The Physics of Racing, Part 12: CyberCar, Every Racer's DWIM Car?

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The cybernetic DWIM car is coming. DWIM stands for "Do What I Mean[1]." It is a commonplace term in the field of Human-machine Interfaces, and refers to systems that automatically interpret the user's intent from his or her inputs.

Cybernetics (or at least one aspect of it) is the science of unifying humans and machines. The objective of cybernetics is usually to amplify human capability with "intelligent" machines, but sometimes the objective is the reverse. Most of the work in cybernetics has been under the aegis of defence, for building advanced tanks and aircraft. There is a modest amount of cybernetics in the automotive industry, as well. Anti-lock Braking (ABS), Acceleration Slip Reduction (ASR), Electronic Engine Management, and Automatic Traction Control (ATC) are cybernetic DWIM systems – of a kind – already in production. They all make "corrections" on the driver's input based on an assumed intention. Steer-by-wire, Continuously Variable Transmissions (CVT), and active suspensions are on the immediate horizon. All these features are part of a distinct trend to automate the driving experience. This month, we take a break from hard physics to look at the better and the worse of increased automation, and we look at one concept of the ultimate result, CyberCar.

Among the research directions in cybernetics are advanced sensors for human inputs. One of the more incredible is a system that reads brain waves and figures out what a fighter pilot wants to do directly from patterns in the waves.

A major challenge in the fighter cockpit is information overload. Pilots have far too many instruments, displays, horns, buzzers, radio channels, and idiot lights competing for their attention. In stressful situations, such as high speed dogfights, the pilot's brain simply ignores inputs beyond its capacity, so the pilot may not hear a critical buzzer or see a critical warning light. In the "intelligent cockpit," however, the pilot *consciously* suppresses certain displays and auditory channels, thus reducing sensory clutter. By the same token, the intelligent cockpit must be able to override the pilot's choices and to put up critical displays and to sound alarms in emergencies. In the reduced clutter of the cockpit, then, it is much less likely that a pilot will miss critical information.

How does the pilot select the displays that he[2] wants to see? The pilot cannot afford the time to scroll through menus like those on a personal computer screen or hunt-and-peck on a button panel like that on an automatic bank teller machine.

There are already sensors that can read a pilot's brain waves and anticipate what he wants to look at next. Before the pilot even consciously knows that he wants to look at a weapon status display, for example, the cybernetic system can infer the intention from his brain waves and pop up the display. If he thinks it is time to look at the radar, before he could speak the command, the system reads his brain waves, pops up the radar display, and puts away the weapon status display.

How does it work? During a training phase, the system reads brain waves and gets explicit commands through a button panel. The system analyses the brain waves, looking for certain unique features that it can associate with the intention (inferred from the command from the button panel) to see the radar display, and other unique features to associate with the intention to look at weapon status, and so on. The system must be trained individually for each pilot. Later, during operation, whenever the system sees the unique brain wave patterns, it "knows" what the pilot wants to do.

The implications of technology like this for automobiles is amazing. Already, things like ABS are a kind of rudimentary cybernetics. When a driver stands all over the brake pedal, it is assumed that his intention is to stop, not to skid. The ABS system "knows," in a manner of speaking, the driver's intention and manages the physical system of the car to accomplish that goal. So, instead of being a mere mechanical linkage between your foot and the brakes, the brake pedal becomes a kind of intentional, DWIM control. Same goes for traction control and ASR. When the driver is on the gas, the system "knows" that he wants to go forward, not to spin out or do doughnuts. In the case of TC, the system regulates the torque split to the drive wheels, whether there be two or four. In the case of ASR, the system backs off the throttle when there is wheel spin. Cybernetics again.

