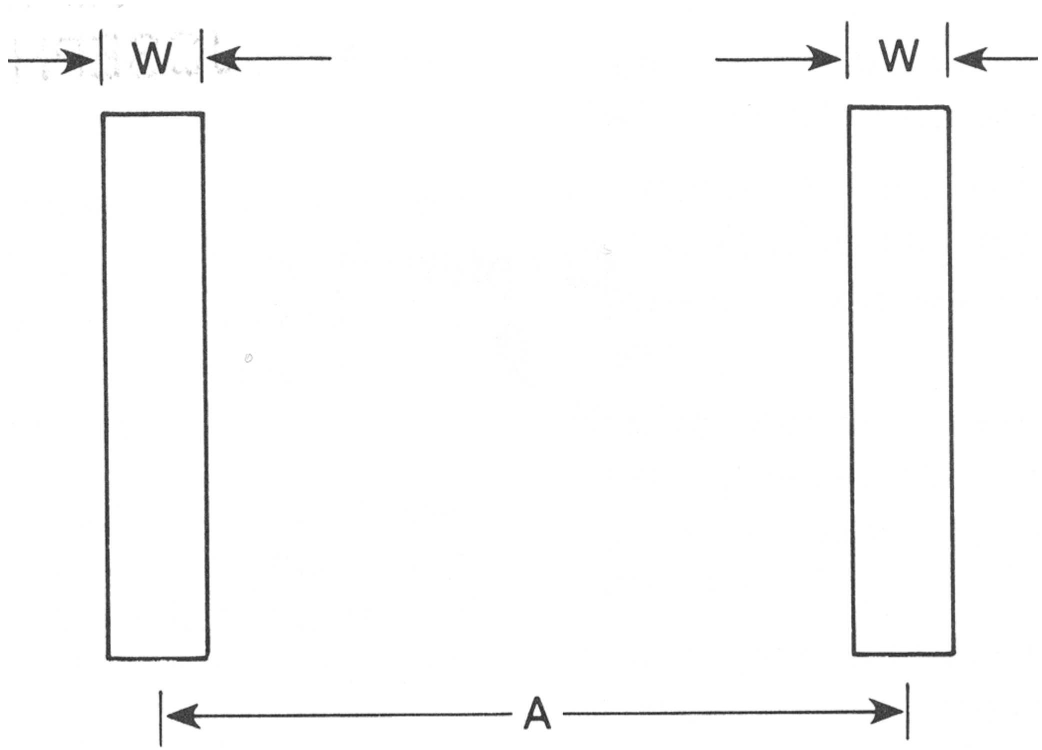
Movement

Prof. Joseph Giacomin

Fitts' Law

In 1954 Dr. Paul M. Fitts of the USAA Aero Medical Laboratory at Wright Field conducted a systematic analysis of the relationship between the speed and the accuracy of human motion.

Fitts' Law



The tests adopted the *Fitts' Paradigm* in which the participant is asked to tap a hand-held stylus alternately between two target plates as rapidly as possible for 20 seconds, while trying to limit misses to no more that 5 percent of the total. The targets were of width W and had a separation A. The test score was taken to be the number of taps (even when outside the targets) achieved in the 20 seconds.

