

The lawful nature of learning: acquisition of driving skills.

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ABSTRACT

This paper considers the processes involved in the acquisition of driving skill, and in particular, the crucial role that practice has on pupils' learning. The results of two unique longitudinal studies of the development of learner drivers' skills are summarised. These show that a pupil's initial aptitude for driving, depend on personal characteristics such as intelligence and personality. Subsequent progress in learning to drive is heavily influenced by initial aptitude, but then overwhelmingly affected by the amount of driving experience gained. Whether this experience is built up with tuition and supervision from a professional driving instructor or a parent has minimal effect. The power-law that describes the relationship between practice and level of performance also predicted future driving ability. The implications of these results for how we view learning to drive, and how the process of learning is best supported by training, education and licensing are discussed.

KEYWORDS

Driver training, novice drivers, learning

INTRODUCTION

A century ago, almost nobody drove (see Groeger (1)). Now, in Great Britain for example, almost every able-bodied adult under the age of 45 can drive, or holds a provisional license. This says a great deal about the attractions and benefits afforded by the motor car, but it might cause us to underestimate the difficulties presented by driving. If everybody does it, it can't be that difficult- or can it? Until 1920s popular motorised transport meant that no human travelled at more than 20 miles an hour or so, and with the exception of objects propelled by some external force (e.g. musket balls, objects in strong winds, arrows, etc.), nothing else did either. The time in which people had to react, the distance over which they had to monitor for things which might do them harm, and the requirement to do several things at once under strict time pressure, were all less exacting than they are in the normal course of driving. It may *seem* unnecessary to state it explicitly, but I believe it is fundamentally important to realise that people are not born drivers, but need to *learn* to drive. Driver education, training and licensing regimes need to provide the opportunity for that learning to happen safely. The novice-driver and young-driver literature abounds with papers and reports concerning 'training', 'instruction' and 'education', but very rarely is there any consideration of the fundamental goal of such programmes- *learning*. This paper seeks to be an exception, and to summarise work on how drivers learn that I have been involved with over the past ten years. It tries to begin to answer four questions

- what do we mean by learning?
- how can we measure learning?
- what do we find when we measure learning?
- what do the findings imply for instruction, training and licensing?

What do we mean by learning?

In the context of driving, learning refers to the *development of suitable sustainable ways of meeting task demands*. This may seem an unusual way of defining learning, which usually has connotations of 'change', 'improvement' and, perhaps, 'lacking in competence'. Let me unpack it piece by piece, backwards!

Meeting the task demands of driving requires the achievement of multiplicity of different goals, which are more or less conscious, more or less obviously driven by intention, more or less explicit, more or less abstract or closely specified, and more or less particular to a particular place and time. For example, I may be aware of, and can report upon, my goal to drive to a particular part of my journey reasonably fast to avoid being caught in the likely congestion caused by people leaving University for the day. At one and the same time, I may move my left foot from covering the brake in order to depress the clutch so as to enable me to change gear. As I do so I am also moving my left hand from the steering wheel in order to grip the gear lever, because I am approaching a bend which is too severe to be driven at my current speed. Although the driver does not usually choose to be conscious of details of driving performance at this level, it is obviously possible to be so. This example also serves to illustrate another aspect of the task demands of driving. Some authors, such as Ivan Brown (2) and Leonard Evans (3), have suggested that driving is a self-paced task, i.e. that the task demands of driving are self-imposed. This is true, but only partly so. I cannot choose my own pace for changing gear, because the engine will stall unless I perform the coordinated activities required within a closely and externally specified interval. I cannot decide to drive slowly or solely in a particular lane in busy suburban commuter traffic where other vehicles are parked by the road-side. Nor can I decide to expose myself to a particular level of risk, other drivers or road conditions may dramatically and drastically alter the collision likelihood in ways far beyond my control.

The '*sustainable*' in my definition carries with it the notion, widespread in the psychological literature on learning, that once something is learned, performance becomes 'consistent'. Arguably, one of the strategies we use when driving is to re-create familiar task situations (e.g. always driving with a particular time headway when following), so as to minimise the mental workload involved when we do not rely on familiar well practiced routines. However, just as there are a multiplicity of goals that must be achieved when driving, there are a variety of ways in which some of these goals can be met. Drivers adopt different headways behind different types of vehicles (4), when roads are more congested, and where their journey purpose is different (5). The learning I do as a driver must be capable of supporting these different ways of performing, and having learned implies that these alternatives are available to me, even though I have not chosen them continually or recently.

