What's Your Reaction Time When Stopping?

Harrington Driver Training Services

Reaction times vary greatly with the situation and from person to person. Some accident reconstruction specialists use 1.5 seconds. A controlled study in 2000 [1] found average driver reaction brake time to be 2.3 seconds. The human perception is how long the driver takes to see the hazard, and the brain to realize requiring an immediate reaction. The perception can be as long as a quarter to half a second at 100km/h means a car travels 110 metres before the brakes are applied. On the road, distractions, speed, driving experience, and physical and cognitive fitness can seriously affect reaction times. This paper examines reaction times when driving and its various components. It also looks at age and gender as they relate to reaction times. It compares the reaction times of the average driver to that of racing drivers or fighter pilots which is quite considerable. It concludes with final comments.

What's Your 'Reaction Time' When Stopping?

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> ***Reaction time is the time it takes you to react to a hazard. It involves these steps: (1) seeing something; (2) recognizing it's a hazard; (3) deciding whether to brake or steer around the object and (4) reacting to it. Reaction distance is the distance the vehicle travels during your reaction time. The distance depends on the reaction time (in seconds) and speed (in feet per second).*** [1]

Introduction

The reaction time of drivers has been researched extensively over many years in various ways, often with different results. The reaction time of a driver is referred to as perception-response time. What is meant by perception-response time? ***Olsen (2003)*** [2] describes it as this time as having four major steps which a driver goes through when reacting to an event. The first of these is detection, something comes into the field of view of the driver and ceases once the driver is consciously aware of it. The second stage is known as identification where the driver needs to take in as much information as possible to allow a decision to be made as what to do. The third is the decision, where the driver makes the decision of how he is going to react to the situation, such as do nothing, steer or brake. Lastly, the response and the action and where the action is carried out. These four steps will be adhered to for an unexpected situation; however, for experimental purposes especially, they can all be altered or some removed from the sequence to shorten the time. An example of this is enabling the driver to react to a situation by a single response, such as to apply the brakes and then the decision time has been removed from the four stages.

Racing Driver/Fighter Pilot – 0.2/0.3 Seconds

Driver reaction time is the length of time it takes for a person or system to respond to a given stimulus or event. Reaction time is measured for various reasons in order to identify and manage a slow reaction time. Athletics, emergency management systems and even animal attacks are measured to determine the time between the application of a stimulus and the needed reaction. In driving, changes by fractions of a second in reaction time may mean the difference between a collision and the avoidance of one.

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[1] Driving Tests. drivingtests.co.nz

[2] *Driver reaction times to familiar but unexpected events.* G. Coley *et al.* Published project Paper. PPR 313. TRL Ltd.

On the road, distractions, speed, driving experience, and physical and cognitive fitness can seriously affect reaction times. Even drivers with relatively quick reaction times in normal circumstances may see drastic changes based on distractions, driving under the influence of alcohol or drugs, sleepiness, acute illnesses or stress. One study from Texas shows texting while driving nearly doubled a driver's reaction time. One common variable affecting average reaction time is age. As drivers age, physical and cognitive functions slow, causing an increase in the time between when a stimulus (or road hazard) is recognized, and the time the driver reacts by braking or turning the wheel. In many cases, the speed with which a person can respond - "reaction time"- is the key to assigning liability. It is common practice for those who reconstruct accident scenes to simply use a standard reaction time number, such as 0.7 seconds, when analyzing a case. In fact, reaction time is a complicated behaviour and is affected by a large number of variables. There can be no single number that applies universally. Studies reflect that a person's reaction time is anywhere from one to three seconds. In general, three seconds is probably more accurate. Other factors, however, can increase reaction time. These include the person's physical condition, age, and experience; fatigue; hypothermia; drugs and alcohol. Reaction time is a surprisingly complex topic and varies from one driver to the next. A professional racing driver who is physically fit and trained in high-speed driving might have a reaction time of 0.2/0.3 seconds for a given situation. Also a fighter pilot's reaction could be as low as 0.2 seconds while the average motorist may have a slower reaction time of 0.5 seconds, 0.8 seconds or even one second or more. Unfortunately, most "experts" used canned numbers without a good appreciation for where the numbers originate, how they were obtained or the variables that affect them. Moreover, there are several distinct classes of reaction time, each with somewhat different properties. In this article, some keys issues are briefly described. The discussion focuses primarily on driver reaction time.

