest but a long draught.

Not all sweat is salty. The acclimated person or the person sweating slightly will find thirst to occur early and appropriately, as the chief effect of such sweating is dehydration.

So if you are thirsty, drink water. If you are drenched with sweat or your skin is getting crusty, drink electrolyte solution or have some chips with your water.

Our bodies lose about 50 ml/hr of sweat as an obligatory minimal amount; just enough, I suppose, to keep the pumps in shape and the pores open. On a hot day and with vigorous physical activity up to 1600 ml/hr can be produced. That's right, folks. 1.6 liters/hour. Fortunately piloting aircraft is not a vigorous physical activity, but sometimes it's quite a warm one. So bear this range in mind.

8. Water conservation

Your body does have several ways in which it tries to conserve water. The most obvious is that all your body secretions diminish as you dry up. *One clue of mild dehydration, for example, is whether you need to take a sip of your beverage in order to chew your toast comfortably.* Ardent spit production means you're well hydrated.

That emissions-control device, the colon, has as one of its main functions the removal of water from its contents. It receives twenty liters a day of watery post-digestion fluid, nearly all the nutrients removed, and reabsorbs the water and most of the electrolytes. Cholera prevents this reabsorption, and causes death in hours through volume depletion. (And as it causes loss of water in excess of sodium is associated with weakness more than thirst.) "Food poisoning" and other causes of diarrhea are conditions in which actually the colon is not working rather than being overactive.

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One clear sign of dehydration is firm stools. In my part of the country, hot weather arrives in June. People don't hydrate until they start sweating or feel hot and thirsty. But before that happens, the weather turns comfortably warm and they perspire insensibly. They don't get dehydrated or volume depleted because the colon faithfully extracts every last drop of water from the stool to protect life. The first firm clue that the weather has turned warm comes the next morning when they try to expel the brick that was manufactured to prevent thirst. For the pilot this is a check whether, on the average, your hydration attempts have been adequate. *If your stools are soft, your water balance is OK; if they are firm, drink harder.*

Your kidneys are designed to regulate blood volume. It is their job to get rid of extra stuff and conserve scarce stuff. Sometimes water is the "extra stuff" and sometimes it's the scarce stuff. Healthy kidneys can conserve water to the extent of making only about 1/4 liter of urine daily or get rid of extra by making about 20 liters a day.

A biological mystery not yet solved is the origin and purpose of *urochrome*, the chemical that makes urine yellow. As a constant amount of this stuff is made, the intensity of color varies with how concentrated the urine is. This provides another clue to the success of your hydration efforts: *if your urine is dark yellow, drink harder; if it is pale, you're probably doing fine.* The kidneys react very quickly to your volume status, so if you pee just before a flight you can judge immediately whether you've hydrated well enough.

9. Diuresis

There are several ways in which pilots make it hard for themselves to stay hydrated. These all involve "diuresis" of one kind or another. Diuresis is the process of making extra urine. Physicians produce diuresis deliberately when medical conditions hinder the kidneys from getting rid of extra salt or water. Pilots produce diuresis unintentionally, a problem only when the main goal is to conserve water.

Sugar

For most pilots, sugar is not a problem, and medical certification is difficult for diabetics. But if you are, especially you who are and don't know it, or you who think their diabetes is mild and requires little attention, listen up.

Sugar in the blood above a certain amount which is different for everyone, spills into the urine. The level at which sugar begins to "spill" is called the "renal threshold," and is important because this can be fairly near normal, as low as 150 mg/dl. This is significant because a normal *fasting* blood sugar is 70 – 110 mg/dl, and a normal after-meal blood sugar is up to about 150 (some would say 180). A person can have mild diabetes with no symptoms at all, and even a normal fasting blood sugar, and after

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eating (or more significantly, after over-eating) can run the blood sugar up to 250 mg/dl or more and have it stay there for hours.

When sugar spills into the urine, it creates an "osmotic gradient" that pulls water into the urine (or hinders its reabsorption). This results in excess loss of water. As the water is lost through an osmotic process, you feel thirst as a result and drink more water, so generally people are able to maintain their blood volume easily. But it does require that you drink a lot more water than might otherwise seem reasonable and sufficient, possibly a problem during a long flight in a warm cockpit on a hot day.

And people age, people who haven't had diabetes but might have older relatives who have had it, people who might be a little more portly than they used to be or intended to become. These folks, not you or me, but some other folks, might develop diabetes without ever being aware that it is happening, without ever feeling badly. It can sneak up on a person, just as old age tends to do. Think about it.

Caffeine

Caffeine is, plain and simple, "a diuretic to the kidneys" as the Doane's Pills ads used to say. It is relatively harmless, it is a useful stimulant, but it *is* a diuretic, and if you drink it, you will get rid through your kidney most of the beverage in which it is imbibed.

The moral here is, *if you don't want to be inconvenienced by copious urination during a long flight, don't drink caffeinated beverages before flight.* And if you are trying to hydrate on a warm day, either avoid caffeinated beverages or double the amount you might otherwise drink.

Soda is the source of caffeine by which you might be caught unawares. In my area, for example, Barq's root beer is caffeinated, but Barq's diet root beer is not. The only clue is the fine print on the label. In addition, the word "soda" is contracted from "sodium," the cation of table salt. See "salt," page 8.

And "de-caf" coffee is not caffeine free. Depending on how it's brewed, decaf has 16-25% as much caffeine as a cup of regular coffee. Less, but not none.

Alcohol

Well, none of us would ever drink alcohol before flying any more than we would take a sleeping pill before flying. But I mention it because of its effect on post-flight hydration. Alcohol is a diuretic. *If you drink alcoholic beverages while you are re-hydrating, you must over-hydrate in order to compensate for the diuresis.*

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Water

This is a surprise, isn't it? Water is a diuretic? Here's how the process works.

Mark McMurray, eager to avoid the dangers of dehydration, avidly and steadily drinks water in various forms. His stools are soft, his mouth moist, he sweats easily, his urine is pale as water and he's in the rest room or irrigating a bush every couple of hours.

What Mark doesn't know is that his kidneys must establish an osmotic gradient within their substance, that body water conservation requires a metabolic and hormonal shift that requires a few hours to become complete. By keeping himself in a persistently over-hydrated state he causes himself no injury, but puts himself in a situation in which his biological momentum is entirely in the direction of getting rid of excess water, requiring that he continue to drink ardently. And if he runs out of water, he'll have to become somewhat volume depleted in order for his kidneys and endocrine system to shift quickly into water-conservation mode.

So the risk to Mark is small, but by over-hydrating he does make adjustment a little harder when he makes that off-field landing and begins working to conserve his water supply. *Better that he should keep a little color in his urine by not hydrating quite so single-mindedly.*

Salt

Americans love salt! Restauranteurs and food processors love it even more, because salt enhances flavor, and flavor sells food.

This is a problem for the pilot trying to hydrate because the kidneys are obligated to get rid of excess solute. If they do not, our obligation to preserve osmotic balance (via thirst) causes hypervolemia. Not a big problem to the healthy young pilot, but possibly a troublesome one to the older pilot with a gristly heart and stiff arteries. Excess volume for these folks can cause high blood pressure, swollen ankles, and even pulmonary edema.

Even for a healthy young pilot, excess salt can take two or three days to dissipate. Meanwhile you're drinking extra water to maintain normal osmolality and peeing twice as much as usual to get rid of the excess salt (obligate solute excretion, if you care to know).

Other solutes can contribute slightly to this problem, but salt is the main one. The average American consumes about 10 grams of sodium daily; the minimum daily requirement is more like 10 milligrams. It's hard to eat a diet, even with diligent effort, containing less that 2 grams. So sodium deficiency is definitely not one of our worries.

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As we've observed earlier, water follows salt, so if we get faint from excessive sweating, eating salty food and drinking water guarantees that we'll restore lost volume.

But how is salt a diuretic? Well, extra salt *must* be gotten rid of. And the body uses water to carry away this salt. The brick that you passed while on the commode this morning was almost salt-free, I'm sorry to say. So for every dollop of extra salt that you eat, you must also excrete an aliquot of water that you might have otherwise used as sweat to keep yourself cool or to make spit to keep your mouth moist, or to keep your mucus moist so that the inside of your nose doesn't crust up.

The summary is that *eating extra salt causes extra urination, an inconvenience during flight; it wastes water (as urine) that might be better spent as sweat.* It thus creates a requirement that you drink extra water, making it harder to hydrate adequately just as caffeine does.

Conclusion: you're best off avoiding salty food unless you, the non-acclimated pilot, have been sweating heavily. Salt creates a need for excess water that is swiftly excreted to get rid of extra salt and does nothing to protect your hydration status.

10. Cockpit waste management

Unless something *really* scary happens, the only waste disposal problem in the cockpit, besides power-bar wrappers, is likely to be what to do with the urine created by your vigorous hydration-work.

For some reason, women have in general just gone ahead and pragmatically solved the problem for themselves while men have endlessly debated techniques. The solutions have been characteristically interesting. A bottle is a favorite; peeing uphill can be a challenge, the cap may leak or be knocked off, and the occasional pilot forgets to stow and zip after landing. One pilot famously finished his 6-hour duration by unbuckling to pee and afterward did a celebratory loop. He did this badly, pulling some negative g's at the top and falling out through his canopy, presumably with his pee-bottle close behind, thus discovering pilot impairment: he'd not re-fastened his seat belt. The bottle did not have a parachute, but the pilot did, which is why we know the story.

I heard of an inelegant doctor, a soaring pilot, who seemed to delight in catheterizing himself and wearing a leg bag that was not quite hidden by his Bermuda shorts. I have not heard of any copy-cats.

The condom catheter (or Texas catheter) is a favorite with some pilots, as it's non-invasive. A leg bag can be connected, or the tubing can be led outdoors. The risk with these is of course plumbing leaks, disconnections and fractures.

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Darth Vader prefers one-quart baggies (I presume zip-lock—twisties might be a challenge in contest conditions) which come back unless very full. Those are used to bomb competitors. No word on any missing hikers...

The current fad seems to be the relief tube led out the gear-well door. No word about style points from the mechanic doing the gear maintenance, or whether there's an aroma-surcharge; no word from pilots on what they do when their dilute, well-hydrated urine ices up on wave flights. Urine is a strong salt solution, and most of us do not spray brine deliberately on the working parts of our aircraft. Such a tube can be connected either to a condom cath or a funnel.

Many women and all the astronauts have discovered a very efficient solution that requires no engineering at all: *Depens*™. As you might surmise, under weightless conditions urine does not fall into the bottle, and furthermore tends to break up and aerosolize. This being hard on fellow-astronauts and integrated circuits, the answer is to not let it escape at all.

Adult "briefs" are available for $12-18 for 18-22 diapers. If you hydrate well, I recommend the "overnight" model. No caps, no tubes, no catheters, and no leakage unless your production is truly stupendous. They keep you damp but not wet, and are easy to remove. They fit invisibly under normal clothes (cycling shorts and chinos excepted).

11. Oxygen

Extracted from the AvWeb article by Michael D. Sebastian, M.D., (c) 1996.

What Does Oxygen "Do?"

In a nutshell, oxygen enables the cells of the body to release the energy stored as high-energy chemical bonds in our food, and enables them to use that energy to do what cells do: namely, to keep us alive, heart beating, brain thinking, and kidneys turning our Diet Cokes into unplanned pit stops. Virtually every cell in the body needs oxygen in order to perform its part in the complex symphony of skills and judgment that enables us to fly an airplane....

We commonly function in a hypoxic, or low-oxygen, environment, ...since the partial pressure of oxygen we breathe decreases as our altitude increases.... Though our cells and organs don't die outright because of the decrease in oxygen, they don't work at maximum efficiency either. This oxygen-deprived state has significant effects on our performance of complex tasks, like flying.

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Aviators are most concerned with hypoxia's effects on the brain. Hypoxic symptoms can be present even at modest altitudes, lower than those at which we're required to put on the canula. The symptoms become progressively worse along a continuum as we continue to ascend or as our time at a given altitude increases. We might notice fatigue or degradation of night vision beginning at pressure altitudes as low as 5000 or 6000 feet....As an approximation, the ceiling for an aviator in a nonpressurized cockpit not breathing oxygen is about 23,000 feet. At this altitude, his blood contains only half the oxygen present at sea level. Any higher, or any longer than a brief exposure, and he is unconscious.

...total pressure is the barometric pressure (Pbaro). In a roomful of air at sea level the PP of nitrogen is 78% of 760 mm Hg, or about 593 mm, while the corresponding O2 PP is 21% of 760, or 160 mm. In Denver, where Pbaro is about 624 mm, that same 21% oxygen gives us a partial pressure of 131 mm; and at FL180, with Pbaro at about 404 mm, only about 85 mm O2 PP. These may not seem like huge differences, but they are physiologically significant.... The partial pressure of oxygen, not its concentration, is the most important determinant of how much oxygen gets from the atmosphere into our cells. Within certain limits, your body does not care whether you are breathing 50% oxygen at 320 mm Hg pressure or 21% oxygen at 760 mm, because in each case you are breathing an oxygen PP of 160 mm....

How Much Oxygen is Enough?

Good question, since this tells us how high we can safely go with and without oxygen. There is no absolute safe level of blood O_2 PP or O_2 sat. However, some rough guidelines exist regarding hypoxemic tolerance. Judgment and fine motor control begin to deteriorate appreciably at a blood O_2 sat less than about 85% in the healthy but unacclimatized pilot. This corresponds to a blood oxygen PP of about 55-60 mm Hg. Unconsciousness ensues after all but the shortest exposure to a blood O_2 saturation of about 50% or less; you will encounter this level of hypoxemia at an altitude of about 23,000 feet as I mentioned earlier. Of course, one's tolerance for hypoxemia is significantly diminished by smoking or by certain heart or lung diseases such as emphysema or congestive heart failure....