It is also generally considered that for learning to have occurred, performance must reach a criterion of some sort. I use the term '*suitable*', that is suited to a particular purpose, to convey that while this is also the case with learning to drive, there are a range of behavioural criteria a driver may be required to, or choose to, meet. Thus, the learning may be '*suitable*' for being entrusted with a parent's vehicle, '*suitable*' for passing the driving test, '*suitable*' for driving in slippery winter conditions, '*suitable*' for being judged a safe person to drive with, '*suitable*' for reducing wear and tear on the vehicle, etc. The notion of '*satisficing*' (i.e. sufficient to meet a particular demand, albeit not necessarily the perfect or optimal solution), introduced to the driving literature by Peter Hancock (6) captures the spirit of this very well.

The initial term, *development*, implies the progress towards these performance standards, and is the kernel of the rest of this paper.

How can we measure learning?

Because learning implies change or development, it can only be properly assessed by measuring the performance of a given individual on at least two, and preferably many more, occasions.

Measuring learning in the context of driving provides a methodological challenge not usually encountered in studies of learning- what exactly should be measured? Since driving is a multi-faceted task, acquisition of driving skills cannot simply be quantified by counting numbers of errors or measuring response time, although I will mention studies below which have used these and other parameters, e.g. physical measures of tracking accuracy and speed control, expert-appraisals and self-assessments of performance. The problem, which Ben Clegg and I have been working on over the past few years, is how to quantify learning in complex tasks, particularly those in which different aspects of the task may be learned at different rates. One of the indices of a learner's performance we consider worthy of detailed consideration is the amount of instruction provided to the pupil by a teacher when performing the task. This, as is shown below, provides not only quantitative data on current level of performance across a broad range of aspects of the driving task, but also qualitative information on which aspects are improving and which are not. On its own, as an index, it is subject to biases of different sorts, but used along side other

measures, we believe that quantifying instruction provides unique and valuable insights into driver performance and how and why it develops.

What do we find when we measure learning?

It is unusual to have access to a performer's whole learning experience, but this is very largely the data we collected in a project exploring the content of driving instruction (7). All of the driving lessons of twenty teenage learner drivers were video recorded as they drove with their professional instructor¹. Unusually for British learners, they rarely if ever drove outside formal lessons, and since video-recordings were available from their first lessons until they successfully passed the state practical driving examination, we can legitimately claim to have a complete record of the training experience of these learner-drivers. Some of the outcomes of this project were of immediate practical importance, others have had a more important theoretical and methodological significance.

By virtue of having complete actual records of lessons, we were able to say what was explicitly taught, how frequently and when. For illustration, we found that some 50% of all the instructional comments made referred to car controls and their use. This was by far the highest category of comment at the outset, and across the whole of training. In contrast, 'risk', 'danger' and 'hazard' were rarely if ever mentioned or referred to during lessons, and comprised only 2% of all instruction given. Assuming these lessons are representative of driving instruction, and we have no reason to believe they are not, it is hard to see how a pupil could avoid the view that what is important about driving is car control. Their relative mastery of car controls by the time they take their driving test, and the dearth of opportunity to develop skills of anticipation or interpretation of the likely behaviour of other drivers, may reflect part of the reason drivers have an unjustifiably positive view of their own abilities.

However, it was another finding, apparently of less immediate application, which fascinated us. The amount of instruction given by instructors did not remain constant over time, but reduced as lessons progressed. While at the outset almost every manoeuvre the pupil made was commented upon, by the time the pupil was about to take their driving test, the instructor commented much less frequently. The striking thing was that the reduction in instruction on a particular manoeuvre reduced systematically, as a function of the number of times that manoeuvre had been performed by the pupil in all lessons until that point. Neither the time period over which lessons had taken place nor the frequency of lessons was systematically related to the extent of the reduction. In contrast, hours of prior training, because it is a good proxy for the number of manoeuvres carried out, also proved to be a good predictor of what was evidently a systematic, but probably unintentional, removal of instruction by instructors. A particular mathematical relationship, a power-function, proved to be the best quantitative description of the relationship between amount of driving experience and amount of instruction received. Importantly, each one of the twenty pupils individually demonstrated a statistically reliable relationship of this type. This was so for each type of manoeuvre (e.g. turning left at a roundabout), and for all but one of the categories of instructional comment (e.g. use of car controls, road positioning, use of mirrors etc.).