Driving Simulators

An article featured on the website [3] discusses reaction times and the variations in speed between motorists. *"You might have a rough idea, even an inflated one, of how good your reactions are, but your own time is difficult to measure unless you have a proper medically-verified check."* Driving simulators can be used to objectively measure reaction times. Simulations can incorporate various hazards such as other vehicles, pedestrians or animals in the roadway.

[3] www.howacarworks.com

The simulator measures and records the time from when the hazard is displayed and to the time the potential hazard that occur on the roadway. Simulator scenarios can also be used to provide practice and training tools to improve reaction times. Clinical simulators can steadily increase the difficulty of simulations to heighten a driver's awareness, and increase reaction speed over time. For aging drivers, simulator feedback can provide insights on adjusting and/or limiting driving to account for slower reaction times. This can be helpful when drivers are reluctant to admit any decline in driving fitness. Safe drivers of any age must account for their own reaction times and the reaction times of others around them. Driving at night, inclement weather and other factors require a greater space between other vehicles and hazards to account for slow reaction times. While the most effective way to improve reaction time is to exercise your mind and body, there are ways to compensate for slower reaction times and eliminate driving distractions.

Reaction Time Components

When a person responds to something s/he hears, sees or feels, the total reaction time can be decomposed into a sequence of components:

1. Mental Processing Time

This is the time it takes for the responder to perceive that a signal has occurred and to decide upon a response. For example, it is the time required for a driver to detect that a pedestrian is walking across the roadway directly ahead and to decide that the brakes should be applied. Mental processing time is itself a composite of four sub stages:

- ✓ *Sensation:* the time it takes to detect the sensory input from an object. ("There is a shape in the road.") All things being equal, reaction time decreases with greater signal intensity (brightness, contrast, size, loudness, etc.), foveal viewing, and better visibility conditions. Best reaction times are also faster for auditory signals than for visual ones. This stage likely does not result in conscious awareness.

- ✓ *Perception/recognition:* the time needed to recognize the meaning of the sensation. ("The shape is a person.") This requires the application of information from memory to interpret the sensory input. In some cases, "automatic response," this stage is very fast. In others, "controlled response," it may take considerable time. In general, novel input slows response, as does low signal probability, uncertainty (signal location, time or form), and surprise.

- ✓ *Situational awareness:* the time needed to recognize and interpret the scene, extract its meaning and possibly extrapolate into the future. For example, once a driver recognizes a pedestrian in the road, and combines that perception with knowledge of his own speed and distance, then he realizes what is happening and what will happen next - the car is heading toward the pedestrian and will possibly result in a collision unless action is taken. As with perception/recognition, novelty slows this mental processing stage. Selection of the wrong memory schema may result in misinterpretation.

- ✓ *Response selection and programming*: the time necessary to decide which if any response to make and to mentally program the movement. ("I should steer left instead of braking.") Response selection slows under choice reaction time when there are multiple possible signals. Conversely, practice decreases the required time.

Lastly, electrophysiological studies show that most people exhibit preparatory muscle potentials prior to the actual movement. In other words, the decision to respond occurs appreciably faster than any recordable response can be observed or measured. These four stages are usually lumped together as "perception time," a misnomer since response selection and some aspects of situational awareness are decision, not perception.

2 Movement Time

Once a response is selected, the responder must perform the required muscle movement. For example, it takes time to lift the foot off the accelerator pedal, move it laterally to the brake and then to depress the pedal. Several factors affect movement times. In general, more complex movements require longer movement times while practice lowers movement times. Finally the Yerkes-Dodson Law [4] says that high emotional arousal, which may be created by an emergency, speeds gross motor movements but impairs fine detailed movements.

3 Device Response Time

Mechanical devices take time to engage, even after the responder has acted. For example, a driver stepping on the brake pedal does not stop the car immediately. Instead, the stopping is a function of physical forces, gravity and friction.

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[4] The Yekes Dodson Law suggests that there is a relationship between performance and arousal. Increased arousal can help performance but only up to a certain point. Where arousal becomes excessive, performance diminishes. The Yekes Dodson Law & Performance. verywellmind.com

Here's a simple example. Suppose a person is driving a car at 55 mph (80.67 feet/sec) during the day on a dry, level road. He sees a pedestrian and applies the brakes. What is the shortest stopping distance that can reasonably be expected? Total stopping distance consists of three components:

- ✓ ***Reaction Distance.*** First. Suppose the reaction time is 1.5 seconds. This means that the car will travel 1.5 x 80.67 or 120.9 feet before the brakes are even applied.