FAR's require the pilot in a nonpressurized aircraft to don oxygen above 12,500 feet MSL for that part of the flight exceeding 30 minutes. Further, the pilot is required to use oxygen for the entire flight above 14,000 feet. At the latter altitude the pilot's blood O_2 sat would be expected to be around 80% without oxygen, clearly below the "safe" minimum level . So physiologically, the altitude regulation makes some sense.

12. Temperature homeostasis

We are mammals; we are homeotherms. Biologically this means that our enzymes are designed to work best at about 37° C. If our body goes much above or below this temperature, the chemical reactions that keep us going simply don't work well. Temperatures above 42° are usually fatal or disabling. We can survive cold temperatures much better than warm ones, but rarely can function well below about 31°.

Mountain soaring is a particular challenge because the flight may start in hot, dry conditions and proceed fairly quickly to high altitudes near cloud base. If the cloud base is reached, the ambient temperature will be at the dewpoint, which may be 5°C. or less in dry desert conditions.

The sweat that formed at low altitudes to save us from disabling hyperthermia becomes dangerous, its evaporation accelerating our body's cooling, or saturated clothing conducting heat away. There is little physical activity to generate extra warmth through muscle metabolism.

Abnormal body temperatures slow thinking and impair judgment just as insidiously and just as surely as fatigue or hypoxemia or dehydration; and of course all four factors may commonly combine on a single extended task. Concentrated attention to the basics and disciplined adherence to simple procedures can save you from serious or impulsive errors in judgment or technique at these times.

The cardinal warning signal of impending hypothermia is shivering. Shivering begins at about 93° F. or about 34° C. If you begin shivering, it's time to descend to *much* warmer air, and to plan a landing. If you are shivering, count on half an hour to an hour to warm up even if you can quickly get into ambient temperatures above 85°. The fastest cure for hypothermia is a nice bath at 100-110° F, not available in any glider or at most glider ports.

Temperature management in mountain soaring requires flexibility in managing clothing. *Your greatest site of heat loss is your head, especially if balding.* In hot conditions, uncover your head and provide a breeze across it; in cold conditions cover it. *The second greatest site of heat loss is the front side of your trunk, especially the area of your breastbone.* A lightly insulated jacket that can be easily kept open in warm air on the ground and quickly closed at cool altitudes will provide maximum flexibility.

Your hands and feet are relatively unimportant in managing your temperature except in extreme conditions. *The chief meaning of cold hands or feet is a signal that you will become hypothermic if you don't take action to conserve heat better.* If you can't do that, land, or play at a warmer altitude.

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13. Conditioning

Maintaining some degree of cardiovascular conditioning through regular exercise is useful, not only in walking out for help after a landout, but also provides for a better response to stress in the cockpit. The deconditioned pilot reacts physically to stress with higher blood pressure, more rapid heart rate, and a greater degree of hyperventilation than the pilot who is conditioned.

Disease

The effects of specific diseases, and of non-disease conditions such as intestinal gas, are sometimes very important to flying safety, but each of these would require an essay in itself. The important principle is that if you have any medical condition, you should educate yourself on its nature just as avidly as you educate yourself about the flight characteristics of your ship. By doing this you will be able to recognize signs of impending performance degradation or incapacitation and avoid risky flight.

Disorientation

The complexities of spatial (dis)orientation are a fascinating topic, and probably, in subtle forms, are involved in many soaring accidents, especially those in the pattern after a long task. But such a discussion is beyond the scope of this essay.

Actinic damage

Sunburn, corneal light injury, and the delayed effects of sun exposure are important to glider pilots. They affect comfort more than performance, so I will add material on these topics only if I get inspired, which I am not at the moment. It is interesting that diffuse sunburn is characteristically associated with hypothermia during the 12 – 24 hours following exposure, due to the dilated blood vessels in sunburned skin radiating heat to one's surroundings. It is possible that intense light exposure contributes to macular degeneration.

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Physiology: Clues You Can Use

This manuscript describes some essential physiologic requirements for safe glider (or powerplane) operation, and suggests simple clues pilots can use to detect an abnormal physiologic status.

1. Spatial Disorientation: How to Have an Accident, Confidently

Pilots do not intend to damage themselves or their aircraft, yet pilots crash. I guess that's why we call them "accidents," to differentiate them from the stupid things we *plan* on doing.

To oversimplify a whole lot, we can divide accidents into simple categories:

- the airplane is out of whack
- the pilot is out of whack
- somebody else whacks the pilot or his airplane
- acts of God.

To get the theology out of the way pronto, since this is not our main subject, let me just say that, knowing God personally, I can say that not only do people ask Him to do a lot of things that He doesn't have any particular interest in doing, but also that people blame Him for a great many things He didn't do in the first place. He put us into a livable environment, gave us motor skills and a fine analog computer, some basic essential instincts, and a parenting system — really, quite enough to live prudent and safe lives if we pay attention to details.

And to get the sociology out of the way, I can also say with some authority that whatever I say here isn't going to affect the other guy one little bit, because he isn't here listening, for one thing, and neither of us can predict his behavior, for another.

And let's get the airplane thing out of the way, too. That's your responsibility, not mine. You've purchased a proper, careful annual inspection, you've researched the vagaries of your machine and its fittings, you do a careful pre-flight followed by a positive control check, and from the moment you attach the tow cable you have contingency plans for disaster in hand.

So that leaves the pilot. Hi! Here we are! That's us!

Let me say right now that not one pilot goes into an accident intending to have one. And inspecting accident records shows that some of these pilots are experienced and skillful. We expect stupid, careless, clumsy pilots to have accidents, so illogic leads us to conclude that any pilot having an accident is stupid, careless, or clumsy. If you've ever damaged an aircraft, you've felt this illogic from some of your comrades, have you not?

So our aim here is to explain some ways in which a bright, careful, skillful pilot like yourself

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might be surprised by an accident.

2. *Accidents of Thinking*

Frank Caron, in his Technical Soaring article on French glider accidents (V. XXIII, No, 3, July, 1999 p. 71-5)), uses James Reason's error model of cognitive errors leading to glider accidents. Here's the breakdown:

cognitive processes	accidents	fatalities	injuries
routines	37 (16%)	1 (10%)	6 (15%)
inaccurate representation of glider status	55 (23%)	7 (70%)	11 (28%)
inaccurate representation of environment	64 (27%)		9 (23%)
incorrect choice of procedure	54 (23%)	2 (20%)	10 (25%)
bad resources management	9 (4%)		
1 (3%) wrong intention	12 (5%)		
3 (8%) violations	5 (2%)		
Totals	235 (100)	10 (100)	40 (100)

Notice that the entries beginning with "in-" account for about 3/4 of accidents and injuries and 90% of fatalities, and they add up to "I didn't realize exactly what was going on!"

I don't believe that French pilots are basically any different than we are, even though they might like to think otherwise.

Let's take a moment right now to observe a particular peculiarity of glider accidents. They nearly all involve the ground. This is because air is relatively soft, and so for an accident to involve damaging collision with the air, some pretty spectacular weather has to occur, which scares away most of us. Such accidents have occurred, but not often. And there are hard objects in the air, which sometimes collide with and damage gliders, but nearly all these hard objects contain brains in one form or another, and detection systems, and genuinely want to avoid each other, so such accidents are less common. I don't know what your experience has been, but every time I've had a close encounter with a bird while piloting an aircraft, the bird has been in "aggressive avoidance mode." Airplane pilots are less observant. I remember asking a macho local friend, after we both landed, "When the glider is inside and below the Pitts and both are on base for the same runway, which aircraft has the right of way?"

His answers were pretty humorous:

- "I called three miles out — didn't you hear me?" [why didn't you get out my way?]
- "I didn't hear you on the radio" [you must not have used one].
- "Well, I'm a lot faster" [why do you even bother to bring this up?]
- "I didn't get in your way" [no blood, no foul].

Most glider accidents involve collision with the ground because (a) there's a lot of it; (b) earth attracts gliders to it — "ground" is what generates "gravity;" (c) glider pilots must perform their most precise maneuvers real close to the ground, e.g., the turn from base to final.

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If we look carefully at the results of this study of French accidents, we'll note that "mistakes from an inaccurate representation of the situation or the status process" result in 27% of the accidents, 37% of the injuries, and 73% of the fatalities. This somewhat cryptic phrase means basically that the airman did not correctly perceive the glider's current status, condition, or position relative to the air flow; or the situation on the ground. Another phrase that says something pretty similar is "spatial disorientation." More on that later, but a more instructive term might be "spatial
misinterpretation."

Thus the pilot's inaccurate perceptions cause most of the fatalities and many of the accidents. Why does such inaccuracy occur? It happens not because pilots are negligent, but because our perceptions have limitations and are subject to (undetected) error.

Let's say this again, differently. Pilot error — "inaccurate representation of the situation" in Reason's eloquent rhetoric — occurs because your body and your senses are working the way they are designed to work, not because you are a dumb klutz. Well, OK, you and I might both be klutzy under some circumstances, but spatial "misinterpretation" usually occurs because your visual and vestibular senses are working just the way they are supposed to *and are prone to certain predictable errors*.

I want to show you here some ways that the ***normal*** operation of your senses, in ***usual*** flying tasks, can lead even the skilled pilot to incorrectly perceive the glider's status or its relationship to the ground. Understanding the circumstances in which this is prone to happen can help you distrust your senses at the right times, and look for confirming cues to sort out what's correct and what's real.

3. *Accidents of Perception*

First, let me mention two books that may help you study and understand the illusions leading to confident error:

Human Factors in Aviation, Earl L. Wiener and David C. Nagel, eds., Academic Press, 1988, ISBN0-12-750031-6 (www.apnet.com), especially Chapters 4, The Human Senses in Flight, by Herschel W. Leibowitz, and 9, Human Error in Aviation Operations, by David C. Nagel.

Fundamentals of Aerospace Medicine, second ed., Roy L. DeHart, ed., Williams & Wilkins, 1996, ISBN 0-683-02396-9 (www.wwilkins.com), especially Chapter 11, Spatial Orientation in Flight, by Kent K. Gillingham and Fred H. Previc.

Second, let me emphasize that, even if we understand the perceptual illusions to which we pilots are prone, to realize that "something is wrong" is very different from correctly analyzing *what* is wrong and even that is well short of *acting correctly* and doing this *in time to avoid bonking the ground.*

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Third, it is important to realize that in severe turbulence or when doing aerobatics, it is possible for your brain to become so discombobulated that it is not even possible to read your instruments: this is called "nystagmus," and prevents your eyes from focusing on your instruments to read them and to understand what they are trying to tell you or from focusing on the ground to understand your orientation. This is rare, but has killed pilots, especially fighter pilots in real or practice air combat.

And fourth, sometimes these illusions are dismissed by glider pilots as unlikely to happen, for textbooks present them as problems that plague instrument-airplane pilots, who are continually functioning in conditions of reduced visibility or absent visual cues. But they can and do affect glider pilots, only somewhat differently in visual conditions; and we need to remember that glider pilots do sometimes fly in cloud in other countries; and even in visual flight conditions, that haze, smoke, dust, unexpected cloud formation, dirt on the canopy, rain and dusk can significantly degrade outside visual references, sometimes at inconvenient moments.

Let's stop for a bit to discuss the functional anatomy involved: the inner ear and the eyes. "Seat-of-the-pants" flying, which dominates soaring and gliding, requires fine coordination of the vestibular system, chiefly involving the "inner ear," and the eyes.

The inner ear has three interconnected parts: the cochlea, which parses sound into discrete frequencies; the semicircular canals, which detect rotation in three axes, and the otolith apparatus — the utricle and saccule — which detects gravity and linear acceleration.

The key to understanding the inner ear is that it detects *change*, not the status quo. That is, it detects not whether you are turning, but whether the rate of turn has changed. It detects not whether you are moving or still, but whether your speed has changed, not whether you are floating through space, but whether you got kicked in the rump.

The sensations of the inner ear are linked within the brain and cross-checked against perceptions of neck position and visual perception, to build a composite of your relationship to space, time, gravity, and the cockpit. Each of these parts — and the brain itself — is susceptible to predictable errors, to inherent limits, to disease, to degradation from fatigue and dehydration, and to aging.

When these systems are working well, pilots can do amazing feats of skill and precision; the problem is that pilots are often unaware of subtle degradation, or underestimate more severe degradation of these perceptual systems. Understanding the way they work and the illusions we are susceptible to, and adapting our flying intelligently, can help us avoid catastrophe.

Next, the eye: it has two visual functions:

- ambient vision and
- central vision.

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Ambient vision is most important in maintaining spatial orientation through detecting patterns and movement through peripheral vision. If you doubt this, try flying your glider while looking through a pair of paper tubes. Only with a safety pilot!

Focal vision is most important in object recognition through processing of fine detail. It is not as important as ambient vision in keeping track of where you are in space. Ambient vision knows you're in a bank; focal vision knows the cloud up ahead has a tight bottom.

Let's catalog the illusions of perception one by one, briefly.

4. Visual Illusions

Shape constancy. We expect all runways to have similar trapezoidal shape when we're on final. Larger or smaller runways look nearer or further than they "really" are, compared to the runway we're most used to; an upsloping or downsloping runway likewise looks nearer or further, respectively, than it really is.. This illusion has led to numerous overshoot or undershoot accidents, and it's not an easy one to overcome, especially when the strange runway is almost like the one at home.

Size constancy. Size is the main clue to distance beyond the 15-foot range of binocular vision; we tend to flare high over a big runway and low over a narrow one. Sloping terrain causes high or low approaches based on the changed size of objects on the ground.

Aerial Perspective. Haze, fog, or rain, may obscure distant landmarks that would otherwise give clues to distance.

Absent focal cues. Smooth water and fresh snow are the classic examples; glider pilots do not normally land on these surfaces, but have done so by not realizing how close they really are.

Absent ambient clues. A gust front has been approaching, and you begin to transition to flare just as it crosses the airport boundary and puts you into a turbulent dust cloud. Or you have lingered too long in wave, and the evening is well along before your final glide takes you over the darkening airport. You of course have no landing light, and the asphalt is just a well between the glowing runway lights. Or you are between thermals on a hazy day, and you see a small, blurry insect stuck on your canopy, which you suddenly realize is another aircraft.

