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Driver Reaction Times in Road Traffic

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Reaction time, distribution function

1. Introduction

The assumed driver reaction time has an enormous impact on the avoidance of an accident. Nevertheless, it is more or less considered as a constant by German jurisdiction, at least since the «*Deutscher Verkehrsgerichtstag (DVG)*» (German Council on Jurisdiction in Traffic) has given its recommendations in the early eighties. Our experiments – as well as others – yet reveal a considerable variation of the reaction time, even for one and the same person, under strictly controlled test conditions.

We conclude that reaction times may only be described by statistical means, the upper and lower acceptable limit being defined by *percentiles* (see the text below for an explanation of all special terms). Unfortunately, the limits proposed by the DVG are not based on the percentiles found in the raw data of the underlying experiment. Instead, the distribution of the reaction times had been approximated by an analytical *density function*, and the percentiles were then derived from that approximated function. By this procedure, longer reaction times were excluded and did not contribute to the recommendations.

The underlying raw data has been re-interpreted by us, revealing that the ancient evaluation procedure had mathematical deficits that provoked misinterpretation. It turns out that the distribution found in the experiment has the typical pattern revealed by any reaction experiment. Using adequate techniques, the distribution may be approximated by a single distribution function, avoiding the former difficulties. We conclude that the original experiment has to be interpreted in a different way: Even in most simple situations, reaction times of 1.5 s have to be accepted as quite normal.

In order to understand the mathematical problems leading to the former misinterpretation of the data, we first have to introduce some statistical methods not common to the reconstructionist. This is a necessary torment, otherwise the reader would not be able to follow the argumentation. If we call into our mind what impact this experiment and its interpretation has had on German jurisdiction, it is worth this brainwork. And as German usage of reaction times seems to have influenced most of continental Europe, we think it is justified to consider this aspect at an European conference.

2. Experimental difficulties

There is no such thing as «**the** human reaction time». The come-out of a reaction experiment strongly depends on the test conditions. Considering road traffic, we have to distinguish at least two reaction situations:

- Driver reaction in normal day traffic, that means in regard to traffic lights, traffic signs, changes in road curvature
- Driver reaction in case of an accident, that means under sudden threat, potentially life-threatening.

As reaction times depend (amongst others) on the urge for the response [Burckhardt 1981], we should not mix these and in this paper, we are talking about the latter. (The original title of the paper «Driver reaction times **for defensive actions** in road traffic» has been cut off by the organization committee.)

Obviously, it is not easy to simulate a life-threatening situation within a reaction experiment! There have been various attempts to do so: Puppies darting out behind obstacles [Burckhardt 1981], foam bars lying on the street [Olson 1996], opening of the driver's door of a parking car [Summala 1981] or even a full size foam mock-up of a passenger car [McGhee 2000]. In all these experiments, the test persons were unaware of the oncoming threat. There are two difficulties with this kind of experiment. You cannot really confront the test persons with real threat, not even with staged threat. You would risk to provoke evasive actions that might really harm the test persons. The other problem is that you can only fool them one time, afterwards the test person is warned and thus biased. You will either need a lot of participants or get only few data. (All of the experiments mentioned above got off with the latter.)

Another problem with this kind of experiments is, that you cannot clearly define the start of threat (or what the test person takes for it). Take the experiment involving the mock-up as an example: The mock-up was towed by another vehicle. When test vehicle approached an intersection, it triggered a light that cued the driver of the tow vehicle to start. The time between trigger and throttle release then was considered as the reaction time. Definitively, it included the tow vehicle driver reaction time and the towrope slack as well as other possible delays. All other experiments of that kind had to face comparable difficulties.

Newer experiments sometimes use driving simulators instead of on-road experiments. This is a tempting approach as it promises to give situation specific reaction times, avoiding real threat and potential harm. The problem is that you cannot judge on how deep the test person has sunken into the simulated scenario. So in the simulation, he/she might take risks that he/she would not take in real traffic. The efforts taken to diminish the difference between simulation and reality may get expensive and the experimenter will still not know how applicable his/her results are to normal day traffic. As with the on-road experiments, you can only fool the participants once.