- ✓ ***Brake Engagement Distance***. Most reaction time studies consider the response completed at the moment the foot touches the brake pedal. However, brakes do not engage instantaneously. There is an additional time required for the pedal to depress *(Take up the slack or "feel in" Ed.)* and for the brakes to engage. This is variable and difficult to summarize in a single number because it depends on urgency and braking style. In an emergency, a reasonable estimate is .3 second, adding another 24.2 feet.

- ✓ ***Physical Force Distance***. Once the brakes engage, the stopping distance is determined by physical forces ($D=S^2/(30*f)$ where S is mph) as 134.4 feet.

Total Stopping Distance = 120.9 ft + 24.2 ft + 134.4 ft = 279.5 ft

Almost half the distance is created by driver reaction time. This is one reason that it is vital to have a good estimate of speed of human response. Below, are some values which are derived from experience and from an extensive review of research results? Response speed depends on several factors so there can be no single, universal reaction time value. Here is a list of factors which affect reaction time. In all cases, the times assume daylight and good visibility conditions.

Expectation

Reaction times are greatly affected by whether the driver is alert to the need to brake. Alertness can be divided into three classes:

- ✓ ***Expected:*** the driver is alert (concentrating) and aware of the good possibility that braking will be necessary. This is the absolute best reaction time possible. The best estimate is 0.7 second. Of this, 0.5 is perception and 0.2 is movement, the time required to release the accelerator and to depress the brake pedal.

- ✓ ***Unexpected:*** the driver detects a common road signal such as a brake from the car ahead or from a traffic signal. Reaction time is somewhat slower, about 1.25 seconds. This is due to the increase in perception time to over a second with movement time still about 0.2 second.

- ✓ ***Surprise:*** the drive encounters a very unusual circumstance, such as a pedestrian or another car crossing the road in the near distance. There is extra time needed to interpret the event and to decide upon response. Reaction time depends to some extent on the distance to the obstacle and whether it is approaching from the side and is first seen in peripheral vision. The best estimate is 1.5 seconds for side incursions and perhaps a few tenths of a second faster for straight-ahead obstacles.

Perception time is 1.2 seconds while movement time lengthens to 0.3 second. The increased reaction time is due to several factors, including the need to interpret the novel situation and possibly to decide whether there is time to brake or whether steering is a better response. Moreover, drivers encountering another vehicle or pedestrian that violates traffic regulations tend to hesitate, expecting the vehicle/pedestrian to eventually halt. Lastly, there can be response conflict that lengthens reaction time. For example, if a driver's only possible response requires steering into an oncoming traffic lane (to the right) there may be a hesitation.

Urgency

People brake faster when there is great urgency, when the time to collision is briefer. The driver is travelling faster and/or the obstacle is near when first seen. While brake times generally fall with greater urgency, there are circumstances where reaction time becomes very long when time-to-collision is very short. The most common situation is that the driver has the option of steering into the oncoming lane in order to avoid the obstacle. The driver then must consider alternative responses, braking vs. steering, weigh the dangers of each response, check the left lane for traffic, etc.

Cognitive Load

When other driving or non-driving matters consume the driver's attention, then brake time becomes longer. For example, on a winding road, the driver must attend more to steering the car through the turns. Another major load on attention is the use of in-car displays and cell phones. There is no doubt that both cause delays in reaction times, with estimates ranging from 0.3 to as high as a second or more, depending on the circumstances.

Stimulus-Response Compatibility

Humans have some highly built-in connections between percepts and responses. Pairings with high "stimulus-response compatibility" tend to be made very fast, with little need for thinking and with low error. Low stimulus-response incompatibility usually means slow response and high likelihood of error. One source of many accidents is the human tendency to respond in the direction away from a negative stimulus, such as an obstacle on a collision course. If a driver sees a car approach from the left, for example, the overwhelming tendency will be to steer right, often resulting in the driver steering right into the path of the oncoming vehicle. The stimulus-response capability overrides and the driver simply cannot take the time to observe the oncoming car's trajectory and to mentally calculate it simple, reflexive future position. In short, the driver must respond to where the car is now, not where it will be at some point in the future. Most people have experienced this phenomenon when going into a skid. The correct response is to turn the wheel in the direction of the skid, but it takes practice and mental concentration to avoid turning the wheel away from the skid, which is the high compatibility response.

