Aiming for smoothness – changing up through the gearbox

That's right, an article for advanced motorists on how to change gear (or telling Grandma how to suck eggs). This article is from Wirral Group's Guy Lightfoot.

This should go down well! Please don't be offended; although I passed the advanced test back in 1980, I feel I have got to grips with this issue only recently.

We are all familiar with 3-phase braking – the onset and (particularly) the offset of braking should where possible be gradual, rather than just stabbing the brake. It is the abrupt change in deceleration that passengers feel as they are momentarily thrown forward when brakes are suddenly applied and then thrown back when the brakes are suddenly released. The same is true when we change gear.

Take the scenario where we are waiting at a red light on a road with a national speed limit; on green we want to make rapid progress up through the gearbox towards 60mph but with maximum smoothness – minimising the forward & backward forces associated with gear changes.

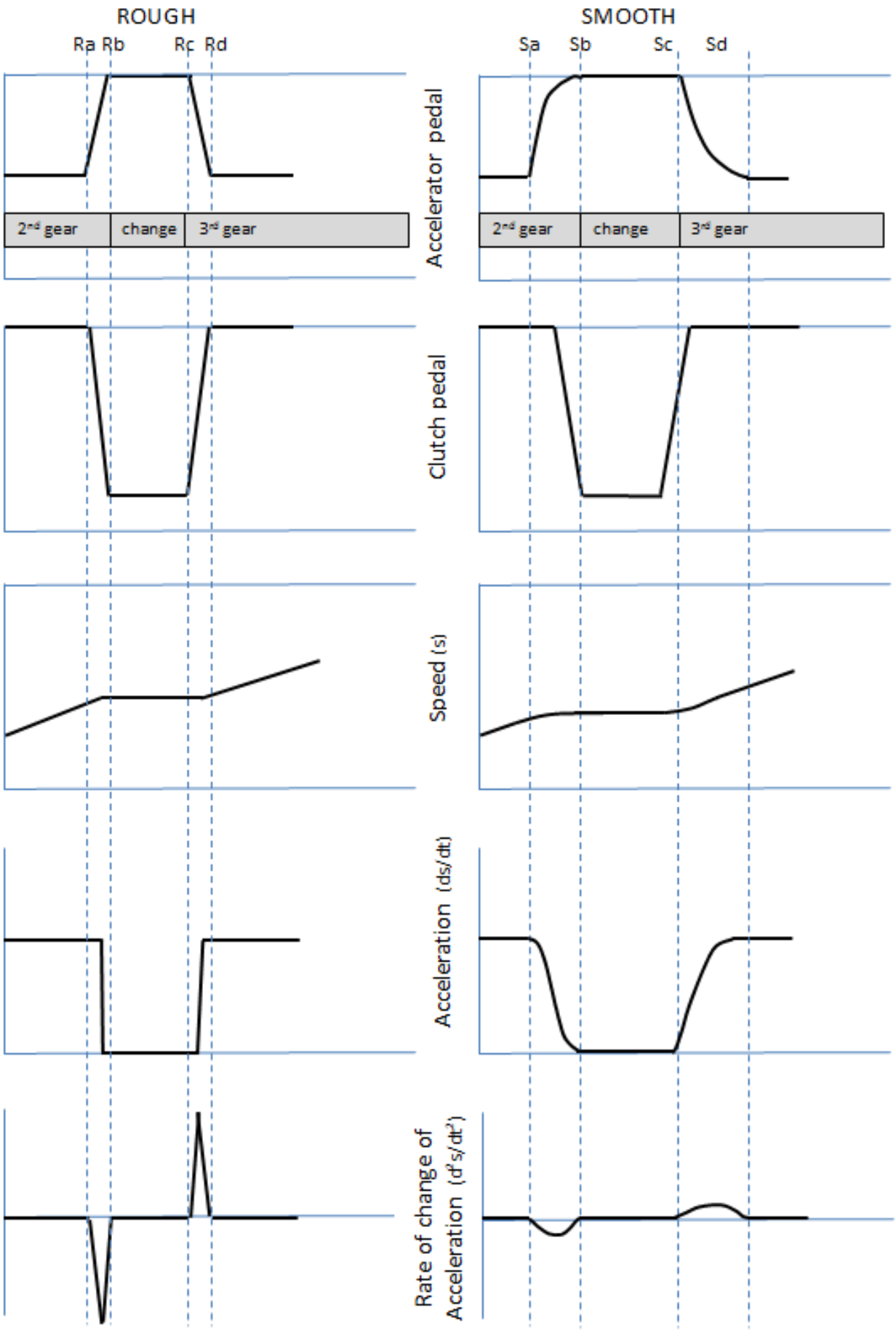
Let's consider a change from 2nd to 3rd gear. Although we may be accelerating firmly in each gear, in a car with a manual gearbox the acceleration must fall to zero when the clutch is depressed – the engine is temporarily disengaged from the road wheels and the car is briefly coasting.

My scientist's brain can't resist plotting graphs to explain what's going on – see the figure below. The leftmost column describes a "rough" gear change. The horizontal axis is time – about a 1.5 second snapshot encompassing the gear change. The top two graphs chart the position of the accelerator and clutch pedals. The top line corresponds to our foot being off the pedal whereas the bottom line is the pedal fully depressed. Initially our foot is on the accelerator and the clutch is up. At time Ra we decide to initiate a change from 2nd to 3rd and from time Ra to Rb we more or less simultaneously release the accelerator and depress the clutch. The middle graph shows our speed which now no longer increases. The fourth graph shows that the acceleration falling quickly to zero and the bottom graph, the rate of change of acceleration, shows a spike. This is what the passenger feels as the acceleration force is abruptly removed. We change from 2nd to 3rd between Rb & Rc, after which we release the clutch and press the accelerator. This results in another spike as the resumption of acceleration presses the passenger back into the seat.

To achieve smoothness we need to minimise those spikes. Now look at the rightmost column, detailing the "smooth" approach. Here, at Sa, we start to release the accelerator slightly before declutching and we do so less abruptly. This "feathering" of the accelerator has the effect of smoothing the transition from acceleration to no acceleration (during which we change gear). Likewise a slower and more progressive depression of the accelerator and release of the clutch after changing gear, from Sc to Sd, reduces the force we feel, as the bottom graph reveals.

There is a price to pay for that smoothness: we probably lose about a car length of progress. Worth paying? I reckon so!

All of that applied to an up-shift; rev-matching of downward shifts applies a different and more challenging technique, but that's for another day. Bet you can't wait!


ROUGH
Ra Rb Rc Rd
2nd gear
change
3rd gear
SMOOTH
Sa Sb Sc Sd
2nd gear
change
3rd gear
Accelerator pedal
Clutch pedal
Speed (s)
Acceleration (ds/dt)
Rate of change of Acceleration (d²s/dt²)