You may draw back your demands, tell the test persons what kind of reaction signal will appear and how they will have to react. This path has been taken by the DVG [Burckhardt 1985] and Cohen [Cohen 1987]. In the DVG experiment, the participants had to react to the break lights of the car in front, touching their brakes pedal themselves. Cohen covered the windshield with an LED array, switching them randomly. The drivers had to answer the lit of a LED by touching a switch mounted on the steering wheel. In these experiments there is no threat, only the driver's ambition to be a good performer. You gain a lot of single reaction experiments, but you cannot really control the test conditions. You never know whether the driver's concentration is absorbed by other conducting tasks or in what direction the driver's gaze is pointing. (I.e. you cannot control the gaze angle at which the stimulus appears, unless you are using eye trackers. This turned out to become a source of imponderability in the DVG experiment.)

Finally, you may decide to become ever more modest and take control over the test situation at the price of abstraction. This is the decision we made in our experiments [Zöller 1995, Hugemann 1996] and that has been made by innumerable others. You cannot expect those experiments to give numerical values for the reaction time in case of an accident, but you may study the relative importance of test parameters under very stable conditions.

We see: There is no optimal approach to measuring the driver reaction time for defensive actions. Each approach has its own pros and cons, and we may accept that as long as we are aware of it.

2. The Experiment leading to the German recommendations

The recommendations of the DVG found on a single experiment illustrated by Fig. 1. The test persons had to follow a car steered by the experimenter for about an hour on a country road with sparse traffic. Each time the brake lights of the preceding car lit, the test person had to touch his/her brake pedal as quick as possible. The reaction was defined as the time delay between the lit of the brake lights and the touch of the brake pedal in the pursuing car. The tests included 41 persons, most of them young male students. The total drives yielded 3,846 single reaction experiments, i.e. about 100 for each participant.

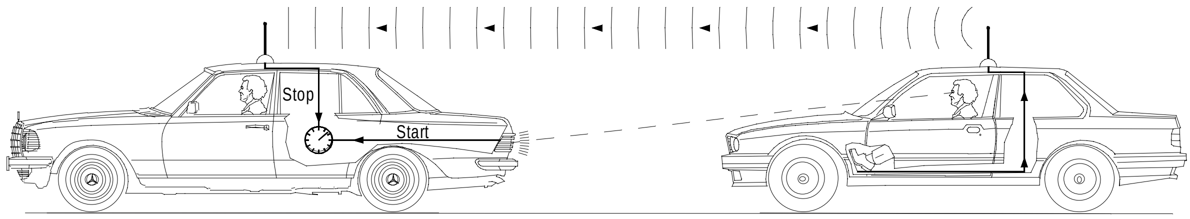
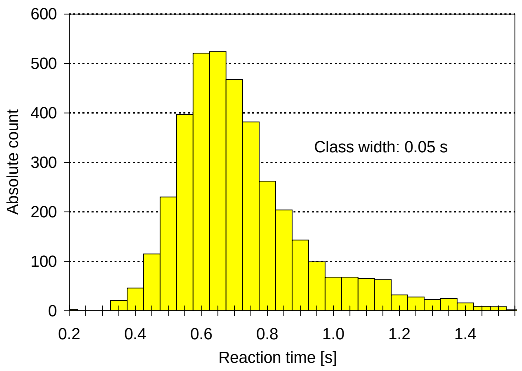
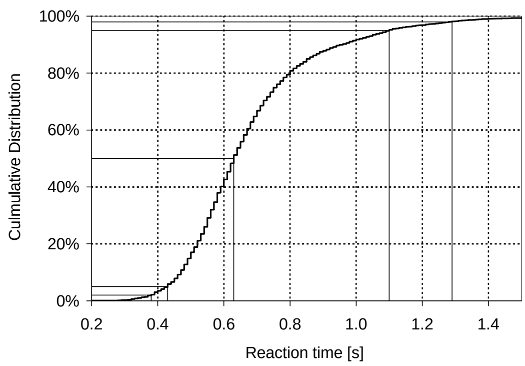


Figure 1. Experiment used for DVG

Conducted in the early eighties, the experiment used analog equipment, the reaction times being noted on paper by the experimenter, a young German student. His diploma work was handed to us, and we typed his data into the computer in order to re-evaluate it. The figures presented in this paper are based on this digitized data. Fig. 2 shows the histogram and the cumulative distribution (see further down for an explanation of these terms) of the pooled reaction times.



a) Histogram



b) Cumulative distribution

Figure 2. Distribution of DVG data

The mathematical evaluation of the experiment was performed by Burckhardt, who was supported by a commission of experts coming from various fields (psychology, ophthalmology, etc.). The results were approved first by the commission and then by the DVG. Few years later, Burckhardt published a book describing the evaluation procedure in detail [Burckhardt 1985]. Therefore we will refer to «Burckhardt’s experiment» or the «DVG experiment» for the rest of the text.