Vection illusion. A fancy name for something we've all experienced. You are in your car, waiting at a stoplight on an upsloping road. You sense your car beginning to creep forward; you jam your foot on the brake to keep from hitting the bumper of the car ahead; nothing happens. The car next to you continues to creep backwards...

You are thermaling at a comfortably high altitude, in a 45-degree bank. The glider pivots around its center of gravity, the inside wing sweeping back across the terrain as you make tiny little

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turns; later, having failed to make a low save over the factory next to the airport, you turn from base to final at 200 ft agl. Despite your aggressive 45-degree bank, the glider makes huge, turns, pivoting around some point in the far distance, and seems to skid across the ground, as it speeds across the terrain. You make an S-turn back to line up with the runway, keep the spoilers tucked in, and hope no one is "admiring" you.

There are three vection illusions in this situation. Two are opposite angular illusion, one well above the pivot altitude, one well below it. The angular-vection illusion of failing to turn sharply when low, below the pivot altitude, contributes to over-ruddered, skidding turns and to spins on the turn to final. And the vection illusion of greater speed when low over the ground surely contributes to inappropriate slowing and to the stall that permits the spin.

False Horizon. You are flying in wave, with lovely lenticular clouds sloping up and away to your left. Your yaw string keeps drifting off to the left across the canopy. What's happening? The lenticular forms a false horizon that your ambient vision keeps trying to use. Or you enter a canyon toward an off-field landing, and overshoot the stub of straight road you had chosen for an off-field landing, realizing too late that the canyon floor only seemed to be level, and was actually sloping subtly away. Your buddy was in a similar situation, only snagged the sagebrush on the way in, landing short because the upsloping floor looked level.

False stabilization. When you are busy inside the cockpit, checking charts or programming your GPS or final glide calculator, ambient as well as focal vision may begin to depend on the stable cues of the cockpit and canopy. Lack of clouds or other outside cues may mean that there's nothing to contradict the false impression of stability. You look up from your map to find the yaw string streaming crosswise across the canopy and the right wing down thirty degrees.

5. *Vestibular illusions.*

Vestibular illusions are much more important in instrument flying than in visual flight, but even in visual flight conditions can lead to seriously uncoordinated flight and can significantly delay our recognition of dangerous attitudes. If you fly gliders in cloud, understanding these illusions is important to safety.

Somatogyral illusion. The semicircular canals sense only *change* in rotation, and the illusion is two-fold: when rotation begins, the rotation is properly sensed, but when steady rotation is maintained, such as with proper thermaling technique, in about ten seconds the sense of rotation vanishes, even though the turn continues. This is the first illusion; the second illusion is of false rotation in the opposite direction when the turn is stopped. Often the *Barany chair* is used to demonstrate these illusions. This illusion is prominent in instrument flight, but not in visual flight because visual cues are overriding. The famous *graveyard spiral* is a product of the somatogyral (somato = body; gyro = turn) illusion, and occurs because the pilot "corrects" for the false sensation of turning that is provoked by stopping the initial, unintended, turn. This results in a gradual turn in the opposite direction; the descent occurs because the pilot reflexively seeks to keep the vertical G-force the same as in level flight.

Oculogyral illusion. During the somatogyral illusion, an isolated object seen at a distance will seem to be moving with the falsely perceived turn. As this involves the eyes, it's called "oculo." This may cause the instrument panel to appear to briefly move when it should not. This illusion is an interesting curiosity, but I don't know that it has any special significance except to alert the pilot to the simultaneous, more subtle and more hazardous somatogyral illusion

The Coriolis illusion. This one is important for glider pilots. Here's the scenario: your body is turning at a steady rate, long enough for the fluid motion to become stable within the semicircular canal which is in line with that plane of rotation. Then you raise or lower your head. A different semicircular canal is abruptly lined up with the fluid flow, and suddenly the fluid is flowing through *another* semicircular canal, creating a sudden, strong sensation of turning in a *different* direction. You instinctively respond to that sense, causing the glider change attitude to "correct" the illusion.

Does this happen? Of course, it does. Remember it takes only about 10 seconds for the fluid flow to stabilize in a semicircular canal. How long do you remain established in a stable banked turn? Longer, sometimes for many minutes when thermaling, but even in a turn from one pattern leg to another the duration is longer than that.

What happens? You are in a stable banked turn, looking ahead, and..

– you look down to check a chart, or
– you look up to check traffic above you in the gaggle.

We are all well advised to keep track of the traffic around us. "Keep your head on a swivel," is the byword. But checking for overhead traffic is clearly dangerous if you've kept your attention forward continuously for as long as ten seconds. And looking down at your checklist or charts, likewise.

Remember, the key to this illusion is having your head's posture stable for more than ten seconds. Continual head movement helps protect against this illusion. In addition, one must have one's head stable at just the right angle — actually cocked downward slightly — in order to experience it most vividly. But there are clearly accidents in which this illusion has been a factor.

Here's an example of how this works, from a 1998 accident, reported in the December and February *Soaring Magazine* (quotations are from those articles):

6. Corliolis Illusion Damages Glider Pilot

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The pilot of the glider was circling above a ridge searching for lift, and circling beneath a 1-34 in hopes of sharing a thermal. The key sentence is, "...not finding any lift under the 1-34, he craned his head back to look directly overhead to center beneath the other glider." We'll assume that he was making left turns, although the direction is immaterial except to make the analysis clear.

Physiologically, the important point is that this pilot, a competent fellow who knows how to fly, was in an established banked turn at the moment he needed to look vertically. This would require him to throw his head back and turn it to the right.

If he had been in the turn for as much as 15 seconds (probable, given that this was thermaling flight), his vestibular system (semicircular canals and otolith organs) would have stabilized.

When a pilot in a stable turn turns his head to the outside and tips it back, an inevitable, strong sensation is created of banking more steeply and diving.

When this pilot looked directly overhead, his visual references to the cockpit and to the ground were dramatically changed and diminished. Technically, this is "degradation of visual referents," which predisposes to motion illusions.

To maintain a sense of remaining in a stable turn, he would have to pull back on the stick and bank toward level. He would have been strongly motivated to obey the seat of his pants by his sense that he was close to the ridge. Whether he was 300 feet as he thought or 955 feet as his GPS readout indicated, is not material; the point is that if the ridge "felt" close, the pilot would have been more motivated to maintain coordinated-feeling flight than if he had been comfortably high.

It is important to realize that these illusions **feel right**. There is no confusion until something happens to contradict the illusion. To continue, "At that point, he indicated that he might have become disoriented, causing the stick to be pulled back excessively, and for the ship to skid. It immediately went into a spin." Well, this is the language of someone who was surprised, who is looking back at the awful fact that a spin happened and trying to understand the cause. It does not say, "The pilot said he became confused." It is the pilot acknowledging that, because the spin happened, the aircraft could not have been in the safe attitude he felt it to be in and which he was trying to maintain.

In this particular case the pilot was flying a glider which doesn't give much warning – buffet or shudder – of a stall, so he had no opportunity to perceive the illusion that injured him until the stall was fully developed.

I hope you do not think, just because this pilot crashed, that he was incompetent, poorly trained, careless, negligent, or indulging in deliberate risky thrill-seeking. In fact, the articles cite several signs of careful planning for possible disaster and awareness of its possibility. The fact is that

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someone just as careful and skilled as you, could, while intending to be extremely careful, experience exactly the same type of motion illusion and crash, with the same humiliation, the same raised eyebrows, the same adverse presumptions about pilot judgment and skill.

Now let's turn to the second key fact of this incident. The GPS data from the flight was analyzed. The pilot says, "The data shows that I was flying straight and level for approximately 1 minute after making the 180-degree turn in which I craned my head back to look up at the 1-34....So, the spin developed from some other reason rather than my distraction with the 1-34."

The GPS data proves that the pilot did respond "appropriately" to his vestibular sense, and did level out and straighten while looking up at the 1-34; the physiologic point is that during this time he would have **felt** as though he was continuing in a stable turn. If he had **not** had illusion, his vestibular system would not be functioning properly.

Got that, guys and gals? The illusion is **inevitable**. It occurs because the system is **working**. It occurs because cross-checks (visual referents, tactile referents) are **diminished**. Everything **feels right**. Suddenly something happens that shouldn't – a stall – and the pilot must quickly re-orient. We hope. What about recognition and recovery?

As the airplane quits flying, the pilot's vestibular system is continuing to function normally, sending wrong information to his cerebral cortex about the glider's motion, interfering with his ability to recognize and recover from the spin. From the pilot's point of view, something has happened, suddenly and unexpectedly. He turns back to look "out the front window," and the message this head movement sends to his cortex is that the glider has pitched up and banked to the right. Meanwhile, the actual movement of the glider has been to pitch his head down, and to turn it to the right or to further to the left, depending on the spin rotation – or perhaps the glider is not rotating; his head movement has only given him the sensation of a spin and the glider is actually in a deep stall. In this case, it will feel right to apply opposite rudder, which will actually cause a spin.

Ignoring the vestibular illusions, please realize that this is not a training session, where we expect a spin for learning purposes. All the pilot knows at first is that the controls are slack and the world is cockeyed. Has he had a mid-air with an unseen glider? Has the elevator disconnected? It will take time to sort this out, time that may not be available, given the alacrity and enthusiasm with which gravity operates.

Now holding in mind that such a situation developed because of motion illusions, what will overcome the illusion? Only a stable visual reference. This may not appear until the spin is fully developed, nose down and dropping. Prior to this, the sense of rotation may be either exaggerated or wrong, and the pilot has no clue (more precisely, has inadequate clues) that this perception is wrong.

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Is this sufficiently clear? There are circumstances in which a stall-spin is inevitable, and there are particular conditions under which even a superb pilot will be genuinely incapacitated from recognizing the pitch of the aircraft and its direction of rotation during those few seconds in which recovery is aerodynamically possible. These circumstances can arise in the normal conduct of glider operations: thermaling "low" over ridges or during approach to landing.

Back to our story. The pilot concludes, "So, the spin developed from some other reason rather than my distraction with the 1-34." He's exactly right. Is it clear to you now what the "other reason" was?

This sentence contains a common misconception: that it is "distraction" that is the problem. It is not. We must "attend to many cues," as the psychologists say, throughout flight, especially in traffic. Every "cue" distracts from every other. The problem is **head movement in turns after holding it stable for 10 to 15 seconds.** Head movement, in a turn, **always** creates a vestibular illusion. This illusion is usually over-ridden by redundant correct sensations, chiefly visual ones. Unfortunately, to avoid all risk of this illusion means not turning the head: not checking for traffic, not checking ground reference points when landing, not visually checking for flap, spoiler, and gear-handle positions, not checking charts. Impossible. But another way to decrease susceptibility is not to hold the head still for more than a few seconds, so that the vestibular fluids never quite stabilize. This is more realistic: Keep your head on a swivel.

7. *Coriolis Illusion Kills Jet Pilot*

Another crash illustrates the risk of checking charts in the pattern.

A fighter was observed by a flight surgeon to be approaching a landing in the early night. Just as it finished the turn to base, he saw the cockpit interior light go on. Then the wings rolled up to vertical, the nose dropped, and the fighter crashed, killing the pilot. What happened? It was the coriolis illusion again.

The flight surgeon knew the fighter's cockpit layout, and realized that when this light came on that the pilot was looking at a board located downward and to his right. To look downward and to the right at the completion of a stable turn to the left, creates the illusion of pitching up and leveling off. Thus the pilot, with his eyes in the cockpit and off the instruments, followed the "seat of his pants" into dropping the nose and rolling to the left.

During the post-crash investigation he explained this mechanism, but the base commander would not believe him, and said, "You can't be right. There must have been a problem with the aircraft. I'll go out and do the same maneuver myself and show you it won't cause an accident."

The flight surgeon, pretty confident that he'd learned physiology correctly, said, "Only if you take a safety pilot!"

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That model of fighter is available as a two-holer; one was on base, and so the challenge was on.

The commander flew the pattern, at night and in vfr conditions as during the accident, and simply looked down and to the right at the chart as he completed the turn to base.

The safety pilot recovered the aircraft less than 100 feet off the ground. QED.

A glass slipper can fall out of the sky from base or final just about as quickly as a jet. It's not only warplanes that carry charts, that have controls down and to the side at which we may wish to look. Don't do it. Keep your eyes out of the cockpit during pattern turns. Use peripheral vision to locate the spoilers, and gear lever. Use feel to check their position.

8. Gravity Magnifies Tilt

Somatogravic illusion. This is an important illusion that can cause slow airspeed on final. (Yes, "gravic" relates to gravity.) This illusion is caused by the proper function of the otolith organ, which as you recall senses gravity and linear acceleration.

Here's the deal: a forward acceleration and a tilting backward cause exactly the same change in the otolith; a slowing and a tipping forward also cause identical response. Which one seems actually to be happening depends on your brain properly integrating other vestibular signals with visual cues.

You are on final in your glider. You sense you are high, and apply full spoiler. This slows the glider abruptly, and the signal from the otolith organ is "nose-down pitch change!" Ground references are not fixed — they're flowing backwards past the nose — so they don't correct the impression readily. If you simply react confidently to this sensation with a nose-up pitch change, your airspeed will diminish and you may quickly develop excessive sink.

You say, "Wait a minute, I can *see* the nose pitching down!" Sorry, pal; that's a related illusion, the ***oculogravic*** illusion. The false sense from our vestibular system causes us to "see" what we feel, and momentarily prevents our vision from correcting the false sensation.

You are taking a winch or autotow launch. As you transition to climb, there's a surge of acceleration as well as a dramatic increase in nose-up pitch. The acceleration greatly magnifies the sensation of nose-up pitch change, and if you fly by the seat of your pants you will level off prematurely. The antidote is to discipline yourself to look out at the wing angle and at the airspeed indicator instead of what feels right.

