“Building Good Habits for a Better Future”

Aileron-Rudder Mixing Explained

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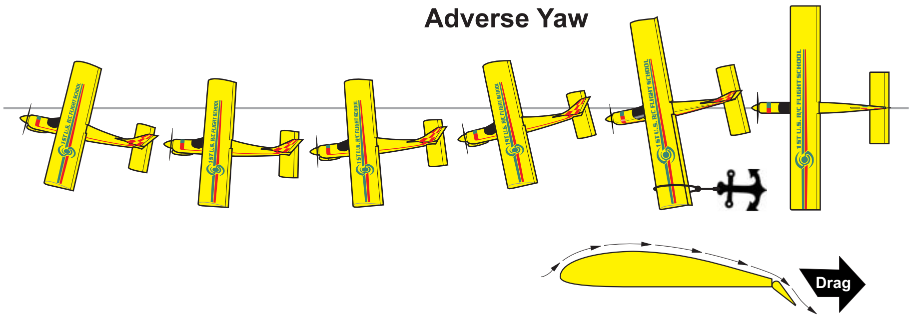
Illustrations by Dave Scott



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Introduction

The following article details the practice of using Aileron-Rudder (A/R) transmitter mixing to eliminate *adverse yaw*, i.e., the inherent opposite yaw or skid that is especially pronounced during aileron deflections on flat-bottomed wing aircraft, such as those used for primary flight training.

As the name implies, adverse yaw is an adverse or unfavorable condition that, among other things, delays achieving solo abilities. Traditionally, struggling and committing to many hours of practice before soloing has been the assumed burden of the student pilot until his or her skills improve. Unknowingly and unnecessarily, novices have been fighting the additional challenge of flying with adverse yaw. Indeed, novice pilots have always assumed that the lack of correlation between their control inputs/intentions and the response of the plane to be strictly the need for more practice, or wind, when in fact adverse yaw has been a big reason!

It’s probably safe to say that most of the people reading this learned to fly at the side of a recreational flyer/instructor with little pre-flight preparation. As a result, most pilots are conditioned to “reacting" to what the airplane does, as opposed to having a plan and pro-actively controlling the plane. Consequently, most pilots naturally think that getting better at making corrections, good reflexes, and more stick-time are the keys to becoming a better flyer. Thus, rarely does adverse yaw or the advantages of A/R mixing when learning to fly ever come up. However, if you where to objectively compare the results achieved training with A/R mixing versus without, you would discover an immediate improvement in consistency and therefore the rate of learning.

1st U.S. R/C Flight School’s mission mandates taking advantage of all the tools available, including the use of A/R mixing, to ensure every primary student can safely solo in all kinds of conditions in less than a week — with the knowledge that they will then use that foundation and confidence to continue learning and advancing on their own. In fact, learning to fly with A/R mixing can be credited for helping to instill proper control habits that actually accelerate future progress.

Adverse Yaw

Space does not permit going into all the aerodynamics involved during aileron deflections, so put simply; adverse yaw is caused by the wing with the down aileron generating more lift and therefore more drag than the wing with the raised aileron. Consequently, the drag differential causes the airplane to yaw/skid in the opposite direction that the ailerons are applied while banking into turns, making course corrections, exiting turns, etc. (see figure 1). Pilots therefore have to hold in the aileron longer to overcome the adverse skid, thus increasing the potential for over-controlling, as well as deal with a lack of consistency caused by the out-of-sync relationship between their control inputs and the response of the plane.

As a rule, adverse yaw is most pronounced on high lift flat-bottom wing aircraft and gets worse at slower airspeeds and/or when making larger aileron inputs -- thus explaining why some people can fly a flat-bottom wing trainer around ok, but then struggle to control the plane during slower speed landings. (Adverse yaw is so severe on a scale Piper Cub for example, that when flown near stall speed it will actually turn left when right aileron is applied and vice-versa.) Also, since the principle effect of wind is exaggerating deviations that would otherwise be minor on calmer days, adverse yaw creates a whole slew of problems when trying to fly a trainer in windy conditions.