3. Methods of statistical description

Fig. 2a shows the typical result of a reaction experiment in terms of a histogram. Typically, we have a minimal reaction time that cannot be beaten. This is due to the minimal mental processing time and to the time needed for the physical aspects of the response. For times little longer than the minimum we observe most of the responses, i.e. the maximum answer probability (the associated time being called the *modal value* of the distribution). Reaction tests that do not get an answer within this «standard time interval», will get an delayed answer – or none at all. As the reaction time has no upper limit (in correspondence to the lower boundary), these delayed answers may take a long time, making up the long «tail» of the distribution to the right. This statistical behavior is typical for reaction times [Luce 1986].

It has to be pointed out that the distribution of the reaction time can not be solely attributed to the differences between various test persons (*interpersonal variation*). You may test one and the same person under controlled conditions and he/she will double his/her reaction time half a minute later (*intrapersonal variation*). The problem of statistical distribution is inherent to reaction times, i.e. the reaction time of even a single person may only be described by statistical means. Now, what are the right statistical means to apply? Obviously, the distribution Fig. 2a does not resemble a normal distribution, i.e. the usual description by mean value and standard deviation is inadequate, or at least insufficient.

3.1 Cumulative distribution, percentiles and histogram

In a first approach we may just sort the raw data by value and count in what portion of the tests the participants have responded within a given time. This leads us to the cumulative distribution in Fig. 2b. This distribution may be characterized by the times that given portions of all results fall below, the so-called *percentiles*. The 50% percentile is called the *median*, it somewhat replaces the mean value in case of a non-normal distribution. Usually, the raw data has to be cut off by the 2% and 98% percentile: The reaction times below the 2% percentile are probably due to misreactions, those above the 98% percentile are due to mental absence. The lower and upper limit of the reaction times as accepted by jurisdiction may be defined solely in terms of percentiles. For jurisdiction, there is no need for further manipulation of the raw data. This is so important that we may repeat it once more: For jurisdiction, there is no need for further manipulation of the raw data.

Considering scientific questions, the raw data may be processed further. We may classify the reaction times into certain bandwidths, so-called *classes*, as has been done in Fig. 2a. This will give us the *histogram* and a more precise idea, in which way the distribution differs from the normal distribution. The typical histogram of reaction times is *left-steep* and has a «tail» of long reaction times to the right.

3.2 Distribution functions

With more experimental results, the cumulative distribution gets more and more continuous, associating a percentile to any arbitrary reaction time. The function gained by this approach is called the *distribution function* $F(t)$. Its derivative is called the *distribution density function* $f(t)$ and is the continuous correspondence to the histogram. The *hazard function* $\lambda(t)$

$$\lambda(t) = \frac{f(t)}{1 - F(t)} \tag{1}$$

is of some theoretical interest. It tells us with what probability the event described by the density function $f(t)$ will happen to the persons (or equipment) remaining. (Its applicability to aircraft failures should be obvious.) Applied to reaction times, the hazard function will answer the question: How probable will a person that has not yet reacted do so in the next instant? It is of some theoretical interest whether $\lambda(t)$ will either tend to zero or increase for long t. Will the non-reactors tend to neglect the signal or does anyone have to react sometime?

There have been numerous attempts to describe the raw data of reaction experiments by an analytical function $F(t)$, or $f(t)$ respectively. Any of the common distribution functions has at least been proposed once for the description of reaction times [Luce 1986]. Looking at Fig. 2a we may state the minimal requirements an adequate distribution density function should fulfill. It should at least have three parameters to describe

- the maximum of the distribution
- the curvature at its summit
- the relative slope left and right of the summit.