Psychological Refractory Period

Following a response, people exhibit a "psychological refractory period." During this period, new responses are made more slowly than if there had been no previous behavior. For example, suppose a driver suddenly steers left and then right. The steer-right response will occur more slowly because it immediately followed the steer-left.

Age

Although most basic research finds that older people respond slower than younger people, the data on older drivers' braking times are not entirely clear. One problem is that different studies have used different definitions of older; that is, sometimes "older means 50, sometimes it could mean 70. Moreover, some studies find no slowing of reaction time with age. Instead, they conclude that the older driver's greater experience and tendency to drive slower compensate all or in part for the decline in motor skills. For simple, reflexive responses, healthy older people show little slowing. For complex and/or low visibility tasks, however, they can be much slower.

Gender

Although the data are not clear, it seems likely that females respond slightly slower than males.

Nature of the Signal

In the examples cited above, the driver detected a distinct signal such as a brake light, the appearance of a clear obstacle in the path, etc. Some braking cues are subtler and more difficult to detect, causing slower braking times. One of the most difficult situations occurs when a driver must detect motion of the car immediately ahead, its acceleration or deceleration. Accidents frequently occur because the driver fails to notice that the car ahead has stopped and does not apply brakes until it is too late. The general problem involves estimating time-to-collision (TTC). It is a tough problem for several reasons. One is that it is much more difficult to judge motion toward or away from you than it is to judge motion of something which cuts across your path. It's simply a matter of optics. Humans, in part, sense motion by registering the movement of an object image projected on the retina, the light-sensing portion of the eye. The movement of the object's image is much smaller with motion toward/away than with motion cutting across the frontal plane. Second, it is more difficult to judge motion of the object ahead if we are moving as well. The visual system must then disentangle the retinal image motion caused by the movement of the object ahead from the retinal image motion caused by our own "ego- motion." This is far more complex a problem than judging motion of an object when we are stationary. Third, the normal expectation is that cars do not stop in the middle of the road. Reaction time, as explained above, is much slower when people encounter a low probability or unexpected event.

Visibility

Reaction time increases in poor visibility. Low contrast, peripheral viewing, bad weather, etc. slow response. Moreover, virtually all reaction time studies have been performed in high light, photopic visibility conditions. At night in urban areas, vision operates in the mesopic [5] range, so there is mixed rod-cone activation. The few existing data suggest that reaction time sharply increases as the rods become the primary photoreceptor. On the other hand, there are some situations in which response is faster in low light. For example, light emitting sources, such as rail-highway crossing signals or brake lights, produce better reaction times at night. With no sun or skylight to reflect off the fixture and with a darker background, the signal has higher contrast and greater visibility.

[5] The terms mesopic and scotopic refers to ranges of human vision adaptation level, which differ in anatomical response spectrum and their effect on visual acuity. The Illuminating Engineering Society of North America. Spectral Effects of Lighting on Visual Performance at Mesopic lighting levels.

Response Complexity

More complex muscular responses take longer. For example, braking requires lifting the foot from the accelerator, moving laterally to the brake pedal and then depressing. This is far more complex than turning the steering wheel. While there have been relatively few studies of steering reaction time, they find steering to be 0.15 to 0.3 second faster. Perception times are presumably the same, but assuming the hands are on the steering wheel, the movement required to turn a wheel is performed much faster than that required to move the foot from accelerator to brake pedal.

Reaction Time At Night

The same factors affecting reaction in daylight conditions operate at night. Light level *per se*, has little effect on reaction time. For example, one study found that under scotopic [6] vision, decreasing light levels by a factor of ten only slowed reaction time by 20-25 m/sec (1/40 to 1/50 second.) However, there are new variables at work. For example, a light which might have low contrast and low conspicuity during the day because the background is bright could become highly conspicuous at night and produce faster reaction times. Always remember that contrast is what matters: people see contrast, not light.