Some common approaches to reduce the effects of adverse yaw in R/C have been: Flying at higher speeds; making the trainer less stable and more maneuverable by lessening wing dihedral; differential aileron travel (more up aileron travel than down); avoiding wind; accepting it as how trainers fly; and continued reassurance from club members that the student will eventually get it with more practice -- all of which only help to small and varying degrees.

Aileron-Rudder (A/R) Mixing

The logical solution to counter adverse yaw is with the surface that controls yaw, i.e., the rudder. Coordinated rudder deflections along with and in the same direction as the ailerons prevent the plane from skidding in the opposite direction while banking into and out of turns, making course corrections, rolling, etc. (figure 2). Most importantly, with adverse yaw eliminated, the response of airplane conforms more closely to the inputs and intentions of the pilot!

Be clear, the function of the rudder here is not to turn the airplane. Rather, the purpose of the rudder is only to prevent adverse yaw in order to achieve a precise "axial" bank and roll response.

1st U.S. R/C Flight School trains its primary students on planes setup to automatically coordinate the rudder with the aileron through the A/R mixing function in the radio. Radio manufacturers have in fact been

Adverse yaw: An inherent *opposite* yaw or skid that occurs during aileron deflections (esp. on a flat-bottom wing).

❶ A flat-bottom airfoil with a curved top surface produces low-pressure lift as air flows over it (ideal for upright flight at slower speeds, i.e., primary training).

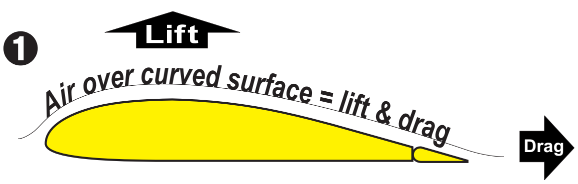
Right Aileron Bank Example:

❷ The lowered aileron increases the curvature of the left wing, thus increasing low pressure lift, causing the wing to lift up and also greater drag.

❸ The raised aileron reduces the effective curvature of the right wing, causing a reduction in lift and less drag.

❹ Increased drag on the rising left wing drags it rearward as the plane is banking right, a.k.a., adverse yaw.

❶



Basic: A flat-bottom airfoil with a curved top surface produces low-pressure lift as air flows over it.

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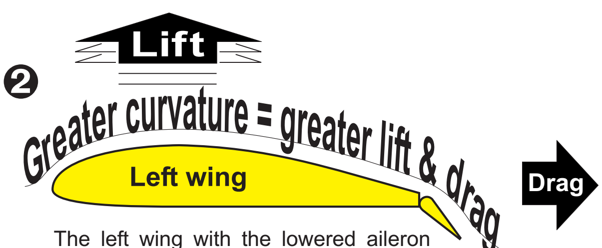

The left wing with the lowered aileron generates more low pressure lift as the air flows over the increased curved surface, causing the wing to lift up and also an increase in drag.