3.3 Moments of a distribution

In order to characterize an distribution by single values, we may calculate the *moments* of the distribution, defined by

$$M_n = \int_0^\infty t^n \, f(t) \, dt \tag{2}$$

The first moment is the *mean value* μ, which is often subtracted to give the *centered moment*

$$\underline{M}_n = \int_0^\infty (t-\mu)^n \, f(t) \, dt \tag{3}$$

If not mentioned otherwise, «moment» usually means «centered moment». The moment of second order is called the *variance* with the *standard deviation* σ defined as its square root. The moment of third order gives the *skew* χ

$$\chi^3 = \frac{\underline{M}_3}{(\underline{M}_2)^{\frac{3}{2}}} = \frac{\underline{M}_3}{\sigma^3} \tag{4}$$

In contrast to mean value and standard deviation, the skew is dimensionless. A symmetrical distribution (like the normal distribution) has zero skew, a left-steep distribution has positive skew. The moment of forth order is called *kurtosis*. The moments of even higher order have no assigned names.

The properties mentioned at the end of the last section may now be represented by the first three moments of the distribution. These moments may easily be calculated from the raw data, whereby the integrals have to be substituted by the according summations.

3.4 Special distribution functions

3.4.1 Gamma distribution

For our experiments, the Gamma distribution perfectly fit to the data [Zöller 1995, Hugemann 1996]

$$F(t) = \frac{\Gamma\left(B, \frac{t-t_0}{T}\right)}{\Gamma(B)} \tag{5}$$

Note that we introduced an offset t_0 that is normally not involved. Though this description in terms of (imperfect) Gamma functions $\Gamma(B,t)$ looks frightening, it is quite easy to handle. Most of all, its parameters are explicitly linked to the moments of the distribution by

$$B = \frac{4}{\chi^2} \quad ; \quad T = \tfrac{1}{2}\sigma\chi \quad ; \quad t_0 = \mu - \frac{\sigma}{2\chi} \tag{6}$$

The hazard function approaches $1/T$ for large times t, that means a constant value. The minimal reaction time is t_0 as $F(t)$ is not defined for values $t < t_0$.

3.4.1 Weibull distribution

Burckhardt has used the Weibull distribution to describe the raw data

$$F(t) = 1 - e^{-\left(\frac{t-t_0}{T-t_0}\right)^B} \tag{7}$$

The special feature of the Weibull distribution is its simple hazard function

$$\lambda(t) = \frac{B}{T - t_0}\left(\frac{t - t_0}{T - t_0}\right)^B \tag{8}$$

which increases monotonically in case of $B > 1$. With questionable arguments, Burckhardt dropped the parameter t_0 to get

$$F(t) = 1 - e^{-\left(\frac{t}{T}\right)^B} \tag{9}$$

The two remaining parameters B and T have a quite nasty correspondence to the moments of the distribution

$$\mu = T\,\Gamma\left(\frac{B+1}{B}\right) \quad ; \quad \sigma^2 = T^2\left[\Gamma\left(\frac{B+2}{B}\right) - \Gamma^2\left(\frac{B+1}{B}\right)\right] \tag{10}$$

with the formula for the skew being even worse. Obviously, there is no way to turn these equations into an explicit formula for the calculation of B and T. If one considers the logarithm of the reaction time $\ln(t)$, both parameters may be calculated from its mean $\tilde{\mu}$ and standard deviation $\tilde{\sigma}$ by

$$B = \frac{\pi}{\sqrt{6}\ \tilde{\sigma}} \quad ; \quad T = e^{\left(\tilde{\mu} + \frac{C}{B}\right)} \tag{11}$$

C is Euler's constant (about 0.5772). This is the way Burckhardt proceeded.

According to Eq. (10), res. (11), the two model parameters are linked to mean and variance of the data. There is no parameter left to characterize the skew, which is simply fixed by B and T. Fig. 3 shows Weibull distributions with $\mu = 1$ and varying B. T is adapted according to eq (10). Normally, the maximum of the density function decreases as it broadens, because

$$\int_0^\infty f(t)\ dt = F(t = \infty) = 1 \tag{12}$$

In order to make the comparison easier, the functions in Fig. 3 have been normalized such that they all have a maximum value of 1. It turns out that Weibull distributions with $B \gtrsim 3.6$ have negative skew, i.e. they are right-steep and inadequate for modeling reaction time data.