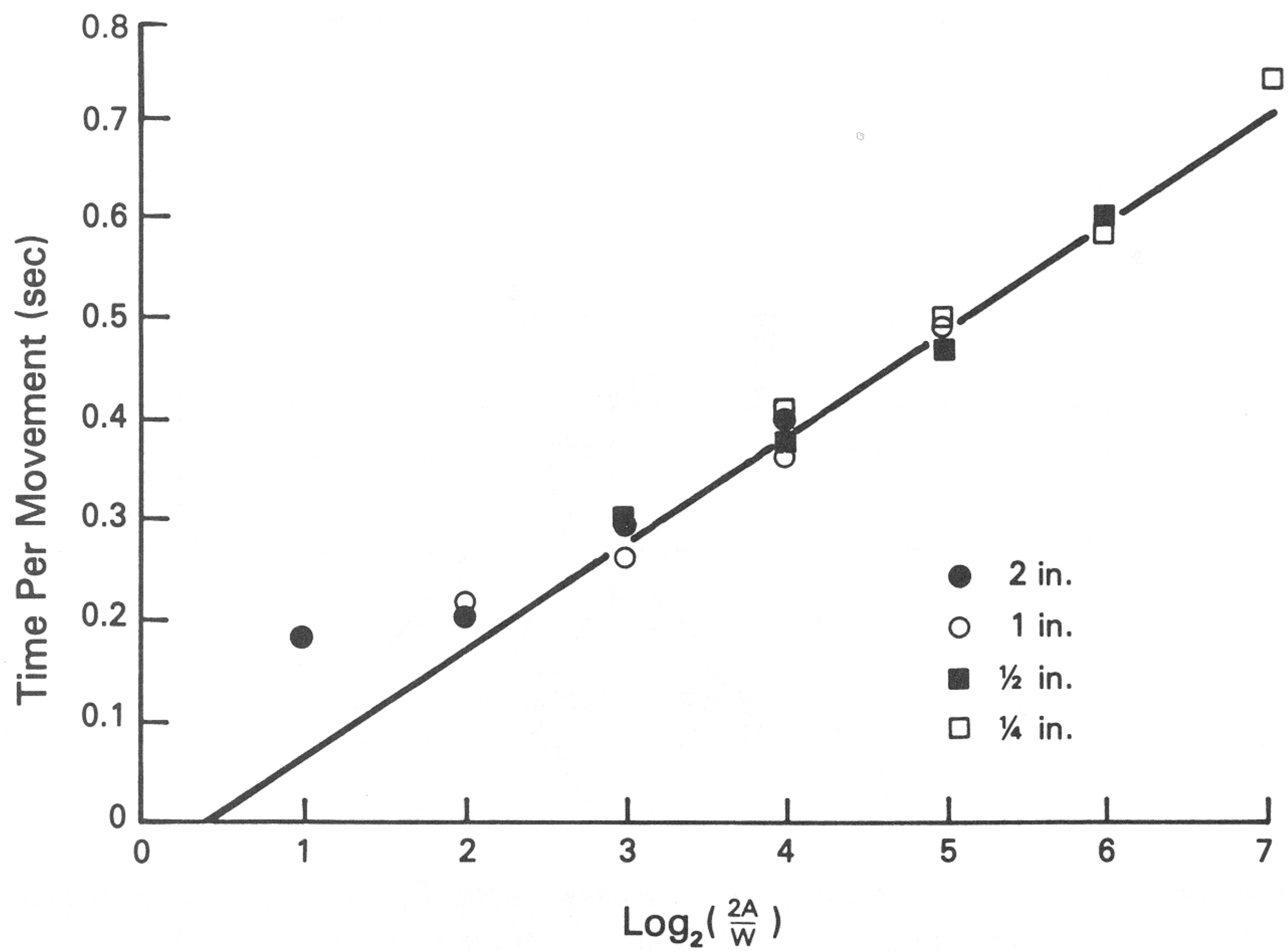
Fitts' Law

The relationship between the time taken to perform a tap and the two test parameters of the target width and the target separation lead to what is now known as Fitts' Law.

$$MT = a + b\left[Log_2\left[\frac{2A}{W}\right]\right]$$

where a and b are constants and MT is the average movement time in seconds.

Fitts' Law



The law is linear in the quantity $\log_2(2A/W)$ which Fitts called the index of difficulty.

Fitts' Law

The expression $\log_2(N)$, where N is the number of equally likely stimulus-response alternatives, is a measure of the information in bits required to solve the uncertainty about N alternatives. $\text{Log}_2(N)$ is found in many information based theories such as Hick's law.

Fitts suggested that the term $\log_2(2A/W)$ was due to the nervous system being a processor of information.

When movements are made more difficult by increasing the amplitude or decreasing the target width, more information has to be processed.