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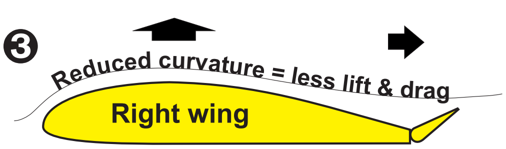
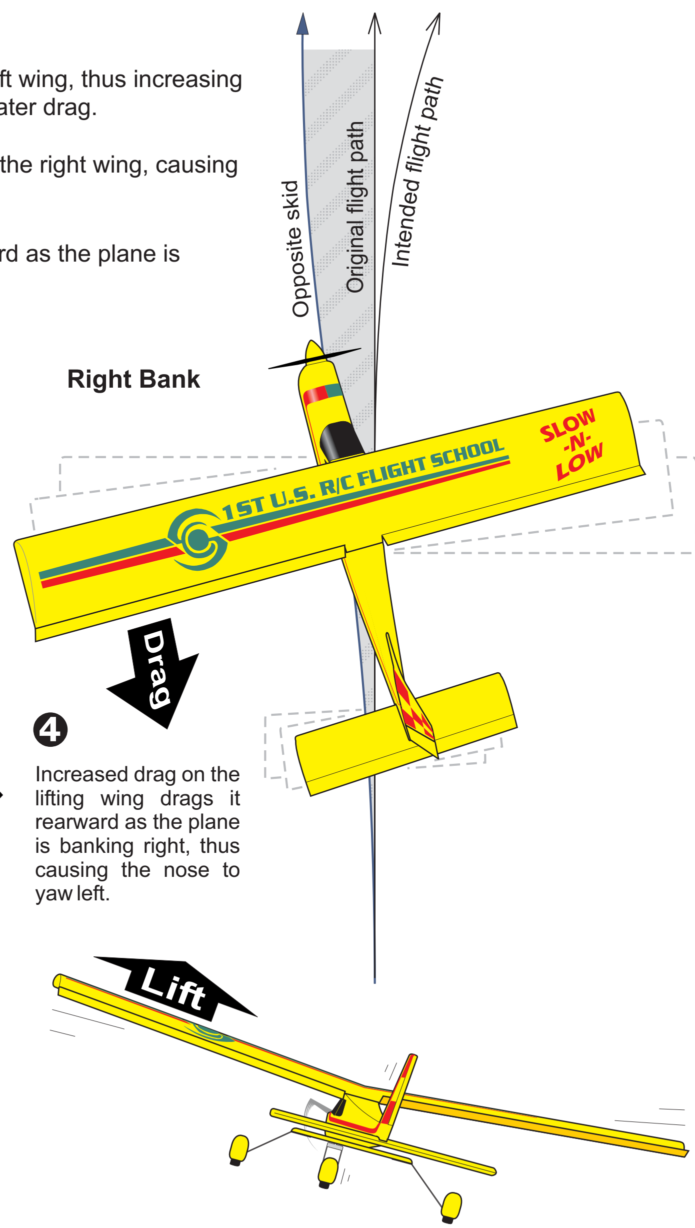


The raised aileron reduces the effective curvature and lift of the right wing, causing the wing to lower and a reduction in drag.