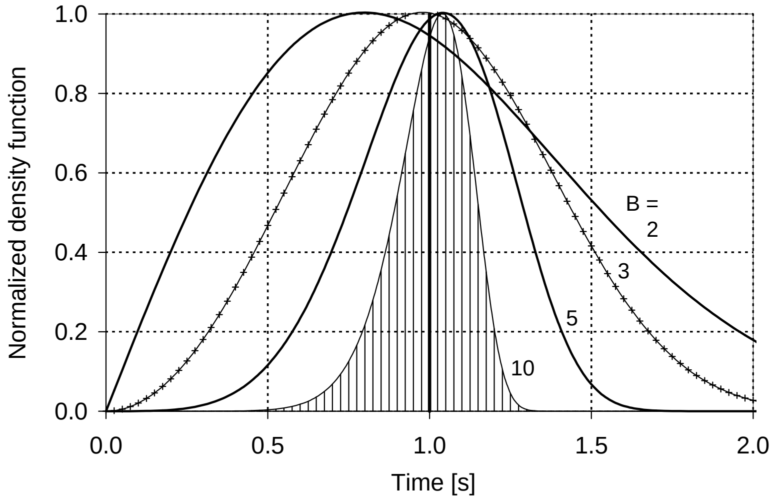


Figure 3. Weibull distributions with same mean value and different values of *B*

3.4.3 Fitting distribution functions to raw data

In the two preceding sections we derived how the model parameters are linked to the moments of the distribution (and vice versa). This seems to propose an easy way to adapt the model parameters, especially easy for the Gamma distribution. Yes, it is easy, but we do not recommend to proceed such. The problem in doing so is that you cannot draw stable estimates for the moments of higher order from the raw data. As the deviation from mean is powered by three (or more), one-offs are overemphasized, leading to false estimates for skew and kurtosis. Thus, this approach is limited to mean and standard deviation. Instead of using higher moments, we should approximate the distribution function directly to the experimental distribution, using best-fit methods.

To do so, we need some measure for the degree of fit reached by different distribution functions. Any distribution function with three parameters may be fitted to the experimental data – how do we judge which is best? There has been some discussion about the right representative for the experimental distribution: Is it the cumulative distribution, the histogram or even the hazard rate? (The use of moments somewhat corresponds to using the cumulative distribution.)

It turns out [Luce 1986] that the cumulative distribution is not adequate to judge the performance of different functional approaches: Their cumulative distribution function will all look more or less the same. The density function gives a better idea of the fit, as different functions will exhibit a different «tail». It would be consequent to go one step beyond and concentrate on the «tail» by comparing the hazard functions. Though theoretically tempting, this approach would overemphasize the minor portion of the experimental results making up the «tail». We consider the comparison between density function and histogram as a reasonable compromise.

4 Re-evaluation of the DVG data

4.1 Percentiles of the raw data

We have said it already: distribution functions are a playground for scientists, jurisdiction is well off with just the percentiles. For the raw data they are

Table 1. Percentiles of the raw data

Percentile	*Time measured*	*Reaction Time*	*Deviation*
2%	0.36 s	0.56 s	-0.27 s
5%	0.43 s	0.63 s	-0.20 s
50%	0.63 s	0.83 s	0.00 s
95%	1.10 s	1.30 s	0.47 s
98%	1.29 s	1.49 s	0.66 s

Note that the measured reaction times do not comprise the deceleration build-up time, as the clock was stopped already by the **touch** of the brake pedal. According to DVG, the deceleration build-up time is about 0.2 s. (We believe it to be longer for just a normal driver.) This constant value has been added in the third column of the table to calculate what usually is called «reaction time» by German jurisdiction.

The last column gives the deviation from the median. As typical for left-steep distributions, the lower percentiles do not differ that much from the median as the higher percentiles. The question where to place the acceptable limit therefore has more influence on the higher percentiles. The 98% percentile is about 1.5 s.

4.2 Beating Weibull

Fig. 4 compares our approximation of the raw data (Gamma) with Burckhardt's (Weibull). There should be few about discussion which one suits better. The main problem of the two-parametrical Weibull distribution is that it cannot reflect the skew correctly. We also made attempts to fit the three-parametrical Weibull distribution to the raw data in order to give it a fair chance. The results are not reproduced here: It did not look **that** bad, but Gamma still was significantly better.