This illusion is a special danger to airplane pilots taking off into IFR or night skies. Many accidents have involved such an airplane flying through the fog or the night into the ground, just a few miles from the airport. Acceleration during the ten seconds after takeoff from 100 to 130 knots creates only a 1.01 G gravitoinertial force, but gives the unsuspecting pilot the sense of a

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nine-degree nose-up pitch attitude. As single-engine aircraft typically climb at about 6 degrees, a seat of the pants correction yields a three degree descent, exactly a normal instrument final-approach slope.

You can imagine the special danger in taking off at night or in fog from an aircraft carrier, with the dramatic, 3 to 5 G acceleration of a catapult, and the false sensation of nose-high pitch can last for 30 seconds or more after the acceleration slows.

This illusion can also lead to a form of graveyard spiral. If the pilot maintains a sensation of constant G force while failing to perceive a slow roll, the only way to maintain the proper G force is with a descending turn. In 1978, a Boeing 747 left Bombay at night, taking off over the dark sea under high overcase. The flight data recorders indicated that the pilot, flying at night by the seat of his pants instead of his instruments (which he misperceived to be malfunctioning), maintained a constant G force of 1.0 +/- 0.1, as if he were in a 10-12 degree climb; he actually leveled off as an unperceived turn began and then descended in a spiral, crashing almost inverted.

9. Gravity and Gliding Accidents

Inversion illusion ("Sub-Gravity"). In its extreme form, from which this illusion has received its textbook name, the pilot feels the aircraft has pitched upward and over on its back. The classic situation happens when a jet fighter abruptly levels from a steep climb and accelerates, especially in turbulence. The vestibular system sends the message, "Hey, you're tumbling over on your back!" and the pilot instinctively puts the stick full forward. This doesn't make the illusion any weaker! And the result may be a vertical dive into the ground, which is always down there somewhere.

This is a dangerous illusion for glider pilots, for whom it evolves differently than in this textbook depiction. The illusion for glider pilots is of a dramatic nose-up pitch change (rather than actual inversion), which occurs because of a sudden nose-down transition and acceleration, producing less than 1 G on the pilot's body, a forward rotation, and some degree of forward acceleration. Forward acceleration is not essential to the illusion, but magnifies it greatly. Thus, both the semicircular canals and the otolith organ participate in the illusion, which can be very powerful and has killed quite a few pilots.

Derek Piggott has thoroughly analyzed this illusion in his monograph, *Sub-Gravity Sensations and Gliding Accidents* (1994, published by the author). He does not explain the physiologic operation of the vestibular system in this phenomenon (it is complex), but he describes the situations well in which it arises, and shows exactly what pilots do in response to these situations. He has observed that this illusion is more likely to occur in low-G situations.

Piggott also shows vividly that fright or panic may completely mask corrective sensory information, "locking" the pilot into this illusion.

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And he does us a service in observing that the susceptibility of pilots to this illusion, and the degree of panic they experience, differ greatly between individuals. He suggests an approach to training that identifies susceptible individuals and prepares them to responds to the illusion.

The situations in which this illusion occurs in gliders are less dramatic than in fighters but not less dangerous. First, consider those situations in which you the pilot might make an abrupt nose-down pitch change; in all such situations the glider will either accelerate or stop slowing (which are equivalent to our otolith organ).

- Recovery from a cable break during a steep winch or autotow launch.
- Abrupt recovery from a stall.
- Abrupt nose-down pitch in turbulence and wind shear.
- Pilot-induced strong pitch oscillations.
- Any time the stick is abruptly put well forward.

G-excess effect. This illusion's physiologic origin is complicated, but a simple explanation will give you the idea. If you tilt your head while sitting in a chair on the ground, your vestibular organs correctly estimate the degree of tilt. However, if you are sitting in a seat in an aircraft that is banked or swooping and tilt your head, the excess G force magnifies the amount of sensed tilt. In a 45-degree bank, our usual attitude, the 1.5 G introduces a 5 to 10 degree error in perceived bank when we tilt our head to look outside to check traffic or terrain. The bank seems to level when we look to the inside of the turn. If we react instinctively to this, as skilled and experience pilots tend to do, the yaw string will be adrift when we look back. Not a problem unless slow speed or turbulence puts you at the edge of stall, at which point an incipient spin could develop. Perhaps you looked out because you're in a gaggle. You see where I'm leading. Has this sort of thing cause fright or mid-air collisions? I don't know. It clearly has caused accidents in attack aircraft when the pilot looked outside at the opponent during a 5-G tight turn.

The elevator illusion. Because the utricle is not exactly horizontal, vertical acceleration causes a sensation of tilting. To go up in an elevator causes a sensation of both climbing and tipping backward; to go down in an elevator causes a sensation of descending and tipping forward.

So when you fly into a strong thermal, the aerodynamic pitch-up that occurs is magnified falsely by the elevator illusion; and when you fly into strong sink, the nose-down pitch change feels greater than it actually is.

And if you level off abruptly during a descent, there is an immediate, erroneous feeling that you raised the nose too much. In fact, if pilots close their eyes immediately after leveling off, they resume a descent at about 2/3 of their previous descent rate.

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The Leans. Everyone who has ever flown in actual instrument conditions has experienced the leans — the persistent sense that the aircraft is turning when the instruments say it is not. As you know, this sense can be powerful and persistent. And the leans are not due to any single vestibular or visual illusion, but can be caused by many different stimuli. They contribute to erratic and uncoordinated flying, and for glider pilots are a factor chiefly in cloud flying.

10. Spatial Disorientation

It is very important that you understand that "spatial disorientation" does *not* mean "totally discombobulated." It means that you have misinterpreted the glider's attitude, speed, or position with respect to other ships or the ground, *however slightly*. This is why I prefer to speak of "spatial misinterpretation."

It's useful for us to acknowledge that spatial disorientation may affect ourselves in three ways:

I – unrecognized. Of course, at first it is unrecognized. That's what "dis-" is all about. But fortunately you have flight instruments and eyes, and a multitude of sensory inputs. So pretty soon you realize that maybe your sensations aren't accurately representing the real world.

But knowing "something" is wrong is far different from correctly analyzing *what* is wrong and acting accurately and confidently and expeditiously based on this analysis while your body is shouting "NO!"

II – recognized. You have both recognized that something is amiss and have correctly analyzed what the error is. Now we hope that you have the training and skill — and altitude — to recover.

III – incapacitating. Each of us must acknowledge that disorientation may truly be incapacitating. In its most severe form nystagmus develops, and the pilot's eyes are unable to focus or fixate on the visual cues that will permit reorientation. Panic or fear may cloud reason, delaying recognition or hindering analysis. Or we may fly into bad visual conditions in which re-orientation is difficult or impossible. In the end,
incapacitation only lasts until we strike the ground...

Dynamics of Disorientation

Visual dominance and Vestibular suppression. Normally visual cues dominate our interpretation of our orientation in space, and vestibular cures are relatively suppressed. Disorientation occurs when visual cues are reduced, vague, or ambiguous; or when, due to unusual aircraft movements, vestibular sensations become obtrusively strong. It's important for us each to acknowledge within our selves that our bodies, functioning normally, can produce subtle or powerful false sensations that seem right and valid. These illusions can best be recognized by understanding what they are and looking for them.

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Opportunism refers to the tendency of either the visual or vestibular system to "opportunistically" — reflexively, without conscious decision — fill a void in the welter of information that maintains spatial orientation. This is a powerful that operates without regard to whether the opportunism provides a more correct sensation than the absent information.

Motion Sickness

Motion sickness is a different sort of malfunction of the vestibular system than the illusions we've discussed. This can occur from turning movements, such as thermaling or riding a merry-go-round. The strongest, most persistent motion sickness comes from sub-gravity sensations such as weightlessness.

The important lesson for soaring pilots is to admit to ourselves that motion sickness degrades our flying skills and judgment, and to respond to it by getting out of the sky.

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UNITED

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Working in a Hot Environment

How the Body Handles Heat

As outdoor temperatures sizzle, it's important to remember that exposure to extreme heat can make some employees ill. Heat-related illness occurs when the body's temperature control system is overloaded or when heat is generated or gained by an individual faster than the body can dissipate it. Below is a chart you may share with your employees, describing some heat-related illnesses including dehydration, heat cramps, heat exhaustion and heat stroke.

What Is It?	Symptoms May Include ...	What to Do
Dehydration A decrease in fluid level hinders the body's ability to function.	❖ Thirst, anxiety, weakness; ❖ Decrease in urine output; ❖ Dry, pale skin that doesn't have its normal elasticity; ❖ Increase in heart rate and breathing; ❖ Decrease in blood pressure; ❖ Confusion and even fainting.	❖ Drink plenty of fluids throughout the day — even before you're thirsty.
Heat Cramps Muscular pain and spasms caused by loss of water and salt through sweating. Heat cramps are often the first signal that the body is having trouble coping with the heat.	❖ Painful muscle spasms, usually occurring in the legs and abdomen after vigorous exercise and profuse perspiration.	❖ Sit quietly in a cool place. ❖ Drink fluids. ❖ Avoid strenuous activity for a few hours. ❖ Seek medical attention if cramps do not subside, or if you have a heart condition.
Heat Exhaustion Occurs when body fluids are lost due to excessive sweating, and fluid loss causes a decrease in blood flow to the vital organs.	❖ Heat cramps; ❖ Weakness, dizziness, fatigue, nausea, giddiness, headache; ❖ Victim may vomit or faint; ❖ Damp, cold, clammy skin; ❖ Pale or flushed complexion; ❖ Heavy sweating; ❖ Body temperature may be normal or slightly elevated.	❖ Let victim relax in a cool place. ❖ Victim should drink cool (not cold) fluids. (Do not give fluids to an unconscious or partially conscious victim — they may choke.) ❖ Lay victim down and elevate legs slightly. ❖ **Seek medical attention.**
Heat Stroke Occurs when the body's temperature regulatory system fails. Body temperature rises so high that brain damage and death may result unless the body is cooled quickly. **The condition is life threatening.**	❖ Hot, dry, red, or spotted skin; ❖ Headache; ❖ Rapid, shallow breathing; ❖ Rapid, weak pulse; ❖ High temperature; ❖ Mental confusion, delirium, loss of consciousness (or semi-consciousness); ❖ Victim may experience convulsions.	❖ Move victim to a cool area. ❖ Cool victim rapidly — place in a cool shower; mist with cool water from a garden hose; sponge with cool water; or apply cool wet cloths/towels. ❖ If victim is conscious, give small amounts of water or ice chips. *Small amounts are key due to danger of vomiting.* ❖ Loosen his/her clothing. ❖ Fan the body to increase cooling. ❖ **Seek medical attention immediately.**

Don't Fly With a Cold

How to avoid ear and sinus blocks

Dr. Al Parmet, Sr. AME

The headline says it all. It's really very simple. Don't fly with a cold. Every pilot should learn this, most of us know it, but many have broken this dictum at least once. You have a little cold, but it's a great day to fly or you have to be somewhere, so off you go. Bubbles squeak in your ears and nose, so you equalize the pressure during the climb to altitude. You feel pretty good at altitude, but when it's time to descend — uh oh, you've got a problem. Your head feels like it's in a vise, and descending increases the pressure.

Why does this happen? A human head has holes in it. These holes include the eight major sinuses, which are paired in either cheek, the forehead, between the eyes, and a deeper pair far behind the eyes. Each cavity holds anywhere from a milliliter to four or five tablespoons of air.

Inside our heads, each of our sinus cavities "communicates" with — has an opening to — the nose. This opening, however, is quite small and may be only one millimeter across. Under normal circumstances, this opening is large enough to let air travel freely between its sinus and the lining of the nose. As we gain altitude, the air pressure around us drops so, relatively speaking, the pressure inside our sinuses is higher than outside. The sinuses don't expand like a balloon because air flows through the communicating channel to the nose, thus equalizing the pressure. The reverse happens on descent.

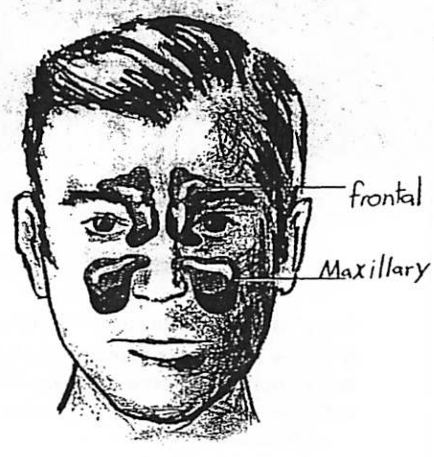
But if we have a cold or other upper respiratory infection, the mucous membranes that line the inside of all our airways, swell and become inflamed. When this happens, the tiny communicating channels can easily become blocked. Then, pressure in the sinuses may be great enough to force air out through a narrowed channel, taking bubbling bits of mucous with it. That causes the squeaking sound we hear as the pressure equalizes.

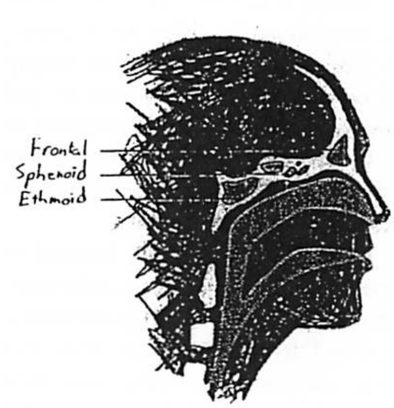
This swelling and inflammation acts like a flapper valve. It lets air out, but it doesn't let air back in. That's why we find ourselves in trouble when we want to come down. Our communicating channels are blocked and simply won't allow air to pass back into the sinus and equalize the pressure.

This is extremely distracting, and a pilot might not be able to fly his aircraft.

We humans also have an air space where the eardrum separates the outer ear canal from the middle ear. The ear drum is a membrane only one centimeter across, composed of only three layers of cells. It is so thin, I can see through it when I examine a pilot's ear.