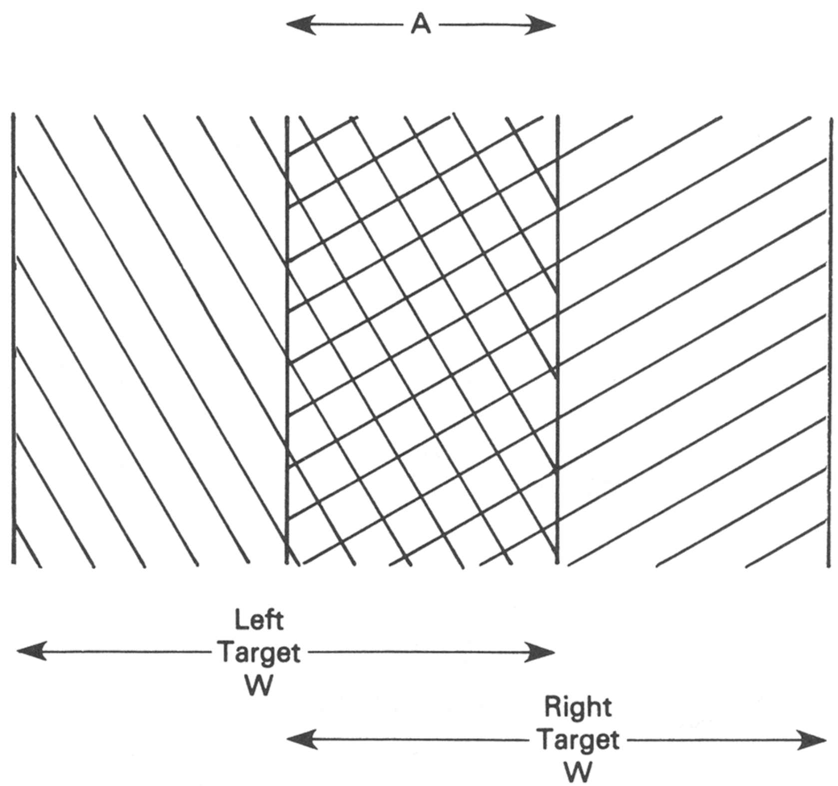
Since the amount of information that can be processed per unit time is fixed, the need to complete all the necessary processing leads to longer movement times.

Fitts' Law

$$MT = a + b\left[Log_2\left[\frac{2A}{W}\right]\right]$$

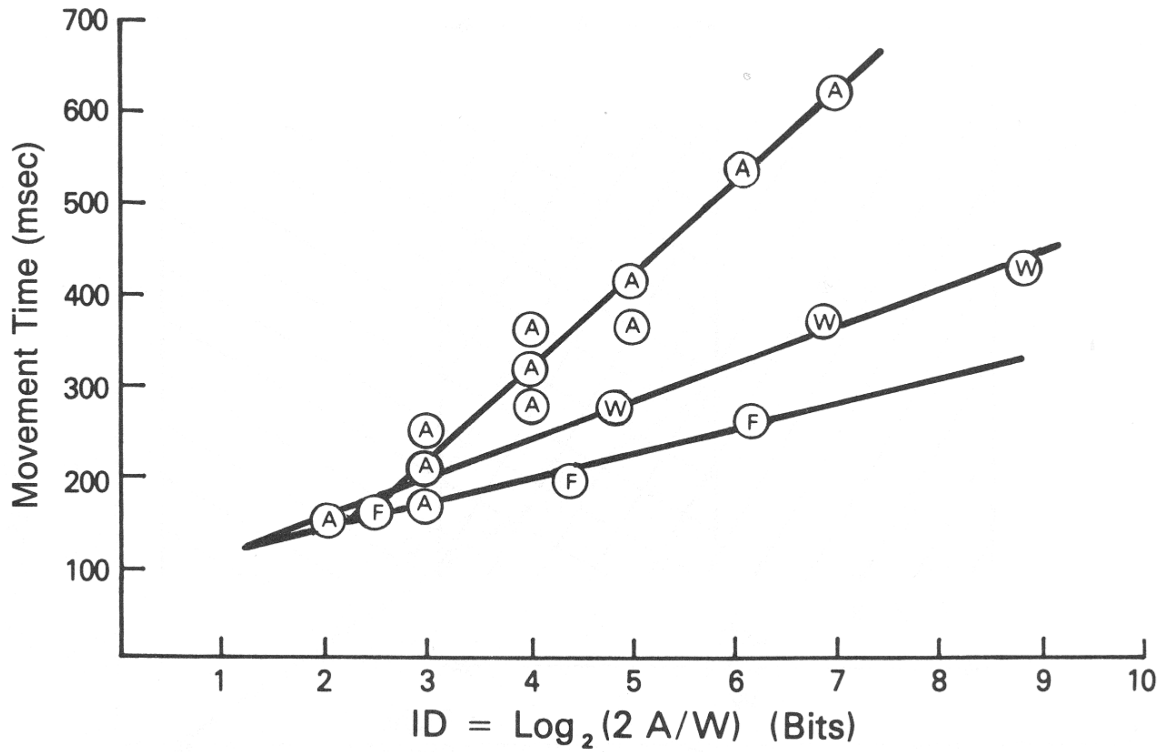
The constants a and b are determined empirically for each type of movement. The value of "a" gives the y-axis intercept, meaning the average movement time when the ID is zero.