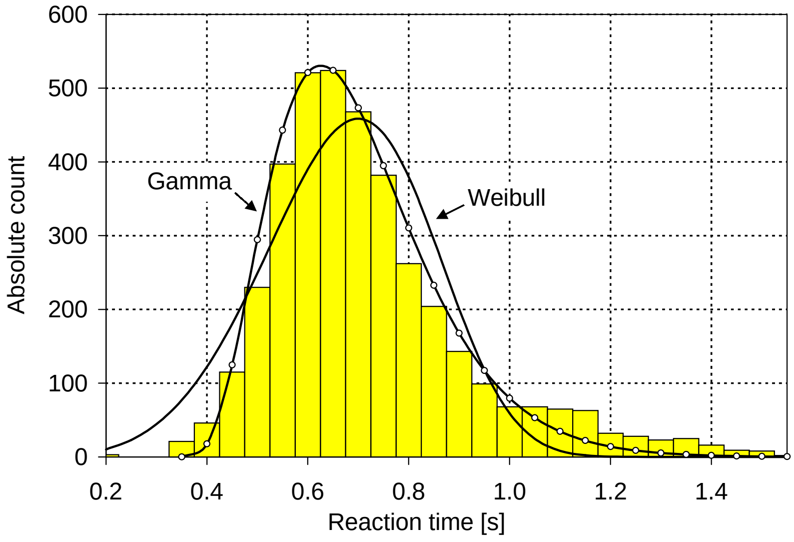


Figure 4. Approximation of the DVG Data by Gamma and Weibull distribution

4.3 Rescue attempt

Instead of switching to a three-parametrical function or considering other distribution functions, Burckhardt chose another explanatory approach. He postulated that the experimental results were the superposition of two distributions

$$f(t) = \phi \; f_1(t) + (1-\phi) f_2(t) \tag{13}$$

$f_1(t)$ representing normal reactions and $f_2(t)$ those where a gaze shift had been necessary to fixate the brake lights of the car ahead. This was based on the paradigm that humans do not react on signals perceived peripherally. Again, this paradigm has been refuted [Hugemann 1996]. It does not make much sense anyway: Why shouldn't a test person instructed so clearly react on a brake light perceived peripherally? But let us have a look an Burckhardt's fit, Fig. 5: The combined power of five parameters does not beat Gamma!

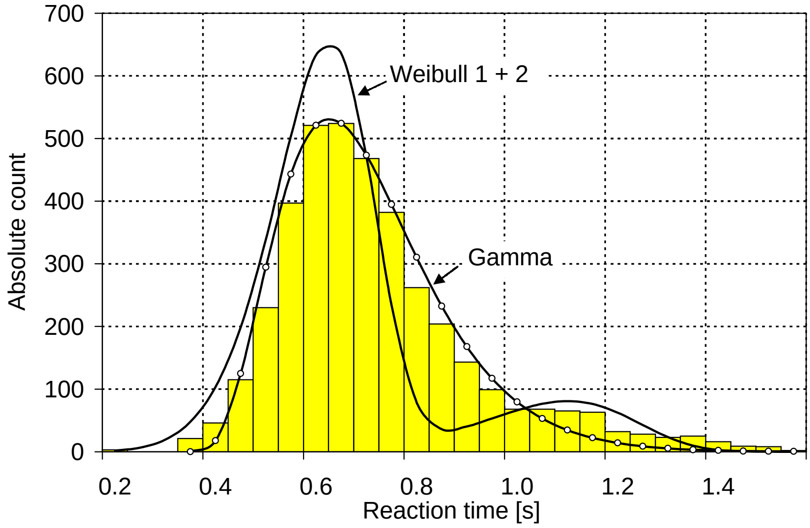


Figure 5. Approximation of DVG data by Gamma and double Weibull distribution

4.4 Explaining Weibull

I never had the chance to ask Burckhardt, why he chose the approach eq. (13) to approximate the data and did not try out other concepts (that are not even discussed in the complete book). I offer three explanations:

4.4.1 Weibull is common to the mechanical engineer

Due to its simple hazard function, Weibull is suited to describe fatigue effects of mechanical components. (In fact Weibull, being a mechanical engineer himself, developed it for that purpose.) Thus the mechanical engineer is well acquainted to the Weibull distribution and to the tools for handling it. Applying it to reaction times may have been just an isle of common in a foreign working field.