For the eardrum to vibrate properly, air pressure on both sides has to be equal. The Eustachian tube connects the middle ear to the back of our throat. Like the sinus communicating channels,





A human head has eight major sinuses, which are paired in either cheek, the forehead, between the eyes, and a deeper pair far behind the eyes.

When the pressure outside your head is greater than the pressure in it, you feels like somebody has run a hot knife into your cheek. The pain can be excruciating, and I know of several accidents that have happened because of this. The pressure differential — increasing ambient pressure causing low pressure in the sinuses — can be so great that the sinus lining literally can be ripped right off the bone.

the Eustachian tube is very small. It is normally collapsed and held closed by a small muscle in the back of the throat.

As we gain altitude, air can spontaneously bubble out of the middle ear. The small muscle in the back of the throat acts like a flutter valve. During descent, we must actively bring the muscle into play to hold our Eustachian tubes open, which allows air to pass through them and equalize the pressure in our middle ears. If we can't do this, the outside pressure can push the eardrum inward enough that it might rupture.

In general, if you can't equalize or relieve the pressure in your middle ears, the pressure associated with a 5,000-foot altitude change will rupture the eardrum. That will relieve you of your pain — and your hearing. A ruptured eardrum isn't a catastrophe. In most cases it will heal on its own in two to three weeks.

As with your sinuses, a little respiratory infection can cause enough swelling to shut your Eustachian tubes and prevent you from equalizing your middle ears, possibly trapping you at altitude.

To open your Eustachian tubes under normal circumstances, use the Valsalva maneuver. Pinch your nose shut, close your mouth, and try to exhale gently through your nose. This forces pressure into both ears. You should feel your eardrums pop.

I prefer an alternative method because it is considerably more gentle on the eardrum. It's called the "Frenzel" or "jaw-thrust" technique. You simply move your jaw as far forward as you can. Sometimes you need to swallow as well. This also opens the Eustachian tubes and allows you to equalize the pressure in your middle ear.

Pilots who have chronic seasonal or perennial rhinitis (allergic inflammation of the nose's mucus membranes) may be fully certified by the FAA once their symptoms are safely controlled. This requires a pilot to tell the FAA and his aviation medical examiner what the condition is and what treatment is being used to control it. If he (or she) has no serious side effects or sedation, the FAA will probably issue the pilot a waiver.

All pilots should know how to clear their ears properly in flight. However, if you have a cold, it may be impossible. I often carry a bottle of nasal spray decongestant as a "get-me-down" safety measure for passengers to use.

For people with chronic allergies or infections, the inflammation of the nose and airway may be enough to cause a great deal of difficulty, even during the most routine flying. You can prepare your passengers by having them take a nasal decongestant, either a spray or an oral drug. When you are piloting an aircraft, you should never use these remedies. Using a decongestant that contains antihistamines can be a deadly combination with hypoxia from altitude because the resulting fatigue will reduce your ability to make good, safe decisions.

If you need to take a cold medicine to prepare your nose to fly, your head should know better. It's a good day to drive instead. Don't fly with a cold.

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rest, etc., this system should *not* be used above 30,000 feet. In view of the practical experience in military aviation, an altitude ceiling of 25,000 feet has been established for this type of equipment, which I totally support.

The diluter demand *pressure breathing* oxygen regulator operates to 30,000 feet by supplying the exact amount of oxygen needed to supplement the ambient air. At 30,000 feet, 100 per cent oxygen is delivered. Beyond 30,000 feet, inboard mask leakage is eliminated by the addition of oxygen at approximately 4 cm H_2O pressure. With the specially designed mask, this provides a tight seal with minimum leakage. At 40,000 feet, additional pressure is added in excess of the ambient pressure. Via a series of physiologic principles, this positive pressure breathing maintains normal alveolar partial pressures of oxygen to approximately 45,000 feet.

Pressure breathing is the reverse of our normal ventilation cycle. Normally, we actively inhale and passively exhale. With pressure breathing, inhalation is passive and under pressure while exhalation is active and also under pressure. It is very tiring. The best technique is to keep some positive (outward) pressure on during inspiration (slows rate of inspiration), pause, then slowly exhale. This pattern of smooth rhythmic breathing should prevent one from hyperventilatin when pressure breathing.

The above are theoretical and practical applications of the commonly used commercially available oxygen systems. It is important to note that *any* system may fail and therefore a back-up system must be immediately available. At this juncture, it is reasonable to mention time of useful consciousness (TUC), or effective performance time (EPT). (See Table II.) These values give you some idea how rapidly things occur at high altitude and how little time you have to correct any malfunction.

Hyperventilation

Hyperventilation is an abnormal increase in the *rate* of ventilation. As a result of the increased rate, carbon dioxide is blown off which in turn makes the blood more alkaline (increased pH). The alkalosis in turn has a number of effects including neuro-muscular irritability leading to muscle spasms; numbness and tingling, particularly around the mouth and hands; decreased blood flow to the brain leading to dizziness and lightheadedness; and unconsciousness.

Pilots are most likely to hyperventilate while flying under stress or at high altitude. Since there is an overlap of symptoms between hypoxia and hyperventilation, it may be difficult to tell which is occurring. I recommend switching immediately to 100 per cent oxygen and at the same time consciously slow your respiratory rate to 12 to 16 times per minute (*do not hold your breath*); with the former, you have treated hypoxia unless above 30,000 feet and with the latter you have treated hyperventilation. As soon as you feel better, switch your oxygen back to its appropriate setting. If your symptoms recur, it was hypoxia; if not, hyperventilation.

Summary

Remember hypoxia is insidious at its onset. Be prepared. Keep equipment up to date and in good repair.

Check list: DEATH PRICE

Drugs	Pressure - (1800-2000 PSI)
Exhaustion	Regulator
Alcohol	Indicator - blinker
Tobacco	Connection - mask, radio
Hypoglycemia	Emergency - bailout

I strongly recommend that *all pilots and crew* take the FAA physiologic training.

Table I

Altitude	Barometric Pressure mm Hg	Total Inspired Oxygen Requirement (per cent)
Sea Level	760	21
5,000 ft.	632	25
10,000	532	31
15,000	429	40
20,000	329	49
25,000	282	62
30,000	225	81
34,000	187	100

Table II

Altitude (feet)	Time of Useful Consciousness
18,000 ft.	20-30 minutes
22,000	10 minutes
25,000	3-5 minutes
28,000	2.5-3 minutes
30,000	1-2 minutes
35,000	30-60 seconds
40,000	15-20 seconds
42,000	9-12 seconds

Altitude Decompression Sickness: Tiny Bubbles, Big Troubles

Most of us who fly unpressurized aircraft at altitudes of 18,000 feet and above don't have a full understanding of the significant medical risks involved and or precautionary measures we should take. The following lecture was presented by two researchers at the FAA Civil Aeromedical Institute (CAMI) and was transcribed by AVweb medical consultant Brent Blue, MD, AME, is "must" reading for anyone who flies at the flight levels.

by J.R. Brown and Melchor J. Antunano, M.D. — FAA Civil Aeromedical Institute

Decompression sickness (DCS) describes a condition characterized by a variety of symptoms resulting from exposure to low barometric pressures that cause inert gases (mainly nitrogen), normally dissolved in body fluids and tissues, to come out of physical solution and form bubbles. DCS can occur during exposure to altitude (altitude DCS) or during ascent from depth (mining or diving). The first documented cases of DCS (Caisson Disease) were reported in 1841 by a mining engineer who observed the occurrences of pain and muscle cramps among coal miners exposed to air-pressurized mine shafts designed to keep water out. The first description of a case resulting from diving activities while wearing a pressurized hard hat was reported in 1869.

Altitude-induced decompression sickness

Altitude DCS became a commonly observed problem associated with high-altitude balloon and aircraft flight in the 1930s. IN present –day aviation, technology allows civilian aircraft (commercial and private) to fly higher and faster than ever before. Though modern aircraft are safer and more reliable, occupants are still subject to the stresses of high altitude flight—and the unique problems that go wit these lofty heights. A century and one-half after the first DCS case was described, our understanding of DCS has improved, and a body of knowledge has accumulated; however, this problem is far from being solved. Altitude DCS still represents a risk to the occupants of modern aircraft.

Tiny bubbles

According to Henry's Law, when the pressure of a gas over a liquid is decreased, the amount of gas dissolved in that liquid will also decrease. One of the best practical demonstrations of this law is offered by opening a soft drink. When the cap is removed from the bottle, gas is heard escaping, and bubbles can be seen forming in the soda. This is carbon dioxide gas coming out of solution as a result of sudden exposure to lower barometric pressure. Similarly, nitrogen Is an inert gas normally stored throughout the human body (tissues and fluids) in a physical solution. When the body is expose to decrease barometric pressures (as in flying an unpressurized aircraft to altitude or during a rapid decompression), the nitrogen dissolved in the body comes out solution. If the nitrogen is forced to leave the solution too rapidly, bubbles form in different areas of the body, causing a variety of signs and symptoms. The commonly symptom is joint pain, which is known as "the bends."

Trouble sites

Although bubbles can form anywhere in the body, the most frequently targeted anatomic locations are the shoulders, elbows, knees, and ankles. Table 1 list the different DCS types with their corresponding bubble formation sites and their most common symptoms. "The Bends" (joint pain) account for about 60 to 70% of all altitude DCS cases with the shoulder being the most common site. Neurologic manifestations are present in about 10 to 15% of all DCS cases with headache and visual disturbance being the mot common symptoms. "The chokes" are very infrequent and occur in less than 2% of all DCS cases. Skin manifestation are present in about 10 to 15 % of all DCS cases.

Medical treatment

Mild cases of "the bends" and skin bends (excluding mottled or marbled skin appearance) may disappear during descent from high altitude, but still require medical evaluation. If the sign and symptoms persist during descent or reappear at ground level, it is necessary to provide hyperbaric oxygen treatment immediately (100% oxygen delivered in a high pressure chamber). Neurological DCS, "the chokes," and skin bends with mottled or marbled skin lesion (see table 1) should always be treated with hyperbaric oxygenation. These conditions are very serious and potentially fatal if untreated.

Facts about breathing 100% oxygen

One of the most significant breakthroughs in altitude DCS research was the discovery that breathing 100% oxygen before exposure to low barometric pressure (oxygen pre-breathing), decreases the risk of developing altitude DCS. Oxygen pre-breathing promotes the elimination (washout) of nitrogen from body tissue. Pre-breathing 100% oxygen for 30 minute prior to initiating ascent to altitude reduces the risk of altitude DCS for short exposures (10-30 minutes only) to altitudes between 18,000 and 43,000 feet. However, oxygen pre-breathing has to be continued, without interruption, with in-flight 100% oxygen breathing to provide effective protecting against altitude DCS.

Furthermore, it is very important to understand that breathing 100% oxygen only during flight (ascent, en route, descent) does not decrease the risk of altitude DCS, and should not be used in lieu of oxygen pre-breathing. Although 100% oxygen pre-breathing is an affective method to provide individual protection against altitude DCS, it is not a logistically simple nor an inexpensive approach for the protection of civil aviation flyers (commercial or private). Therefore, at the present time it is only used by military flight crews and astronauts for their protection during high altitude and space operations.

Table 1 — Types of Decompression Sickness

- Bends
  - » Bubble Location: mostly large joints of the body (elbows, shoulders, hip, wrist, knees, ankles)
  - » Signs & Symptoms: localized deep pain, ranging from mild (a "niggle") to excruciating. Sometimes a dull ache, but rarely a sharp pain; active and passive motion of the join aggravates the pain; pain can occur at altitude, during the descent, or many hours later.
- Neurologic
  - » Bubble Location: brain
  - » Signs & Symptoms: confusion or memory loss; headache; spots in visual field (scotoma), tunnel vision, double vision(diplopia), or blurry vision; Unexplained extreme fatigue or behavior changes; seizures dizziness, vertigo, nausea, vomiting, and unconscious may occur.
  - » Bubble Location: spinal cord
  - » Signs & Symptoms: abnormal sensations such as burning, stinging, and tingling around the lower chest and back; symptoms may spread from the feet up and may be accompanied by ascending weakness or paralysis; girdling abdominal or chest pain.
  - » Bubble Location: peripheral nerves
  - » Signs & Symptoms: urinary and rectal incontinence, abnormal sensations, such as numbness, burning , stinging, and tingling (paresthesia); muscle weakness or twitching.
- Chokes
  - » Bubble Location: lungs
  - » Signs & Symptoms: burning deep chest pain (under the sternum); pain is aggravated by breathing; shortness of breath (dyspnea); dry constant cough.
- Skin bends
  - » Bubble Location: skin
  - » Signs & Symptoms: itching usually around the ears, face, neck , arms, and upper torso; sensation of tiny insects crawling over the skin (formication); mottled or marbles skin usually around the shoulders, upper chest and abdomen, accompanied by itching; swelling of the skin, accompanied by tiny scar-like skin depressions (pitting edema).

Predisposing factors

- **Altitude**

  There is no specific altitude that can be considered an absolute altitude exposure threshold below which it can be assured that no one will develop attitude DCS. However, there is very little evidence of altitude DCS occurring among healthy individuals at altitudes below 18,000 feet who have not been SCUBA (Self Contained Underwater Breathing Apparatus) diving. individual exposures to altitude between 18,000 and 25,000 have show a low occurrence of altitude DCS. Most cases of altitude DCS occur among individuals exposed to altitudes of 25,000 feet or higher. A U.S. Air Force study of altitude DCS cases reported that only 13% occurred below 25,000 feet.

  The higher the altitude of exposure, the greater the risk of developing altitude DCS. It is important to clarify that although exposure to incremental altitude about 18,00 feet show a incremental risk of altitude DCS, they do n show a direct relationship with the severity of the various types of DCS (see table 1).