Fitts' Law



But what is a zero index of difficulty movement ? It is one for which the ratio 2A/W is equal to 1.0 since $\log_2(1)$ is equal to zero. In this situation the separation A is one half the target width W. Since the areas overlap, tapping from one target to the other actually means tapping on a fixed point at the maximum possible rate.

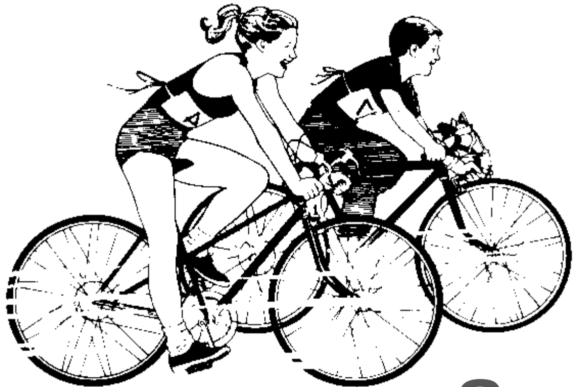
Fitts' Law



The constant b gives the slope of the relationship. It can be interpreted as the sensitivity of the limb movement to changes in ID. The graph above presents Fitts' law relationships for movements of the finger (F), wrist (W) and the arm (A). Note the increase in movement time for progressively larger limbs.

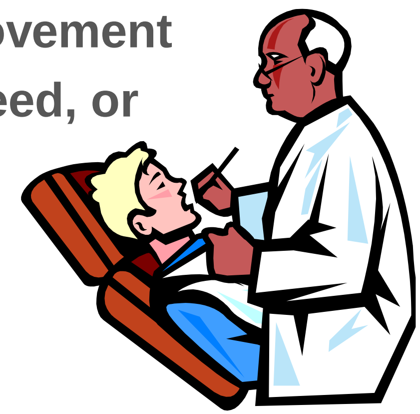
Fitts' Law

Fitts' Law has been found to apply in an impressive number of applications ranging from the motion of children to that of adults, from disabled individuals to professional athletes, for movements in air, water and in outer space, and for movements so small as to require a magnifying glass to view.