Complex Reaction Times

In his classic *"On The Speed Of Mental Processes,"* ***Donder's (1868)*** [7] proposed a classification scheme that experts still use to distinguish among three different types of reaction time, simple (Type A) and more complex situations, choice (Type B) choice reaction time and recognition (Type C). While most of the variables affect simple and complex types in the same way, choice and recognition reaction times each add new factors that must also be considered. This occurs when there are multiple possible signals, each requiring a different response. The responder must choose which signal was present, and then make the response appropriate for that light. This requires two processes not present in simple reaction time: 1) signal discrimination - decide which signal occurred and 2) response selection - choose the response based on which signal occurred. In the classic laboratory procedure, a person sits with his/her fingers on 2 different telegraph keys and waits for one of 2 different lights to flash.

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[6] The terms mesopic and scotopic refers to ranges of human vision adaptation level, which differ in anatomical response spectrum and their effect on visual acuity. The Illuminating Engineering Society of North America. Spectral Effects of Lighting on Visual Performance at Mesopic lighting levels.

[7] Donder's was most interested in how long it took for individuals to make a decision and he measured this by paying attention to how long their reaction time was. He used something called simple reaction time task where he had individuals press a button when a light was illuminated. google.com

When a signal occurs, s/he releases the telegraph key assigned to that signal. Reaction time is again the time between light onset (signal) and release of the key (response.) With multiple signals, the responder cannot simply detect the signal but must also recognize which signal occurred and then mentally program the correct response. These extra mental operations slow reaction. The standard lab version of this paradigm has a subject with his/her fingers on telegraph key and waits for one of x different lights to flash. When the signal light occurs, s/he releases the telegraph. If one of the non-signal lights occurs, then the subject should make no response. This is sometimes called the "go, no-go" paradigm. Reaction times are invariably longer than for simple reaction time. A good example would occur when a police officer confronts a "suspect." The officer sees something in the suspect's hand and must make a go (shoot) or no-go (don't shoot) decision.

Accidents occur in just a few seconds, so think of your speed in feet per second (multiply mph by 1.46667).

- 15 mph = 22 ft. per second
- 30 mph = 44 ft. per second
- 45 mph = 66 ft. per second
- 60 mph = 88 ft. per second

At 30 mph with a reaction time of three seconds, the reaction distance is 132 feet (3 sec. x 44 ft. /sec.).

For the mathematically inclined, another way to change mph to feet per second:

$$\frac{\text{60 mph x 5280 feet in 1 mile}}{\text{3,600 seconds in 1 hour}} = \frac{316800}{36} = \frac{528}{6} = \text{88 feet per second}$$ *(Ed.)*

Final Comments

This article has focused on driver reaction times. While the basic principles generalize to estimating other reaction times, the exact numbers do not. Each type of reaction time has its own peculiarities that must be examined. For example, reaction time for a shooter who is tracking a target might be 0.3 second, but even this would be a function of trigger pull weight. [8] [9]

[8] This is a brief summary/elaboration of the article, *"'How Long Does It Take to Stop?'* Methodological Analysis of Driver Perception-Brake Times" *Transportation Human Factors*, **2**, pp 195-216, 2000.

[9] See Green, M. (2017). *Roadway Human Factors: From Science To Application*. Tucson: Lawyers & Judges Publishig.

First, some braking occurs during the brake engagement period. This is best calculated by assuming that braking is half the maximum during the period. Recent data, however, suggests that the period is longer than the 0.3 second described. Second, drivers do not always depress the brake pedal to maximum or brake in a single continuous movement, so full brake engagement may never occur. Third, vehicles with air brakes require an additional component, "brake lag". Depending on the setting, air brakes have a .03 to .08 second lag before they engage. Most calculations use a nominal lag value of 0.5 seconds, adding another 40 feet to stopping distance. Many drivers will argue that fast reaction times are vital for stopping in time to avoid a potential incident. Yes, that's true but if those drivers were concentrating fully and observing, anticipating and planning ahead, perhaps such rapid-like reactions like racing drivers and fighter pilots would not be necessary as they would be able to reduce speed comfortably thus avoiding panic reactions. Also, they would have that essential ingredient that is so important to stop safely – that ingredient is simply called TIME - which is time to react to danger. You should never have to say, *"The other driver suddenly ..."* Predict what may happen, expect the worse, react comfortably and keep yourself out of trouble.