- **Repetitive Exposures**
  Repetitive exposure to altitudes above 18000 feet within a short period of time (a few hours) also increase the risk of developing altitude DCS.
- **Rate of Ascent**
  The faster the rate of ascent to altitude, the greater the risk of developing altitude DCS. An individual exposed to a rapid decompression (high rate of ascent) about 18,000 feet has a grater risk of altitude DCS than being exposed to the same altitude but as a lower rate of ascent.
- **Time at Altitude**
  The longer the duration of the expose to altitudes of 18,000 feet and above, the greater the risk of altitude DCS.
- **Age**
  There are some reports indicating a higher risk of altitude DCS with increase age.
- **Previous Injury**
  There is some indication that recent join of limb injuries may predispose individuals to developing "the bends".
- **Ambient Temperature**
  There is some evidence suggesting that individual exposure to very cold ambient temperatures any increase the risk of altitude DCS.
- **Body Type**
  Typically, a person who has a high body fat contest is at greater risk of altitude DCS. Due to poor blood supply, nitrogen is stored in greater amounts in fat tissues. Although fat represents only 15% of an adult normal body, it stores over half of the total amount of nitrogen (about 1 liter) normally dissolved in the body.
- **Exercise**
  When a person is physically active while flying at altitude above 18,000 feet, there is grater risk of altitude DCS.
- **Alcohol Consumption**
  The after-effects of alcohol consumption increase the susceptibility to DCS.
- **SCUBA Diving Before Flying**
  SCUBA diving requires breathing air under high pressure. Under these conditions, there is a significant increase in the amount of nitrogen dissolved in the body (body nitrogen saturation). The deeper the SCUBA dive, the greater the rate of body nitrogen saturation. Furthermore, SCUBA diving in high elevations (mountain lakes), at any given depth, results in greater body nitrogen saturation when compared to SCUBA diving at sea level at the same depth. Following SCUBA diving, if not enough time is allowed to eliminate the excess nitrogen stored in the body, altitude DCS can occur during exposure to altitudes as low as 5,000 feet or less.

What to do when altitude DCS occurs

- Put on your oxygen mask immediately and switch the regulator to 100% oxygen.
- Begin an emergency descent and land as soon as possible. Even if the symptoms disappear during descent, you should still land and seek medical evaluation while continuing to breath oxygen.
- If one of your symptoms is join pain, keep the affected area still; don not try to work pain out by moving the joint around.
- Upon landing, seek medical assistance from an FAA medical officer, aviation medical examiner (AME), military flight surgeon, or a hyperbaric medicine specialist. be aware that a physician not specialized in aviation or hyperbaric medicine may not be family with this type of medical problem. Therefore, be your own advocate.
- Definitive medical treatment may involve the use of a hyperbaric chamber operated by specially trained personnel.
- Delayed signs and symptoms of altitude DCS can occur after return to ground level whether or not they were present during flight.

Things to Remember

- Altitude DCS is a potential risk every time you fly in an unpressurized aircraft above 18,000 feet (or at lower altitudes if you SCUBA dive prior to flight).
- Be familiar with the signs and symptoms of altitude DCS (See Table 1) and monitor all aircraft occupant, including yourself, any time you fly an unpressurized aircraft above 18,000 feet.
- Avoid unnecessary strenuous physical activity prior to flying an unpressurized aircraft above 18,000 feet and for 24 hours after the fight.
- Even if you are flying a pressurized aircraft, altitude DCS can occur as a result of sudden loss of cabin pressure (in-flight raid decompression).
- Following exposure to an in-flight rapid decompression, do not fly for at least 24 hours. In the meantime, remain vigilant for the possible onset of delayed symptoms or signs of altitude

DCS. If you present delayed symptoms or signs of altitude DCS, seek medical attention immediately.

- Keep in mind that breathing 100% oxygen during flight without oxygen pre-breathing prior to take off, does not prevent the occurrence of altitude DCS.
- Do not ignore any symptom of sign that go away during the descent. In fact, this could confirm that you are actually suffering altitude DCS. You should be medically evaluated as soon as possible.
- If there is any indication that you may have experience altitude DCS, do not fly again until you are cleared to do so by an FAA medical officer, AME, military flight surgeon, or a hyperbaric medicine specialist.
- Allow at least 24 hours to elapse between SCUBA diving and flying.
- Be prepared for a future emergency by familiarizing yourself with the availability of hyperbaric chamber in your area of operations. However, keep in mind that not all of the available hyperbaric treatment facility have personnel qualified to handle altitude DCS emergencies. To obtain information on locations of hyperbaric treatment facilities capable of handling altitude DCS emergencies, call the Diver's Alert Network at 919-684-8111.

If you are interested in learning more about altitude DCS, as well as the other stressors that may affect your performance and/or you health during flight, we encourage you to enroll in the physiologic training course offered by the Aeromedical Education Division (Airman Education Programs) at the FAA Civil Aeromedical Institute in Oklahoma City. A similar course is also available to you at the U.S. military physiologic training facilities around the country through an FAA/DOD training agreement.

For more information about any of these courses, call us at 405-954-4837.

REHYDRATION

How to Stay Moist or Prunelike Pilots Soar Sloppily

by Dan Johnson

The second in an occasional series of articles on medical factors for soaring pilots.

Some beverages are useful for rehydration; others are better for recreation. The wise pilot will learn the difference.

Cartoon by Rick Kettler

The last time we met (*Soaring*, November 2001), we learned that thirst is a reliable sign that we are *already* dehydrated and that we can use "time to thirst" as a guide to the rate at which we should rehydrate. In this article we'll take a look at how to hydrate efficiently. Here are the main points:

- Weigh before and after soaring to see if you've hydrated successfully.
- Obligatory hydration, with no heat or exercise stress, is about a cup of water every four hours.
- If you rehydrate with fluids that contain salt, alcohol, or caffeine, you are making pee, not rehydrating.
- You can't rehydrate if you're airsick.
- Hydration doesn't "work" when you're getting cold (and rehydration is very important if you've been cold and are warming up).

Weight

How can we know whether we're dehydrated? Thirst isn't a good guide — it's an idiot light, not a meter. The intensity of thirst is not a clue to degree of dehydration, especially in the unacclimated person sweating heavily, who loses both salt and water. The answer is to measure your weight

The weight you lose at the gliderport is water. Even if you don't eat at all, you'll not lose much solid body weight. The average pilot may burn 100 calories an hour just standing around looking intelligent, and putting a glider together and pushing it to the flight line might possibly double this. You can make this up with one chocolate chip cookie, and if you don't, you've lost 2/3 of an ounce of fat. It takes hours of hard work actually to burn up solid body mass, and what we glider pilots do seldom qualifies as "hard work."

So if you weigh yourself (with an empty bladder) before you step out into the sun and again (with an empty bladder) when you come back in at the end of the day, the difference in weight, in pounds, is equal to your water deficit, in pints, since a pint is a pound the world around. (European pilots are just as lucky, since a liter is a kilogram.)

So I recommend that every glider club or FBO keep an electric digital scale handy, with some paper, and every pilot on arrival should weigh and write the number down (subtract fifty pounds if you're embarrassed). Write it down because you'll forget exactly what it was. Use a digital scale so it's easy to be precise. And then weigh on return, or before leaving, to test the effectiveness of your hydration strategy.

How much to Drink

We are just elaborately leaky sponges, exuding water from every pore. With no heat or exercise stress, on average we lose about 2 ounces an hour, not counting spitting on the ground. This is a pint in eight hours — not really very much. Extra water needs are from sweat — hence the usefulness of the scale — and from eating diuretic substances such as salt, caffeine, chocolate, or alcohol. As a rule of thumb, if you feel thirsty, you're down a quart (a liter if you live outside of America). You may not be able to drink this all at once.

What to Drink

Water. Only water rehydrates. The word is from the Greek, hydro, water, via the Latin, hydra. If you're dehydrated, you need water. But water is boring. In some places it tastes bad. So we put additives into it that make it more interesting.

Flavor. Flavor is fine — it encourages adequate hydration. We encourage this, partly because we know that folks consistently under-hydrate. One study found that bicycle racers overestimated their actual fluid intake ten-fold: they thought they'd drunk a cup when they'd only taken a swallow. But they were distracted; normal folks take in about half their water deficit immediately when they're given access to water in response to thirst, and the other half with their next meal, partly as moist food.

Calories. Sweetened drinks are more interesting, and this gives hydration a boost, too. The only folks that might get into trouble are the poorly controlled diabetics for whom sugar is a diuretic, and merely increases urine flow.

Salt. Salt is seldom necessary. Sometimes it's beneficial, sometimes it hinders hydration. Sport drinks contain salt because athletes working out heavily lose extra salt in their sweat. There are two salt levels in sport drinks: the Gatorade(tm) level of 110 mg of sodium per cup and the Powerade(tm) level of 55 mg per cup. The higher level is appropriate for extreme sweating: football players working out in hot, humid weather, diamond miners, perhaps tow pilots. But glider pilots don't sweat like that — they're sitting in an expensive chaise lounge getting a tan.

Salt levels in sweat drop dramatically as we become acclimated to heat, so even with vigorous exertion the acclimated person loses little salt with sweating. In addition, we Americans eat huge amounts of salt — all processed food contains a lot of it. In my own judgment, the mild levels of exertion we indulge in don't require extra salt. Water, flavored if you like, will do nicely.

Salt can be a nuisance. Extra salt must be excreted, through the kidneys, entraining water as it goes. Extra salt makes extra pee. Extra pee is inconvenient, and to make the extra pee, extra water has to be taken. You have trouble getting enough water already; extra salt puts you that much further behind.

Some beverages are useful for hydration; others are better for recreation. The wise pilot will learn the difference.

Conversely, if you avoid processed food, you'll be on a naturally low-salt diet. You will urinate less, it will be easier to stay hydrated because you won't need to take extra water just to balance the salt in your food, and you will develop salt hunger if you become salt deficient from sweating.

Conclusion? Go ahead and use sport drinks if you like, but the calories and salt are not necessary while soaring. On the ground, including tow operations, it may be different. Use your judgment.

Caffeine. Caffeine is a very useful stimulant, especially if you don't use it regularly. It is an appropriate medication to take, in moderation, and with judgment, when you're tired and need to boost alertness. But it hinders hydration, because caffeine is a diuretic, You can't hydrate effectively with coffee, tea, or cola.

That chocolate bar you brought for quick energy does give you fuel (sugar and fat). But the theobromine in chocolate is caffeine-like — it makes you more alert, but it also is a diuretic, making you more dehydrated than you were, and increasing your need for fluid at a time when you might not be keeping up.

Many colas contain caffeine. A cola may pick you up, but it also lets you down, as it fails to hydrate as well as water or juice.

Alcohol. No one we know would be so stupid as to hydrate before or during flight with beer or any other alcoholic beverage. But many pilots rehydrate with a cold one afterward. This is okay, as long as you understand that not only is each bottle of beer or glass of wine metabolically a buttered slice of bread, but that the alcohol is a diuretic.

Well, you knew that, didn't you? I mean, the last time you spent the evening drinking steadily, you had to pee several times, right? So drink alcohol *after* you've rehydrated adequately, not before. Not only does it hinder rehydration, you get intoxicated much more quickly when you're dehydrated.

A Hindrance to Hydration - Cold

One of our ambitions, as soaring pilots, is to climb. The air cools rather rapidly with altitude, when it comes right down to brass tacks. No glider I've ever seen has a heater, and I do know that I've been pretty cold sometimes up there.

As we chill, our peripheral vessels, veins and arteries, constrict. This lets our limbs cool down to keep the vital core warm. But it also decreases the amount of room within our blood vessels, meaning that suddenly we have too much blood for the space available.

If we've let ourselves get dehydrated, this vascular constriction will nicely compensate for mild dehydration, protecting us from its effects. It's an unexpected bonus, but one that might come back to bite us on the way home.

If we're well hydrated, then this vascular constriction causes our kidneys to get rid of the "extra" fluid — we make a lot of urine. This is called "cold diuresis," and we develop a cockpit waste management situation. This is why, after the cockpit gets cold, you notice pretty soon you have to pee. Hopefully you have a plan for this.

Unfortunately, the fluid that was "extra" on the way up becomes a deficit as we warm up on the way down. Even if you weren't dehydrated before you got cold, you are now. And you're dehydrated even if you've been drinking, for if you hydrate aggressively as you become cold, it will just go straight into your bladder.

So if you've been cold while aloft, you *must* rehydrate as you warm up on the way down, else your G-tolerance and your mental functioning may not be acceptable in the pattern and during landing. I am certain that this re-warming dehydration has been a cause of approach and landing incidents. This will bite even pilots who otherwise have paid diligent attention to hydration, for if you've been cold, your blood volume *has* contracted, and re-warming can occur quite abruptly at lower altitudes on sunny summer days. Drink 8, 12, or 16 ounces as soon as you feel warm.

And this is one time when a salty sport drink might be especially helpful, as salt does help restore lost volume — cold diuresis is not purely a water loss. I haven't yet found any studies to allow exact estimation of salt and water replacement needs after cold diuresis.

A Hindrance to Hydration - Nausea

You won't be able to hydrate if you're airsick.

Okay, it's obvious that drinking doesn't work if we're vomiting. But this goes deeper — you quit absorbing water long before you vomit, while only mildly airsick.

If we experience severe pain — such as that piercing headache that came on when the oxygen wasn't working right, and we didn't discover it until at 15,000' — our gut muscles take time out. Medically, the term is "ileus." I use this jargon just to emphasize that it's so common that we have a name for it. The intestines don't pass fluids downstream like they're supposed to. This hinders hydration, as water then isn't absorbed so well.

Beyond this, if we feel a bit queasy, our stomach quits passing that water on to the small intestine (where it's more rapidly absorbed). We may be able to drink, but the stomach just gets full: hydration failure. If we keep on drinking while we feel airsick, we just increase the likelihood that it will all come back up.

So if you're airsick, remember that you can't hydrate. You have two good reasons to carefully go back and land.