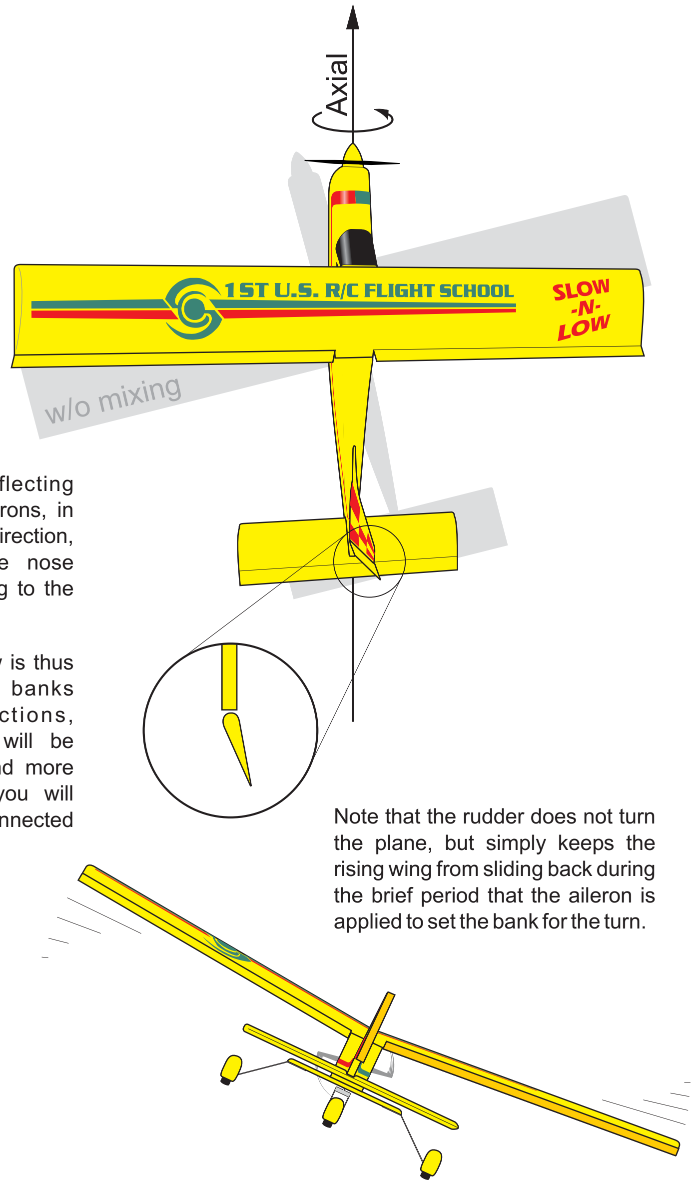


❹ Increased drag on the lifting wing drags it rearward as the plane is banking right, thus causing the nose to yaw left.

Note: The summary information above might upset some career aerodynamicists because it does not address angle-of-attack, camber, induced and profile drag, airspeed, etc.. The objective here is not to teach aerodynamics, but to condense adverse yaw theory into a simple explanation that the average pilot can wrap his head around and thereby improve his odds of success. Anyone wishing to delve into the subject further can easily do so online, e.g., http://en.wikipedia.org providing A/R mixing for the purpose of countering adverse yaw since the 1980's, but since most instructors are inclined to keep passing down the way that they were taught, it is still not widely used or even understood in R/C.

Understand, 1st U.S. R/C Flight School initially operated in the 80's without A/R mixing because it wasn't the norm in R/C at the time, although, full-scale aviation has widely applied the use of *yaw damper* (A/R mixing) since the 1950's so pilots are less encumbered while performing more important objectives. When the school started mixing aileron-rudder on all its primary trainers, the students' weekly average number of landings leaped from 10-15, to 30-40 -- an increase of over 200%! The reasons for the increase are simple: 1. Whether a beginning R/C flyer applies his inputs correctly or not, he always has honest results to learn from. 2. The airplane's truer representation of the control inputs made leads to an improved understanding of proper control. 3. This enhances a pilot's ability to teach himself with greater retention, and therefore his overall practice is more consistent, predictable, and extra productive.

Clearly, one who learns to fly a trainer set up to more precisely reflect the control inputs made is going to learn proper control earlier. However, as a bonus, A/R mixing expands the aerobatic capabilities of primary trainer airplanes as well, e.g., thanks to A/R mixing, aileron rolls remain perfectly axial and on heading throughout. Furthermore, the improved control achieved with A/R mixing permits flying in winds that would normally ground most trainers. I.e., since the main challenge of flying in wind is that it tends to exaggerate deviations, the positive control achieved with A/R mixing makes it possible to more precisely and promptly correct deviations before the wind has a chance to exploit them. Thus, even sport flyers have good reasons to utilize this setup on their flat-bottom wing planes.



Rudder deflecting with the ailerons, in the same direction, prevents the nose from skidding to the left.

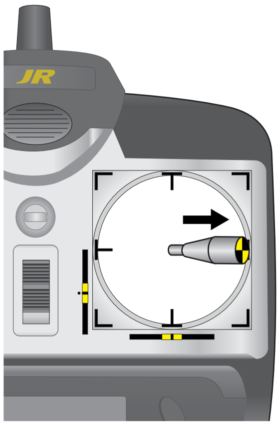
Adverse yaw is thus prevented, banks and corrections, even rolls, will be smoother and more axial, and you will feel more connected to the plane.

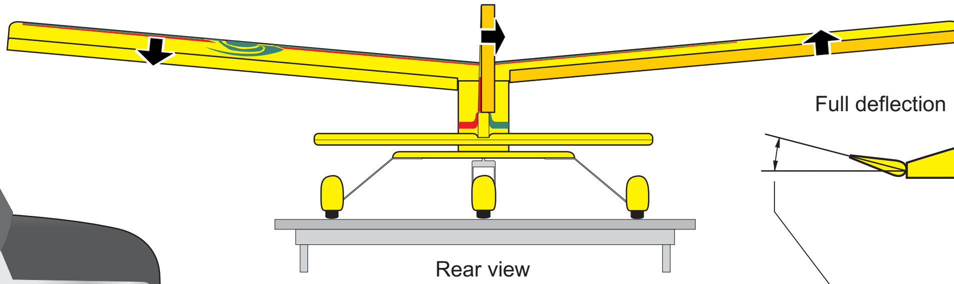
Note that the rudder does not turn the plane, but simply keeps the rising wing from sliding back during the brief period that the aileron is applied to set the bank for the turn.