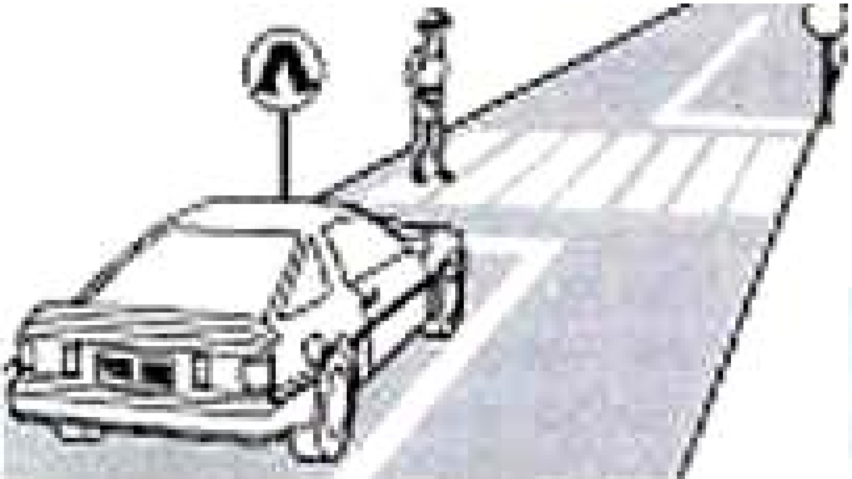


Speed-Accuracy-Trade-Off

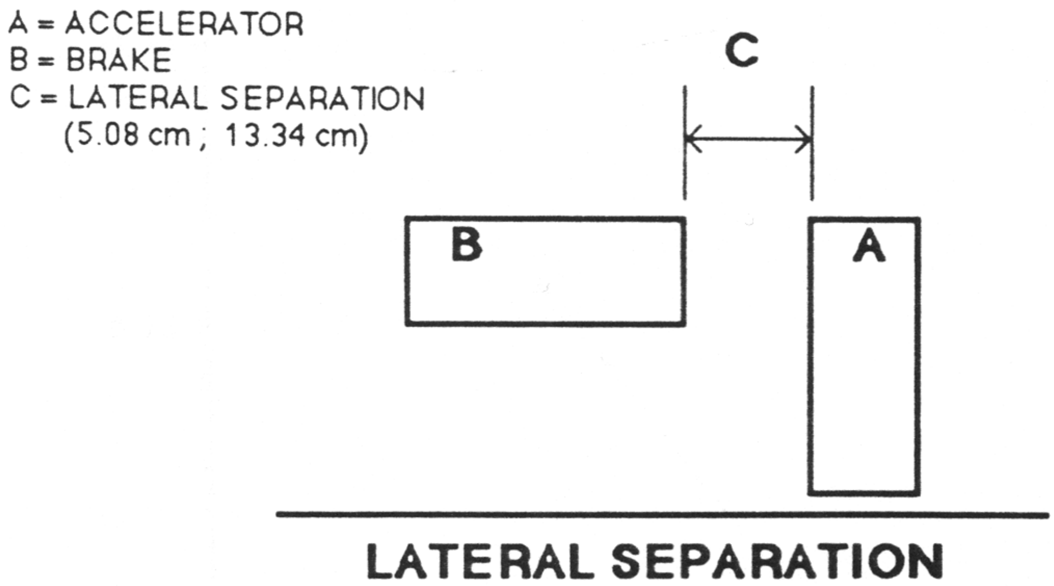
An important implication of Fitts' Law is the so called *Speed-Accuracy-Trade-off*. Since the rate of information processing is constant, movement patterns can be characterised by high speed, or high accuracy, but not both.



Movement Time

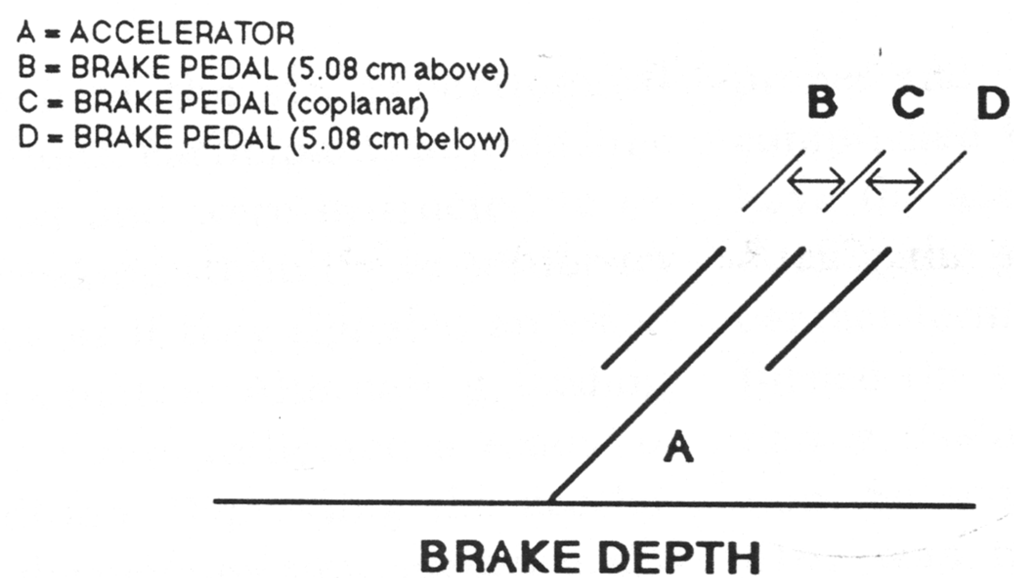


An example of the optimisation of a system based on movement time is the 1986 study by Morrison, Swope and Halcomb which measured the effect of brake pedal location on movement time. Any time reduction through better design would lead to shorter stopping distances.