At the time we drew some tentative theoretical conclusions. Subsequent evidence has reinforced these substantially. These conclusions were that the amount of instruction given is inversely proportional to the pupil's skill level, that the gradual reduction in instruction reflects the gradual acquisition of driving skill, and that actual driving practice was the main influence on the progress made by a pupil. Interestingly, the one comment category that did not display the relationship between driving experience and instruction-reduction was where comments were concerned with appreciation of risk and likely behaviour of other drivers. We consider that it does not show the relationship because there is simply too little opportunity for sustainable learning to take place. Whether the scope for learning might be augmented by classroom based theory lessons or private study is, I believe, a matter for empirical test, rather than supposition, and no appropriate tests of this hypothesis have yet been made.

There was a further implication of what seemed to be a lawful relationship between amount of practice and skill development: amassing the whole of an individual's learning experience was no longer necessary, but rather

¹ The recordings were made by the driving instructor, using a fixed camcorder, unobtrusively positioned in the driving instructor's dual-control vehicle. Instructors were asked to record normal driving lessons, and were free to choose the route, time of day, and duration of lessons. All were top graded instructors according to their most recent Department of Transport assessment.

collecting a relatively small, well-spaced, number of measurement points to track the function would suffice. This methodological insight, allowed Sarah Brady and I to engage on a larger and more complex study, which is I believe is still the only mass longitudinal study of driver's learning (8).

This longitudinal study had a number of goals. We wanted to collect a variety of other measures of driver's skill level, in order to test whether the power-law relationship between practice and skill was still evident when skill was measured in alternative ways. We also wanted to assess what impact individual differences in intellectual ability, personality, motivation etc. might have on a driver's learning progress, and to assess whether the experience gained and progress made by those having largely professional or largely private (e.g. parents) training differed. Over the course of a three-year project we tracked the developing driving performance of nearly 180 teenage drivers and over 100 to a point several months after they had passed their driving test. Approximately two weeks after they first drove, and thereafter every four weeks or so, we had them undergo a driving lesson, in the car in which they normally had lessons, with their usual teacher. The route followed in this lesson was chosen by us and always the same. They drove this route in the presence of an experienced driving instructor, while the lesson was being unobtrusively video taped, with their speed and control of lateral position also being measured over parts of the route. Before each pupil and teacher joined the programme they underwent an extensive interview, and pupils also underwent extensive assessment of their intellectual abilities and personal characteristics. Throughout, pupils kept driver diaries, in which they logged how much driving they did, when, with whom and for what purpose, etc. There is space here to highlight just a few of the results that are relevant to this paper. An extensive report is available in Groeger & Brady (8).

The number of errors pupils committed during our observed lessons reduced steadily as their driving experience increased. As previously found with decline in instruction, error reduction was a power-function of the amount of driving the pupil had ever done until that point. The amount of instruction they received during observed drives was also a power function of their reported driving experience, although error-frequency and comment frequency were only weakly related in individual drives (i.e. teachers do not only, or invariably comment when an error is made). Each pupil demonstrated reliable 'error reduction'- 'increased experience' and 'instruction reduction' - 'increased experience' relationships. The rate of reduction of errors and of instruction were reliably correlated, validating, we believe, instruction-reduction as an index of performance.

So far I have deliberately referred to power-functions without explanation, but a little detail is now needed in order to appreciate what these, and subsequent findings, mean. A power-function is a quantitative non-linear relationship between two variables, such that a small change initially in one variable (X) leads to a rapid change in the other (Y). However, the same amount of change in X later, results in much less change in Y. The effect of X on Y gradually reduces, such that Y can never reach its theoretical maximum level. In the example, X is driving practice, and Y is driving proficiency. That is, there is an immense benefit from a given amount of practice when the pupil is very inexperienced, but much less evidence of improvement in their performance from the same amount of practice later on. However much benefit there is initially, and however much practice is eventually undertaken, performance will never be perfect, that is error free, or unlikely to attract instructional feedback from an expert observer. Power functions are normally written in the form

$$P = E^i + A$$

'P' is the level of performance observed, 'E' the amount of experience the driver has had, 'i' is the rate at which he or she is improving, and A is a constant which reflects his or her aptitude for driving when experience was effectively zero.

Our psychometric testing of these pupils shows that *driving aptitude*, i.e. the pupil's likely starting ability when first taking lessons, can be predicted from certain aspects of intelligence (crystallised intelligence), personality (e.g. achievement motivation). At first it seemed that nothing other than the sheer amount of practice governed progress thereafter, but this was because driving aptitude exerts a very strong influence over subsequent *learning progress*. If the effects of driving aptitude on learning progress are statistically controlled, other aspects of intelligence, particularly fluid intelligence, and personality, particularly Conscientiousness, are associated with faster or slower learning.