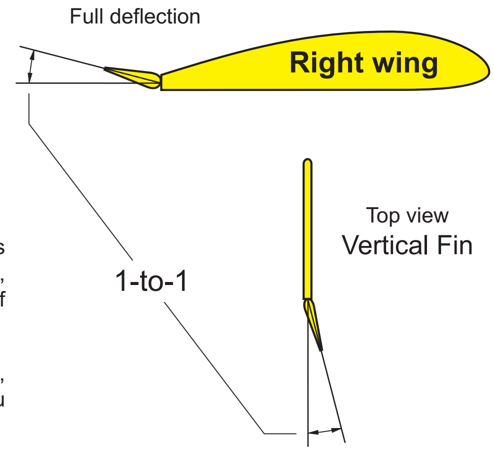
Note: If you're new to A/R mixing, know that pilots still have independent rudder control on the left stick for left-hand ground steering and maneuvers requiring independent rudder. In fact, learning to use independent rudder proves easier after learning to fly with A/R mixing because much of the right stick control will have become routine or automatic thanks to the mix.

Aileron-Rudder Mixing Setup Rules-of-Thumb

Upon activating A/R mixing, you need to confirm that the rudder moves in the same direction as the aileron, i.e., the rudder should move toward the up aileron (figure 3). On a flat-bottom wing airplane, the rule-of-thumb is to set up the A/R mixing so that the degree or angle of rudder throw matches the aileron throw 1-to-1.







Activate A/R mixing and confirm that the rudder deflects toward the up aileron. On a flat-bottom wing airplane, adjust the A/R mixing percentage so that the degree of rudder deflection matches the aileron deflection 1-to-1.

As a result, adverse yaw will be negligible. Banks, corrections, and rolls will be smooth and axial, and you will feel more connected to the plane when you fly.

At the School, we simply gauge the degree (angle) of the aileron deflection visually, and visually match an equal degree of rudder travel. If for any reason we are unable to set a 1-to-1 relationship, we'll get it as close as we can -- knowing from experience that a few degrees more or less is not going to make any appreciable difference. We then check the setup by flying the airplane directly at or away from us while banking left and right to confirm that the banks are axial and the fuselage stays pointed in the same direction throughout.

You can be confident that after applying the 1-to-1 rule-of-thumb to a flat-bottom wing airplane adverse yaw will be undetectable; banks, corrections, and rolls will be smooth and axial, and you will feel more connected to the plane when you fly.

Note: Due to the improved control with mixing, a rank beginner might be wise to initially set up the plane with slightly less aileron travel than what the manufacturer recommends to tame the response a bit, and then match the rudder to that 1-to-1. Furthermore, if you're hesitant to use the A/R mix, you could always start with less, and then keep increasing it until the bank and roll response is finally axial.

Differential Aileron

If your airplane utilizes 2 aileron servos, you can program a small amount of *differential* aileron travel (more up aileron deflection than down) to help further reduce the chances of adverse yaw occurring, particularly at slower airspeeds.

While differential aileron travel is a common practice used to reduce adverse yaw, its effect is slight, and the only way to fully eliminate adverse yaw with a flat-bottom wing airplane is with simultaneous rudder. If you did attempt to reduce adverse exclusively with differential, you would end up with so much up aileron travel that the airplane will push downward entering turns, at the start of rolls, etc.. Thus, a little differential is good, just don't get carried away.

A/R Mixing for the Future

Many new flyers eventually go on to enjoying the "flying on rails" handling and increased capabilities of symmetrical wing sport models. Note that symmetrical wing airplanes do not require A/R mixing because adverse yaw is negligible with this type (see figure 4).