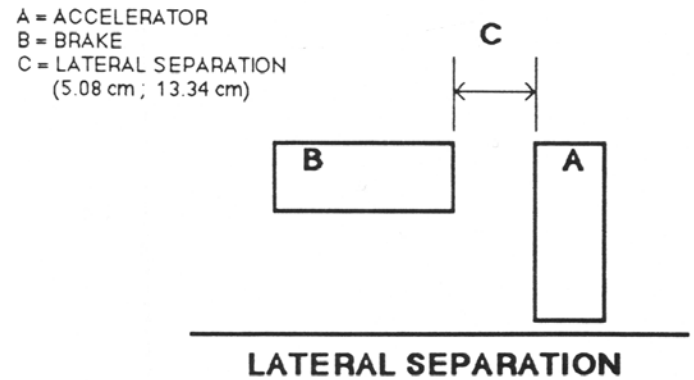
Movement Time

Three brake pedal depths and two lateral separations between brake and accelerator were tested with a total of 60 participants.



Movement Time

Reduced lateral separation between the brake and accelerator pedal was sometimes found to reduce movement time, but the effect was not statistically significant.

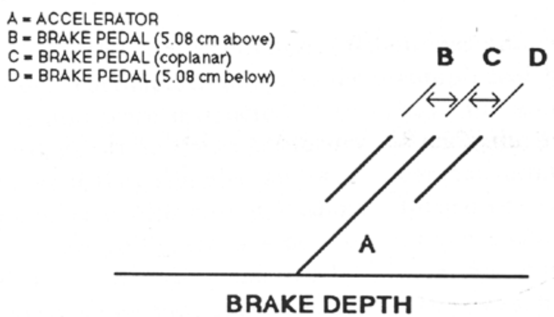


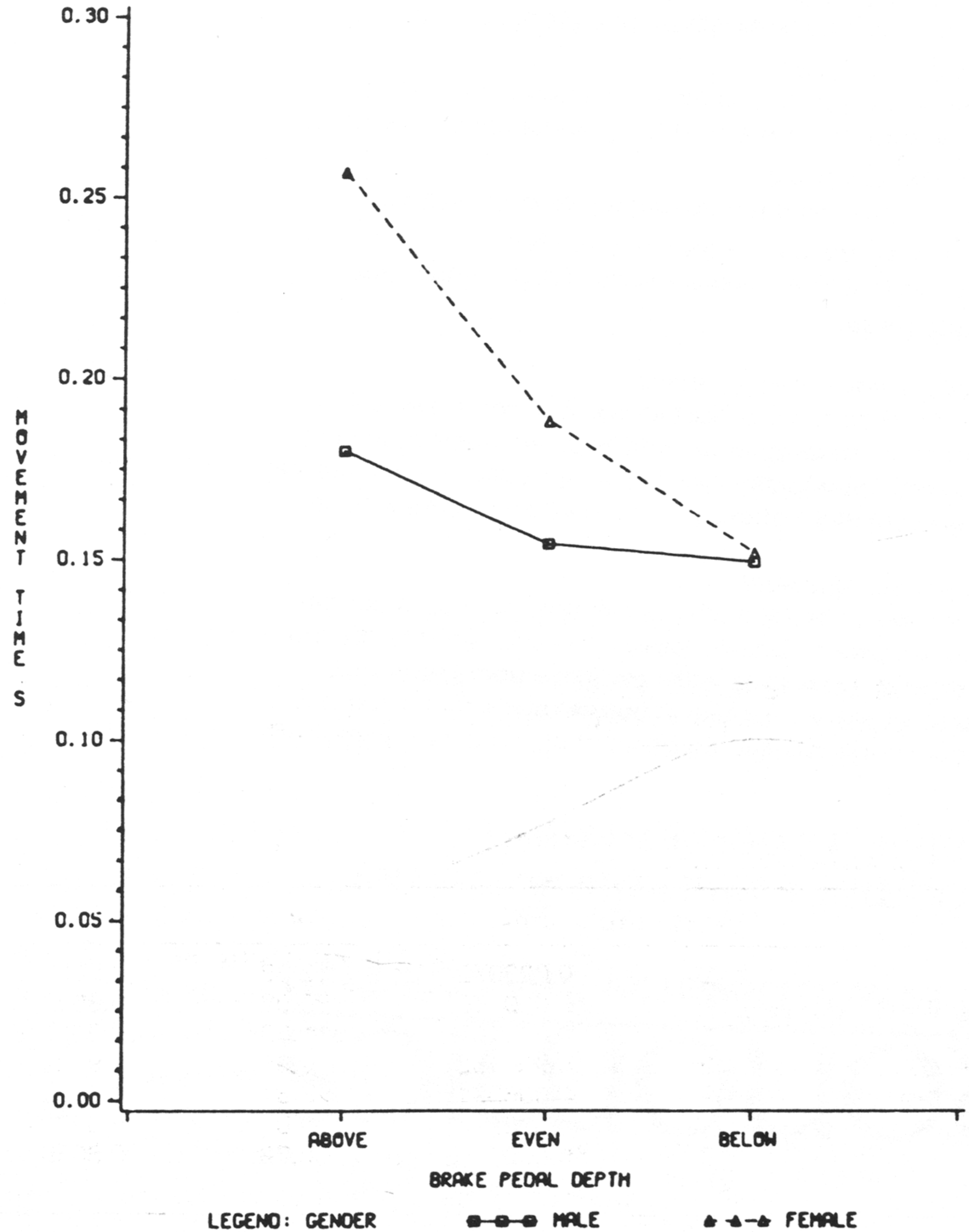
Means and Standard Deviations for Movement Times