4.4.2 Preserving the tradition

Ever since, German jurisdiction has used one second as the standard driver reaction time. There even is a German word for it: «*Schrecksekunde*», which means something like «fright second». The raw data now proved different: Even in the most simple situation (or can the reader imagine a reaction situation more clearly in traffic?), a non negligible portion of driver reaction times is longer than that.

With Burckhardt's interpretation of the data, the tradition is preserved: For the main peak representing reactions without gaze shift, the 98% percentile falls below one second. If misplaced gaze is considered as driver's fault, jurisdiction may still claim a reaction time of one second to the most. (This is a juicy example of the impact that language has on imagination [Orwell 1949].)

4.4.3 He just didn't notice

Burckhardt used double logarithmic diagrams of the distribution function to illustrate his concepts. Eq. (9) may be transformed to

$$G(t) \doteq \ln(\ln(1-F(t))) = B\ln(t) - [B\ln(T)] \tag{14}$$

thus $G(t)$ being a linear function of $\ln(t)$. The Weibull distribution therefore is represented by a straight line in such a diagram. As noted earlier, all distribution functions $F(t)$ all look more or less the same and taking the double logarithm produces a distortion that puts the rest to it. Maybe Burckhardt just didn't notice how far off his approximation was.

5 Other aspects of the DVG model

Inspired by the two distributions «found» in the data, Burckhardt developed a cascading model of human signal processing and reaction, Fig. 6. Based on this model, $f(t)$ would be the result of two cascaded processes. The distribution function $f(t)$ might then be calculated from the known distribution functions of the two processes.

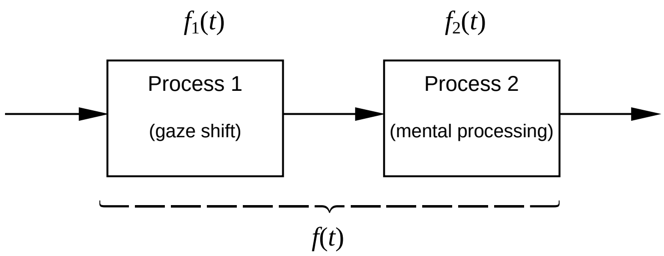


Figure 6. Cascading two stochastic processes

This concept was broadened to the mechanical aspects of the response, i.e. foot moving time, deceleration build-up time and so on. This lead to the recommendations given in Table 2, which may be considered as the «taylorisation of human reaction time». The total reaction time is the result of several components that may be combined arbitrarily. Gaze shift is considered to be necessary each time the reaction stimulus appears extrafoveal, that is more than 0,5° off the center of gaze. (Nobody seems to care that this applies to almost any sudden stimulus in traffic.) In case of gaze shifts more than 5°, a saccadic correction has to be taken into account as the first gaze shift may not have led to precise fixation. Note that all processes but gaze shift and mental processing are more or less constants, the lower and upper percentiles not being much apart. The 2% and 98% percentiles do not just sum up. This is by intention, as the percentiles of the summary distribution of cascaded processes are not just the sum of the according percentiles of the single processes.

Table 2. DVG Taylor model of reaction process

	2%	**50%**	**98%**
Gaze shift < 5°	0.32 s	0.48 s	0.55 s
Saccadic correction (for > 5°)	0.09 s	0.13 s	0.15 s
Mental processing	0.22 s	0.45 s	0.58 s
Foot moving time	0.15 s	0.19 s	0.21 s
Deceleration build-up time	0.17 s	0.22 s	0.24 s
Basic reaction time	0.54 s	0.86 s	1.03 s
+ gaze shift < 5°	0.86 s	1.34 s	1.58 s
+ gaze shift > 5°	0.95 s	1.47 s	1.73 s

Again, Burckhardt made a mathematical error when assuming the summary distribution function to be Weibull, too. If the two processes are uncorrelated, all possible results of both processes may be combined arbitrarily. Therefore, the distribution function of the summary process has to be calculated by the *convolution integral*

$$f(t) = \int_{-\infty}^{\infty} f_1(t)\ f_2(t-\tau)\, d\tau \tag{15}$$

Cascading two uncorrelated Weibull processes will not give a Weibull distribution. Besides that, the cascading model is theoretically questionable. The human brain is no production line, starting the next process when its predecessor has finished. Even if we accept that a gaze shift is needed prior to conscious reaction, the presence of potential threat – initiating the gaze shift – will lower the trigger threshold and fasten the reaction.