Actually, those who learn to fly a flat-bottom wing trainer with A/R mixing will find the transition into symmetrical wing sport models easier than most. That's because the control habits learned flying an A/R mixed trainer are the same techniques used to optimally fly sport models, since in both instances pilots are flying without adverse yaw and maintaining a direct correlation between their inputs and the response of the plane. Conversely, those who learn to fly with adverse yaw (un-mixed) will have to re-train their habits when flying a sport model without adverse yaw.

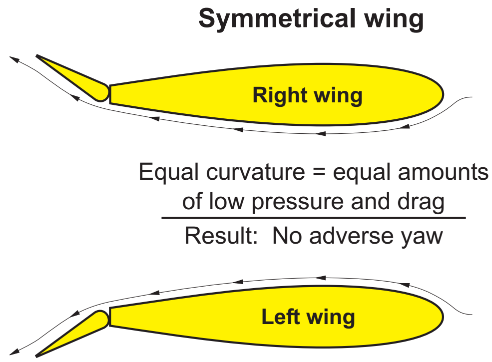
Sadly, since so many people learn to fly with adverse yaw and thus exhibit the same natural-progression of bad habits, (e.g., climbing into turns with descending finishes), a lot of veteran pilots fail to recognize that their difficulties in wind and transitioning to different aircraft types, inconsistent landings, etc., are because the techniques they learned to fly with are no longer appropriate.

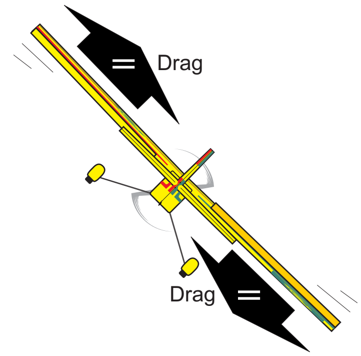
Thus, the aim of A/R mixing a primary trainer is not only to facilitate learning to fly, but also to compliment the transition into higher performance sport airplanes that ultimately don't require A/R mixing.

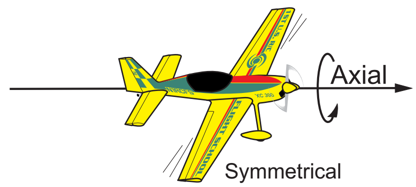
While on the subject, if you're inclined at some point to switch off the A/R mixing on a flat-bottom wing trainer, expect to make a lot more control inputs to overcome the sloppier responses (something that you do not want to make a habit of if you also plan to fly less encumbered sport models). Of course, you could physically coordinate the rudder and aileron together using 1-to-1 movements of both control sticks to eliminate adverse yaw, but understand that this technique only applies to flat-bottom wing airplanes, and would not be appropriate when flying sport airplanes.

Conclusion

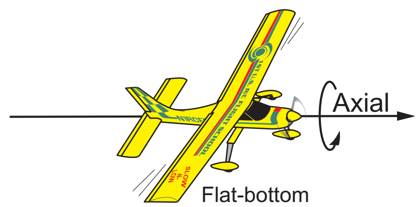
As stated, maintaining a direct correlation between control inputs and the response of the plane is instrumental to developing optimum control habits. Consider that when the initial control inputs are applied correctly, the need for additional corrections may not even exist. That's when a pilot becomes free to think ahead of the airplane and more efficiently take on new challenges. Hence, by removing the obstacle of adverse yaw, A/R mixing proves to be one of the most effective tools to ensure that pilots learn proper control from the start and therefore continue to enjoy steady advancement and a more successful future. Until next time.







Symmetrical wing airplanes exhibit minimal adverse yaw and thus inherently remain axial when banking and rolling. Thus, there's not much need for A/R mixing with this type.



Flat-bottom wing airplanes exhibit significant adverse yaw and thus benefit from A/R rudder mixing to achieve an axial bank/roll response.

When it's all said and done, learning to fly a flat-bottom wing trainer utilizing A/R mixing to eliminate adverse yaw leads to learning the same optimal control habits used to fly a symmetrical wing aircraft, thus making the transition easier.