Brake Depth	*Lateral Separation Brake/Accelerator*	*Gender*	*Mean Travel Time (s)*	*Standard Deviation*
Above	Near	Male	0.171	0.036
		Female	0.260	0.016
	Far	Male	0.190	0.036
		Female	0.254	0.074
Coplanar	Near	Male	0.153	0.034
		Female	0.188	0.049
	Far	Male	0.157	0.047
		Female	0.190	0.047
Below	Near	Male	0.155	0.051
		Female	0.151	0.050
	Far	Male	0.144	0.034
		Female	0.153	0.020

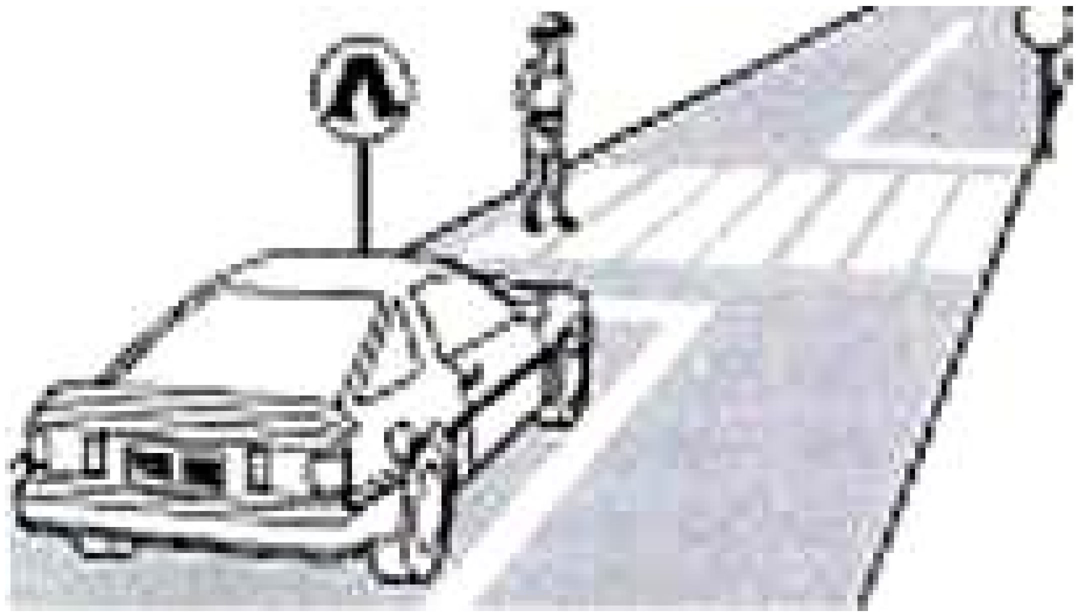
Movement Time

Reducing brake pedal depth to the same value as that of the accelerator pedal, or to less, produced statistically significant reductions in movement time.





Movement Time



The savings in movement time for the brake pedal were of the order of one tenth of a second (0.01 sec) which at a speed of 88 km/h leads to a reduction in stopping distance of 2.44 meters.