5 International usage

It is rather difficult to summarize international usage of reaction time by jurisdiction. First of all we should distinguish between Roman law and Anglo-American Common Law, the first named tending to more general settlements, the latter focussing on the case under consideration. My impression is, that while continental Europe tends towards the German «standard», reconstructionists in GB and the USA strictly reject the idea of standardizing reaction time usage. This is probably also due to the fact that the opposing parties would not (both) accept a reaction time settled by a technical expert.

In 1999, I used an international e-mail forum for a survey and got several answers from both the USA and GB. The answers exhibited a considerable variation in the values used, stretching from 0.7 s to 1.5 s «as a starting point», combined with a tendency to consider a range instead of a single value.

In GB, the National Highway Code suggests a reaction time of 0.68 s, what somewhat lowers the «British mean value». (The Highway Code is a small reader that comprises the golden rules of driving which have to be learned by any novice driver.) The «recommendation» of the Highway Code is based on the bare fact, that the vehicle then will traverse one feet per each mph of driving speed during the reaction, i.e. $t_r = 1.609 / (3.6 \cdot 0.3048)$ s. In its latest edition, the value has been lowered to 0.67 s, now resulting in 3 meters per every 10 mph (British version of adapting SI-units). According to a personal information given to me by Richard Lambourn, 1.0 – 1.5 s are favored in GB. This maybe lowered to 0.7 s in case that there is some degree of warning to the driver, or, likewise, risen up to 2 s (or even more) if the environment is one where no hazards at all would be expected – a quiet motorway, for example.

Generally speaking, Paul Olson's book [Olson 1996] has had a great impact on reaction time usage in English speaking countries. It is indeed a good source of information when concerning driver reaction times in crash avoidance. The prudent recommendations given at its end propose a range of 0.75 – 1.5 s in the most simple situations.

6 Conclusions

We still support the idea of «standards» (or «guidelines» as this term does not seem to be that much opposed to in Anglo-American countries). Guidelines are still better than every expert using his own favorite reaction time.

The DVG took the right approach when it decided to treat reaction times statistically, but its upper bound was drawn too tight, even Burckhardt's experiment proving better. The further processing applied to the raw data was based on questionable arguments. The shortcomings of the mathematical treatment have produced an artificial effect, that is not observed when using the right means.

Jurisdiction should accept what the raw data of the experiment tells us: A reaction time of 1.5 s has to be accepted in the most normal situation, as is the lit of the brake lights of the car just ahead. This has nothing to do with gaze shift, in fact we can think of situations where a gaze shift is unacceptable, even if the reaction stimulus appears peripherally [Hugemann 1996].

The taylor model of human reaction recommended by DVG may sound reasonable to the mechanical engineer, but the human brain is no production line. The mechanical aspects of the reaction may be treated that way, but one sure cannot just add gaze shift time to mental processing time to get an overall result.

In the early eighties, the upper limit of the reaction time was not that much of interest, as cars left skid marks in most cases and longer reaction times put the driver at disadvantage. Nowadays, skid marks have become rare (and a German police sketch noting them even rarer). In this situation, long reaction times put the driver in advantage. (German reconstructionists have been lucky so far as nobody seems to have reported this to German lawyers.)

Whatever upper limit we are going to accept in the future, reconstructionists should neither think of the reaction time as a constant nor treat it that way. In civil litigation the reconstructionst most often investigates two scenarios – one that favors the plaintiff and one that favors the defendant. In these scenarios he should also adapt the reaction times accordingly.

The matter of driver reaction times in crash avoidance is not settled yet and still calling for research work. As nobody (apart from those involved in litigation) seems to be interested in accidents that have already happened, researchers have to think about other justifications for their interest. They might raise money if they put the focus on the influence that reaction time has on crash avoidance (especially when super-focussing on the effects that aging of our society has).

The EVU should take the challenge to make a new attempt on the theme. We need facts for a severe discussion in case anyone should ever talk out the contents of this paper to German lawyers.

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