ABS, TC, and ASR exist now. What about the future? Consider steer-by-wire. CyberCar, the total cybernetic car, infers the driver's intended direction from the steering wheel position. It makes corrections to the actual direction of the steered wheels and to the throttle and brakes much more quickly and smoothly than any driver can do. Coupled with slip angle[3] sensors[1] and inertial guidance systems, perhaps based on miniaturized laser/fibre optic gyros (no moving parts), cybernetic steering, throttle, and brake controls will make up a formidable racing car that could drive a course in practically optimal fashion given only the driver's *desired* racing line.

In an understeering situation, when a car is not turning as much as desired, a common driver mistake is to turn the steering wheel more. That is a mistake, however, only because the driver is treating the steering wheel as an *intentional* control rather than the physical control it actually is. In CyberCar, however, the steering wheel *is* an intentional control. When the driver adds more lock in a corner, CyberCar "knows" that the driver just wants more steering. Near the limits of adhesion, CyberCar knows that the appropriate *physical* reaction is, in fact, some weight transfer to the front, either by trailing throttle or a little braking, and a little less steering wheel lock. When the fronts hook up again, CyberCar can immediately get back into the throttle and add a little more steering lock, all the while tracking the driver's desires through the intentional steering wheel in the cockpit. Similarly, in an oversteer situation, when the driver gives opposite steering lock, CyberCar knows what to do. First, CyberCar determines whether the condition is trailing throttle oversteer (TTO) or power oversteer (PO). It can do this by monitoring tyre loads through suspension deflection and engine torque output over time. In TTO, CyberCar adds a little throttle and counter steers. When the drive wheels hook up again, it modulates the throttle and dials in a little forward lock. In PO, CyberCar gently trails off the throttle and counter steers. All the while, CyberCar monitors driver's intentional inputs and the physical status of the car at the rate of several kilohertz (thousands of times per second).

The very terms "understeer" and "oversteer" carry cybernetic implication, for these are terms of intent. Understeer means the car is not steering as much as wanted, and oversteer means it is steering too much.

The above description is within current technology. What if we get *really* fantastic? How about doing away with the steering wheel altogether? CyberCar, version II, knows where the driver wants to go by watching his eyes, and it knows whether to accelerate or brake by watching brain waves. With Virtual Reality and teleoperation, the driver does not even have to be inside the car. The driver, wearing binocular video displays that control in-car cameras (or even synthetic computer graphics) *via* head position, sits in a virtual cockpit in the pits.

Now we must ask how much cybernetics is desirable? Autocrossing is, largely, a pure driver skill contest. Wheel-to-wheel racing adds race craft – drafting, passing, deception, *etc.* – to car control skills. Does it not seem that cybernetics eliminates driver skill as a factor by automating it? Is it not just another way for the "haves" to beat the "have-nots" by out-spending them? Drivers who do not have ABS have already complained that it gives their competition an unfair advantage. On the other hand, drivers who *do* have it have complained that it reduces their feel of control and their options while braking. I think they doth protest too much.

In the highest forms of racing, where money is literally no object, cybernetics is already playing a critical role. The clutch-less seven speed transmissions of the Williams/Renault team dominated the latter half of the 1991 Formula 1 season. But for some unattributable bad luck, they would have won the driver's championship and the constructor's cup. Carrol Smith, noted racing engineer, has been predicting for years that ABS will show up in Formula 1 as soon as systems can be made small and light enough[2]. It seems inevitable to me that cybernetic systems will give the unfair advantage to those teams most awash in money. However, autocrossers, club racers, and other grass roots competitors will be spared the expense, and the experience of being relieved of the enjoyment of car control, for at least another decade or two.

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Notes

1 And the word play on 'dream' was too much to resist.
2 Everywhere, 'he' means 'he or she,' 'his' means 'his or her,' *etc.*
3 Also known as *grip angle*; see Part 10 of this series.

References

[1] Patrick Borthelow, "Sensing Tire Slip Angles At the Racetrack," *Sensors*, September 1991.

[2] Carrol Smith, *Engineer to Win*, *Prepare to Win*, *Build to Win*, from Classic Motorbooks, P.O. Box 1/RT021, Osceola, WI, 54020.