Deriving a power-function for each pupil allowed us to do more than identify which personal characteristics and attributes were associated with learning. If the power-function relationship between amount of experience and number of errors committed was anything more than a mere description of the data, it should also be capable of predicting how well those individuals would be able to drive in the future. For this reason about 100 of our original set of pupils were invited back to be tested some 3 to 6 months after they had passed their driving test. In the interim they kept regular accounts of their driving experience. By using this information we were able to use an estimate of their total driving experience, and using the particular power-function derived from their learning data, we could predict in advance the number of errors they would be likely to commit on a future test drive. When actually tested, by an examiner unaware of the prediction, the sample as a whole shows a highly reliable correlation between the predicted and actual number of errors. That is, these novice drivers were continuing to benefit from their driving experience, gradually becoming less likely to make errors when assessed.

A final finding I will briefly review here is the contrast between private and professional instruction. While there were very large differences in the type of experience pupils largely trained by parents had, there were few other differences between those who initially chose to learn with parents, or those who chose to learn with professional instructors. There was also no evidence that pupils learning with professional instructors improved faster, or were more likely to pass their driving test. These data explain why Forsyth (9) found that drivers who have large amounts of professional instruction are more likely to fail their driving test, a finding we have subsequently replicated (see Groeger & Brady, 8). It arises not because professional instruction is counter productive, or because instructors initially have less able pupils to teach, but because those who are not making progress with family-based tuition gradually have more instruction from professionals. That is, the samples taught by parents and professionals are not biased to begin with, but become polarised the closer pupils are to their driving tests (see Groeger (10) for further analysis and discussion. This implies that in licensing regimes such as that operating in the U.K., where there is no requirement to have professional instruction, the pupils professional instructors teach most are those less able to drive.

CONCLUSION: Implications for licensing, training and instruction

The nature of the driving task and its inherent complexity make it difficult to learn, but most of us succeed in doing so. For those of us with an aptitude for acquiring skills, driving initially proves easier, but our ability to drive will ultimately depend on the amount of experience we have gained and our ability to profit from this experience. For those of us with less aptitude for acquiring skills, driving initially proves more difficult, and we will tend to rely more on the structured experience of formal training. Ultimately, our proficiency will also depend on our ability to transfer this experience effectively from the circumstances of training to the very different conditions under which we will later drive. The variability of these circumstances, and our own varying level of involvement in the driving task, effectively mean there are many different ways of performing the same manoeuvre. While only one way of performing the manoeuvre may be 'correct' in textbook terms, many others will develop in order to satisfy the plethora of driving goals we have, and these may be practiced more frequently than whatever method was taught when undergoing instruction. Which method is used in a given circumstance will probably depend much more on similarity to previous situations, and probably owes little to deliberate decision-making. The lawful nature of learning, demonstrated by our two longitudinal studies of learner drivers, implies that we will continue to learn as we drive, long after we have passed through whatever assessments are required for gaining a licence. We will learn, however, without supervision, with minimal and largely misleading feedback on our performance. This is the nature of learning with respect to driving, and several implications follow from recognising it.

The need to moderate, or graduate, licensing requirements and entitlements, is one of these implications. By doing so we can shape what individuals concentrate their practice upon when learning to drive. By placing restrictions on what driving a given level of license entitles the holder to do, we can limit novice drivers' exposure to circumstances in which they cannot be expected to perform reliably. Being a reliably safe driver is a matter of years of driving experience not hours, our licensing system must afford individual drivers the opportunity to gain that experience safely.

With regard to formal or professional training, the studies described above, and many more besides, provide no compelling evidence that formal training should be mandatory for all, or that professional training should be the sole

basis of a driver's education. That is not to say that some do not benefit enormously from formal training, or that most would not benefit to some extent, simply that supervised exposure to actual driving is the primary basis of learning and future driving behaviour. Instruction, per se, when it is timely, tailored to the motivations, aspirations and skill level of the pupil under instruction, is certainly likely to have a beneficial effect. However, I feel that it is when formal instruction is fully integrated with extensive supervised practice that its' true benefit will be realised. Our findings suggest that determining the optimal mix of formal training and supervised practice for a given individual is both desirable and possible. We believe that the lawful nature of learning can also provide a basis for identifying and structuring the content of the formal and informal components of drivers' learning.

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