Summary

The most important principles of hydration are:

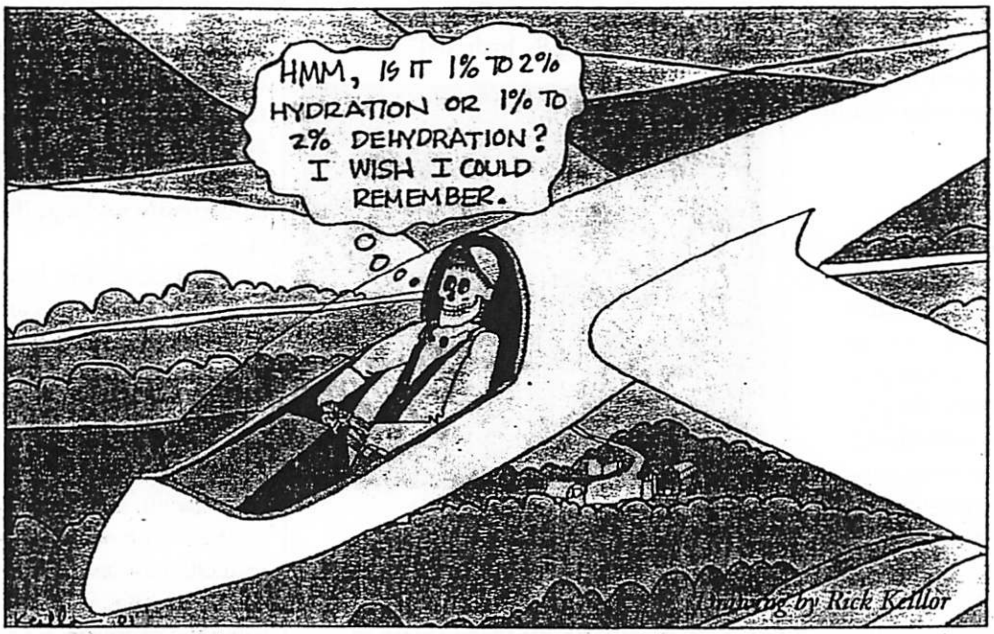
- If you're thirsty, drink a quart.
- Use water preferentially.
- Hydrate on the ground before takeoff to make up for all the work of assembly and staging.
- Hydrate on descent to make up for cold diuresis.

Stay moist, and happy flying!

About the author: Daniel L. Johnson, MD, FACP, Sr. AME

I'm a bald guy, over 50, a physician in western Wisconsin, a specialist in internal medicine, an FAA-designated senior aviation medical examiner, and a commercially-rated glider and instrument airplane pilot with a lifelong interest in aviation and weather. I've been flying since 1985 and soaring since about 1992. Work and other responsibilities held me on the ground until in 1995 I was able to buy a Blanik L-13, and formed a little club around it. We did hundreds of autotow ground launches until 2000, but the club withered and I sold the Blanik to buy a Ventus CM, a big change of emphasis.

Thirst and the



Drawing by Rick Keillor

Drinking Pilot

by Dan Johnson

The author is a physician with an interest in the physiology of flight. This is the first in an occasional series of articles on medical factors that affect soaring pilots.

We all know that dehydration makes good pilots into bad ones, and causes accidents. But along with good ideas, misconceptions about thirst and hydration keep getting spread around, like bad jelly on good toast. "Thirst can't be trusted" tops the list. Like many misconceptions, it's partly true: thirst isn't a "fuel gauge." This is an oversimplification; well intended, but like all oversimplifications it fails to educate, and sometimes misleads, causing bad decisions. This common advice, given to pilots and athletes, assumes that people are dumb animals who need to be fooled into doing what's best. Such people exist — we've all met a few — but they're not the type who would read this article.

Thirst Can Be Trusted

The truth is that thirst can be trusted — but you must know how it works. If you're happy with the idea that thirst can't be trusted, that the only way to avoid dehydration is to keep the pee-bottle full or the nappie wet, simply stop reading here and do something more interesting, like reviewing consumer ratings of adult diaper capacity or skin adhesives for condom catheters. But if you do believe this, please don't run around teaching it. It's like teaching that the best way to avoid stall-spin accidents is not to teach spins. It might "work," but it doesn't make a more proficient pilot.

OK, now that I have you upset, let's talk. In truth, thirst will not keep you ideally hydrated. Thirst is not a fuel gauge; it's a warning light. Thirst begins after we're already mildly dehydrated, it doesn't increase in intensity proportionately with our degree of dehydration, and it's relieved before we've fully rehydrated. But thirst can be trusted because it's consistent and reliable; if you understand how it works (read on) and pay attention to your own thirst, it can teach you how and when to hydrate.

When Does Thirst Begin?

This varies from person to person. Studies of dehydration variously estimate that we are 2% - 3% dehydrated (i.e. we've lost that much of our body weight in water) before thirst begins. But it's not correct to make the obvious connection and assume that the average 170-pound pilot must lose 3.4 pounds of water before feeling thirsty. Last summer, when some of us weighed in and out at the gliderport, it was pretty clear that pilots can learn to detect thirst at 1%. Why is this? Are the researchers wrong?

Here's the key: In the scientific articles there's a lot of talk about percent dehydration, but a lot of silence about just what zero dehydration might be. You might think that your normal, comfortable status is a non-dehydrated situation. Wrong. In fact, it's not all that easy to define what is a "fully hydrated" human.

> *Thirst is a reliable signal that we need to drink a pint to a quart (depending on our size) right now and to increase our rate of fluid intake*

Our bodies are fancy soup, with a specific gravity of 1.010-1.012 (somewhat more dense than water). If the specific gracity of our urine is less than 1.010, we're trying to get rid of extra water — we're over-hydrated. If it's more, we're conserving water and becoming dehydrated. People operate most of the time in water-conservation mode because it's inconvenient to urinate often. On the average, we run happily around, about 1% short of optimal hydration. The worst that happens in this state is a hard stool, not usually something to write to the editor of the local newspaper about.

This means that we can normally tank up with water equal to about 1% of our body weight without causing excessive, inconvenient urination. Since a pint is a pound, one or two pints of water early in the day can give us a head start on avoiding thirst (and dehydration — remember, thirst means we're already dehydrated).

This also means that since thirst begins at 2% dehydration, it begins after a loss of 1% of our usual body weight. We're not conscious of the first 1% that we're always short of, and once we're thirsty we can get back to our mildly parched normal state by drinking water equal to 1% of our body weight.

The delayed onset of thirst is pragmatically useful: If we became thirsty as soon as we needed an ounce of water, we would be continually looking for water, a waste of time. If thirst were exactly proportional to the need, we'd be in agonies of thirst, a distraction, when we don't need to be.

Because thirst begins *after* we are mildly dehydrated, we shouldn't wait until we're thirsty to begin hydrating. The few studies on dehydration and mental performance show that mental acuity and coordination are already decreasing at 1% dehydration, and are consistently and significantly decreased at 2%.

Is this clear? You lose your edge *before* you get thirsty. You can trust this. Thirst is a reliable sign that you are actually impaired, not a casual hint to take a slurp of water to wet your whistle. It's a sign that you should *not* get into an aircraft right now.

In the air, it's a message that large quantities of water should be drunk immediately, and if no water is available in the cockpit, it's time to land and solve the problem. (This is especially true if you're airsick — water is not absorbed when we're nauseated.)

We Can Learn from Thirst

Thirst is analogous to shivering: shivering is a sign that we are *already* hypothermic; to repeat: Thirst is a sign that we are *already* dehydrated. You can trust it: thirst reliably tells you that you have become dehydrated, that you've missed your goal of staying hydrated.

As we noted, thirst appears at about 2% dehydration. The actual level varies from person to person, and sensitivity to thirst decreases substantially in old age. We can train ourselves to suppress this and other body appetites, or to be more sensitive to them; we can discipline ourselves to respond to thirst.

We can also learn from urine color. Diluted urine made by the well-hydrated pilot is pale, white; concentrated urine made by the pilot flirting with

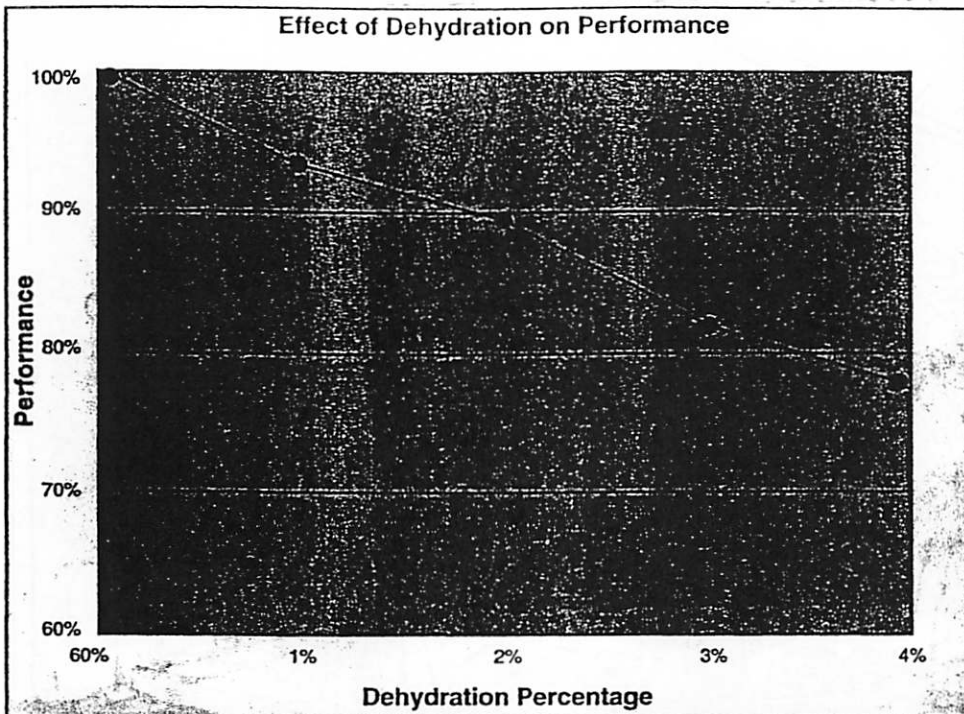


Figure 1. The effect of dehydration on scores achieved on simple mental-function tests such as word recognition, pattern tracing and serial addition.

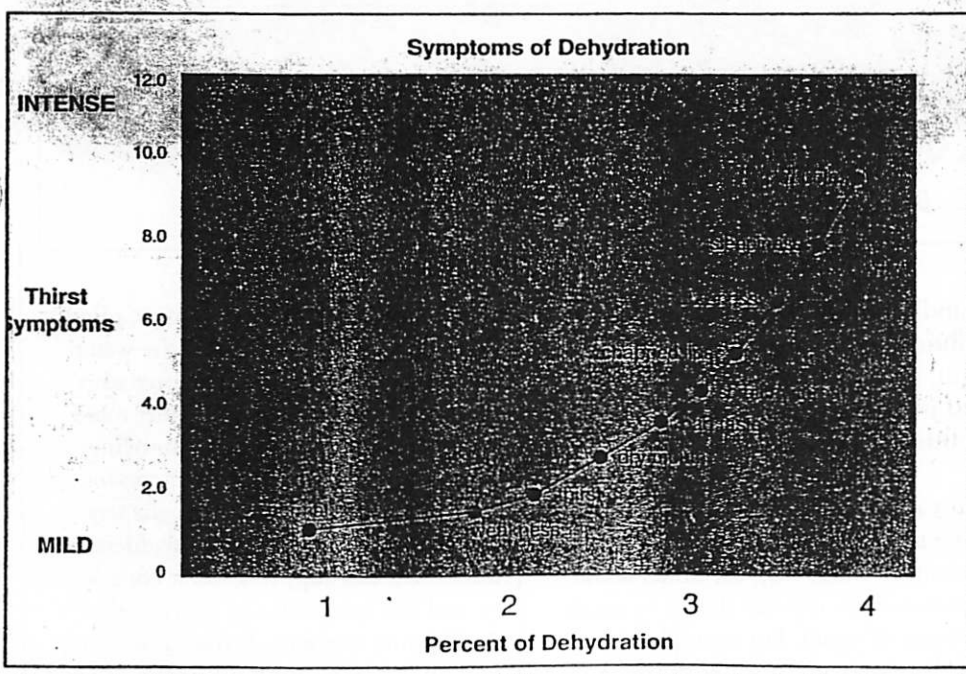


Figure 2 As dehydration increases, symptoms of thirst worsen. Mentation is off peak at 1%, aerobic capacity decreased by 5% at 2% dehydration.

dehydration is golden and sinks to the bottom of the toilet. As you empty your bladder before takeoff, think of this. If your urine is dark, *drink now*, a pint or two.

You can use thirst as a guide to learning how to hydrate. Thirst is a clear sign that your present hydration strategy isn't working and needs to be revised. Let yourself get dehydrated in safe conditions, such as during ground operations, and note the conditions under which your thirst appears: how hard were you working; how appropriate to the temperature was your clothing; what was the air temperature, the wind, the relative humidity; to what extent were you out in the sun? When you become conscious of thirst, ask yourself whether you might have been suppressing this appetite, whether there might have been some earlier inklings of thirst you might have picked up if you'd been paying better attention.

Lost Ability

Dehydration is a problem because physical work capacity and mental sharpness both decrease. At 2%, athletes have lost about 5% of their aerobic capacity — not an issue if your only activity is to gently roll someone else's glider up to the flight line — and coordination and thinking ability are substandard.

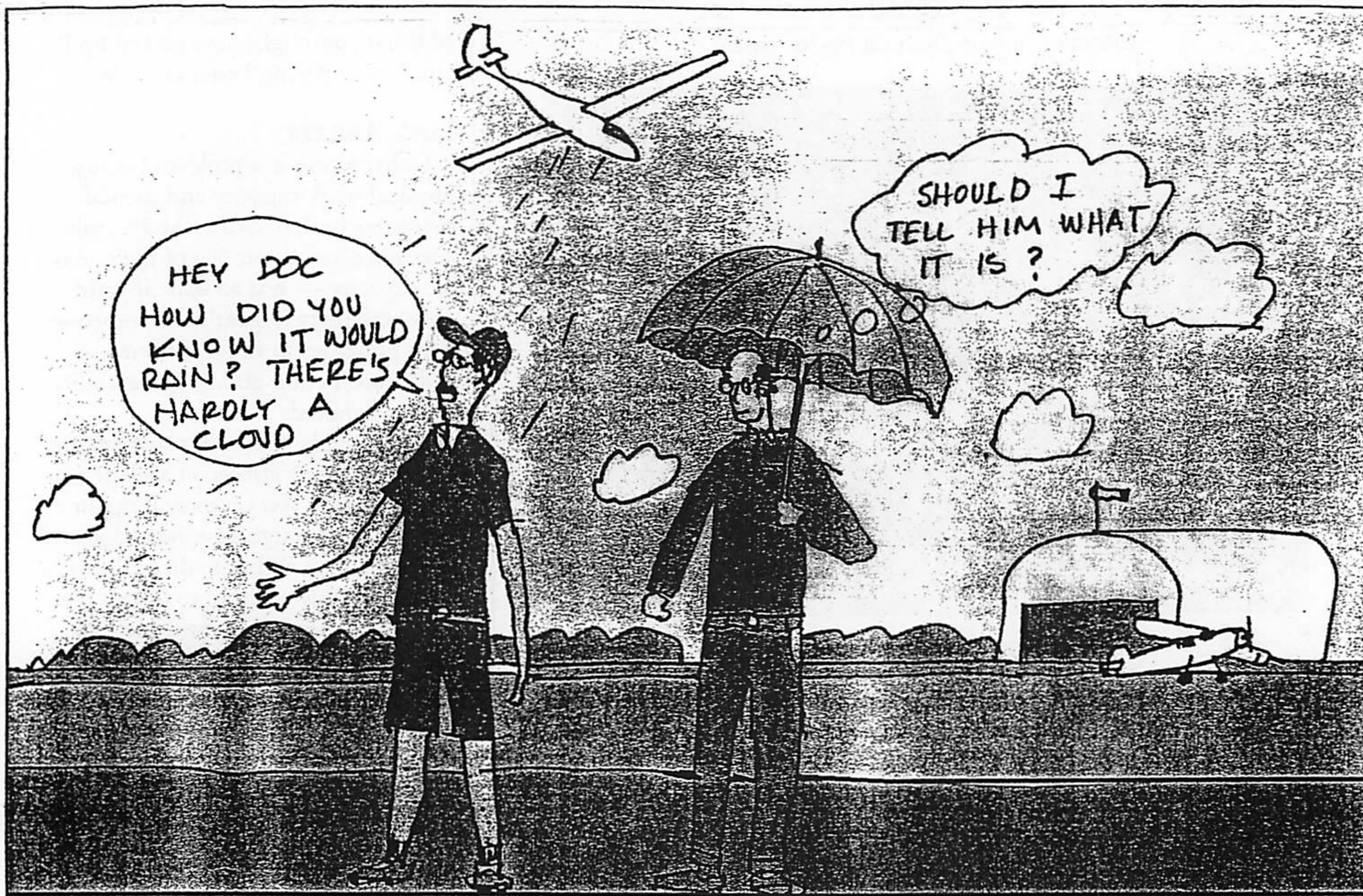
Interestingly, there are many studies of dehydration's effects on athletic performance, but few on mental performance. But enough have been done to know that our ability to do arithmetic, to recall words we hear, to trace a line quickly and accurately on a piece of paper, all are decreased at just 1% dehydration and steadily worsen as the water deficit grows (Figure 1). At 5% - 8%, you can probably keep walking, but you'll have trouble figuring out what direction you're going, and you surely won't be able to thread a needle or calculate a heading.

How Much to Drink?

Thirst should guide your rehydration strategy. If you weigh a hundred pounds, and you sense thirst at 2% dehydration, when you notice you're thirsty you're down a quart *already*. This should lead you to immediately begin rehydrating. Simple mental arithmetic should tell you how much to drink to be fully rehydrated, and how much to drink each hour to maintain hydration.

For example, if it took you two hours assembling gliders in the sun to get thirsty, and you plan to continue working as ground crew today, you need to drink a cup of water every thirty minutes to stay hydrated in these conditions *in addition to* the quart you need to restore yourself, to change yourself from a raisin to a grape. Double these numbers if you weigh 200 pounds, as I do. Yes! a pint every thirty minutes!

Or — more important — if the glider you were assembling and pushing 200 yards to the flight line was your own, you are now about to launch your glider in a dehydrated state. Instead of hooking up, delay



Drawing by Rick Keillor

PILOTS MAY HAVE OVER REACTED TO A REPORT ON THE DANGER OF DEHYDRATION.

your launch and rehydrate. If it's a busy day at the gliderport, the wait for a tow may be 45 minutes anyway; you can spend this time standing in the shade of the upraised wing, avidly drinking.

Estimate Water Needs

Does this give you some clue as to the water you should be carrying? On a hot day (or with vigorous activity even on a cool one) you will lose 300-600 ml (a cup to a quart) of water every hour. You might lose up to twice this much if you've donned heavy clothing for high-altitude flight. You may need to allocate one or two quarts of water just for the ground-operations phase in order to ensure that you don't scare the spectators with an interesting takeoff.

While we're aloft, we usually go up where it's cool or even cold; we don't exert ourselves much while flying, and the rate of sweating abates considerably, perhaps down to the minimum of about 1-2 ounces per hour. You can use this as an indication of the *minimum* amount of fluid you should consume during flight, about an ounce every half hour, with no thermal stress and no sensation of thirst.

We can be fooled

We need to be disciplined about rehydration, as thirst may be, under some circumstances, quickly slaked by small amounts of water. For example, when bicyclists were given water during a race and asked to estimate the volume of water consumed, they over-estimated their water intake *tenfold* — when they drank a scant ounce, they said they had drunk more than a pint. Amazing. But in few studies have people been so dramatically wrong. The lesson is probably that when we're busy, distraction hinders accuracy.

In another study, people were dehydrated by depriving them of water for 24 hours; everyone rehydrated fully within 20 minutes after they were given access to water. In other studies, of athletes, typically about 2/3 of the water deficit was taken promptly after stopping, and the rest with the next meal.

Packing a lot of water is annoying; urinating aloft can be messy; condom catheters fall off, tubes kink, diapers leak, baggies spill, and our bladders can burst. We can suppress thirst consciously, and the symptoms of dehydration don't point to water. A friend of mine said after a week-long bike tour, "I get a little weak after a couple of hours; I don't know why..." His wife interjected briskly, "It's because he doesn't drink!" She was right. Physical weakness is one sign of dehydration. Unfortunately, a late sign of dehydration is impaired judgment — including the idea that it's not *necessary* to drink *yet*.

When our body is working hard to conserve water, urine flow is scant. This may eliminate the need to collect urine during flight. But this is bad judgment. Your brain needs the water, and it is not hard to plan for urine collection.

Thirst Sensations Intensify

Thirst symptoms increase as we get more dehydrated, as illustrated in Figure 2. If you've suppressed thirst until it can't be ignored, you can use the intensity of your thirst as a reliable guide to just how important it is to *not* climb into that tow plane, to get *off* the flight line, to devote earnest and full-time attention to sitting in the shade and rehydrating, or to consuming a large proportion of the water you brought with you on the flight. (You did bring water, didn't you?)

Let me suggest that if you are definitely thirsty during flight, and have less than a pint of water on board, you should seriously consider terminating the flight at the nearest safe landing field that has water. Thirst is a danger signal, an alarm, not a hint.

> *If you are definitely thirsty during flight, and have less than a pint of water on board, you should seriously consider terminating the flight at the nearest safe landing field that has water. Thirst is a danger signal, an alarm, not a hint.*

Weight Reveals Dehydration, not Moral Character

An excellent way to accurately estimate water loss is to weigh yourself. For about 25 bucks you can pick up a simple battery-operated digital electronic scale. (Don't get an analog scale — they're too hard to read precisely.) Keep the scale on a hard level surface out of the sun, near the flight line (so pilots will actually use it).

Weigh yourself before you start the day's activities. Weigh yourself before you launch, to see if you're already dehydrated. Weigh when you begin to feel thirsty, so you know where your own thirst threshold is. And weigh at the end of the day, to gauge your success at keeping hydrated. Always weigh with the same gear, of course: holding that barograph in your hand only after a flight, and not before, will cause a delusion. Keep a log and a pen next to the scale, because we more or less forget exactly what that number was. (If your weight embarrasses you, lie consistently.)

Where Dehydration Occurs

Most of our water losses happen on the ground, before we fly. The folks most in danger from dehydration are the tow pilots, who work continually, in hot cockpits, at low and therefore hot altitudes. Next is the ground crew: the line boy, the SCUM, the pilots assembling.

The main reason pilots get in trouble with dehydration, I believe, is that we take off dehydrated, and then we don't correct the problem well enough. Once we get up in that cool air aloft, sweat losses diminish to a minimum, and we may lose as much moisture in our breath as from sweat.

Dehydration in the Cold

But it's important for pilots to know that in the cold, we will get dehydrated for another reason. When we get cold, the blood vessels in our hands and feet, arms and legs constrict to conserve heat. This makes the blood vessels over-full, and our kidneys, just doing their job, get rid of the extra. So when you get cold, even if you're already dehydrated, you'll lose water and some salt. Perhaps you've noticed that when you get cold, you soon have to pee — this is why. There is no way, my friends, to avoid this cold-induced dehydration except by staying warm. And if it's really cold up there, you're not going to be able to wear enough to stay toasty warm.

This dehydration is not a risk while high aloft. In fact, it tends to compensate for the dehydration that you developed before you launched. If you hydrated aggressively on the ground and early in the flight, you lose much of it when you get cold. Nothing you can do about it — this is how your body works. Set up the pee-collection device and use it.

The risk is what happens when you come back down. You warm up. Your blood vessels dilate again. They dilate tremendously if you come back down to a hot airport, especially if it's humid. But if you've been cold, the water you need to fill these blood vessels is in your nappie, in your bladder, or out the pee tube. It's gone, my friend, and the warmer you get, the worse off you are. The consequence is low blood pressure, low G tolerance, fuzzy thinking or uncoordinated flying, and excitement for the spectators.

The *only* solution is to rehydrate vigorously as you warm up, ***a cup at a time, not a sip at a time***, with the goal of drinking at least a quart and possibly two during the descent.

If you ride the escalator up and down, getting cold, then warm, then cold again, and again warm, it's important to realize that the body's fluid volume contracts anew *each* time you go up, and

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I've noticed that pilots enjoy learning how their machines work and how to maintain them; they learn about weather, memorize regulations and airspace rules, and love stories about flying. But they don't spend much time learning how their bodies function and how to maintain themselves.

There are sound reasons for this. First, a healthy body doesn't need much maintenance — it works well without our having to think about it. Flying an airplane is not a natural action like flirting or picking your nose, so doing it well requires study and training. Second, aircraft are exotic objects whose operation and maintenance demand education. Each comes with a manual. Our body's manufacturer provides no manual. Experts in medicine and physiology have written many "manuals," but rarely for pilots without medical training.

Most accidents — about 80% — are due to pilot malfunctions, not to aircraft malfunctions or to environmental conditions. The soft squishy thing that operates the controls is a lot more complex than the machine it operates. An aircraft is just a prosthetic bird with a removable brain. What the soft squishy part understands about itself and how it maintains itself you need to rehydrate *each* time you descend. (Maybe you should connect a mouth tube to those tanks in the wings...)

When to Stop Rehydrating

Last, you can trust thirst to vanish before you're fully hydrated. When people are given free access to water after dehydrating through physical activity, they reliably drink about two-thirds of what they need, and finish making up the deficit at their next meal. So to rehydrate well, drink until you're satisfied, and then, when your stomach feels comfortable again, drink half again that much.

Enjoy your soaring, and remember that thirst is a reliable idiot light. Use it wisely.

Good pilots have crashes.

No one intends to crash.

Most crashes are from an unexpected malfunction of the pilot, not the aircraft.

Learning how the body works while in an aircraft can help anticipate this, and may prevent your next crash.

have a great deal to do with whether the life insurance policy gets paid off.

When a pilot does something truly hazardous, talk amongst the spectators tends to imply that the pilot was dumb, inadequate, untalented, or poorly trained — different from the rest of us, who have never done anything dumb. Well, maybe we did, once, but it was an accident, an aberration; we've learned better — we're beyond that now. I've never, ever, heard a spectator say, "Wow, that was scary! That's something I might do."

I'm going to write a series of pieces in which I hope to persuade you that you — yes, you, with all your intelligence, experience, good training, sound judgment, and knowledge — might do something that looks really, really, dumb some day. Not only that, there is a very good chance that if you fly enough, you will, without necessarily knowing that it's happening, get into circumstances in which everything will seem perfectly proper and in control but that are very dangerous. You may crash, confidently.

It's going to take more than one column, as there are many different ways in which you can do this to yourself. I think that this stuff is really interesting, and I promise to do my best to show you why. But my goal is to give you clues that you can use to know that your body is trying to tell you that the thin edge of trouble is closer than it seems.

Meanwhile, who am I? I'm a bald guy, over 50, a physician in western Wisconsin, a specialist in internal medicine, an FAA-designated senior aviation medical examiner, and a commercially-rated glider and instrument airplane pilot with a lifelong interest in aviation and weather. I've been flying since 1985 and soaring since about 1992. Work and other responsibilities held me on the ground until in 1995 I was able to buy a Blanik L-13, and formed a little club around it. We did hundreds of autotow ground launches until 2000, but the club withered and I sold the Blanik to buy a Ventus CM, a big change of emphasis.

I'm fascinated by the construction and function of the human body. This has led me to study pilot physiology (fortunately very closely related to human physiology), and to present talks at the last two SSA Conventions on subtle pilot incapacitation, "How to Crash Confidently," which I hope will be a continuing series on how we often become incompetent while being confident nothing is wrong.

Daniel L. Johnson, MD, FACP, Sr. AME