Movement Time

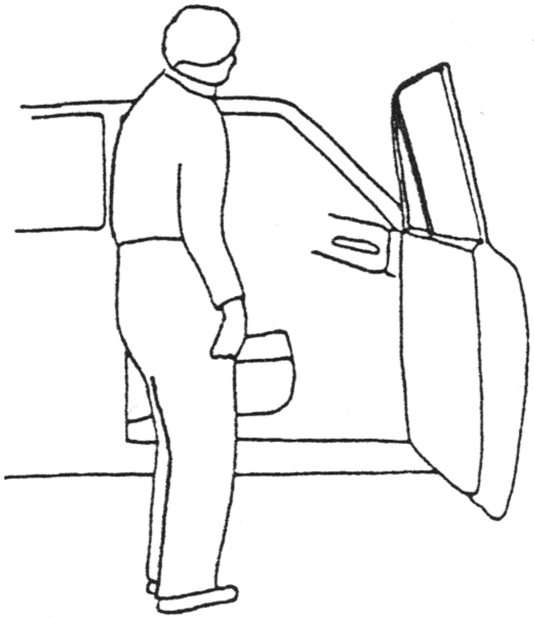
So why don’t automobile designers place the brake pedal in the same plane, or below, the accelerator pedal ?

Movement Time

Because there are Human Factors issues beyond just the movement time.

Casey and Rogers (1987) suggested that inadvertent activation of the accelerator pedal (as in the case of the Audi 5000 of the early 1980s) is more likely with coplanar pedals.

Casey and Rogers also showed that the brake pedal must be set high so as to be reachable by smaller drivers when at its maximum travel.



Movement Comfort

Movement comfort is a primary consideration in the design of structures for ingress and egress from vehicles and buildings.

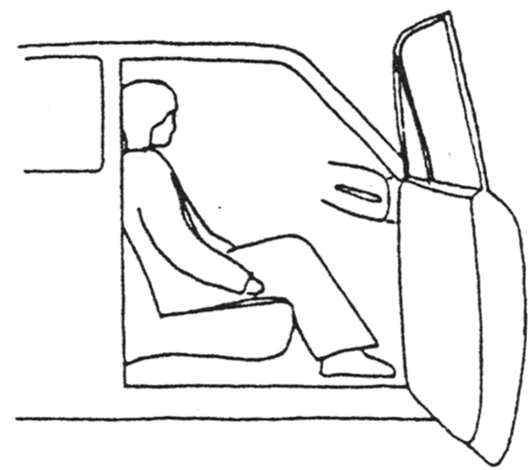
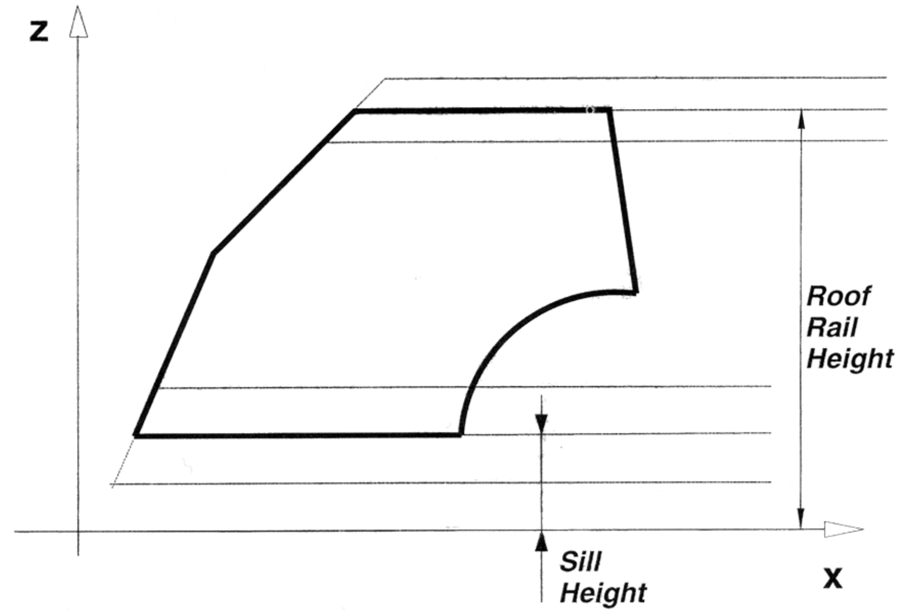


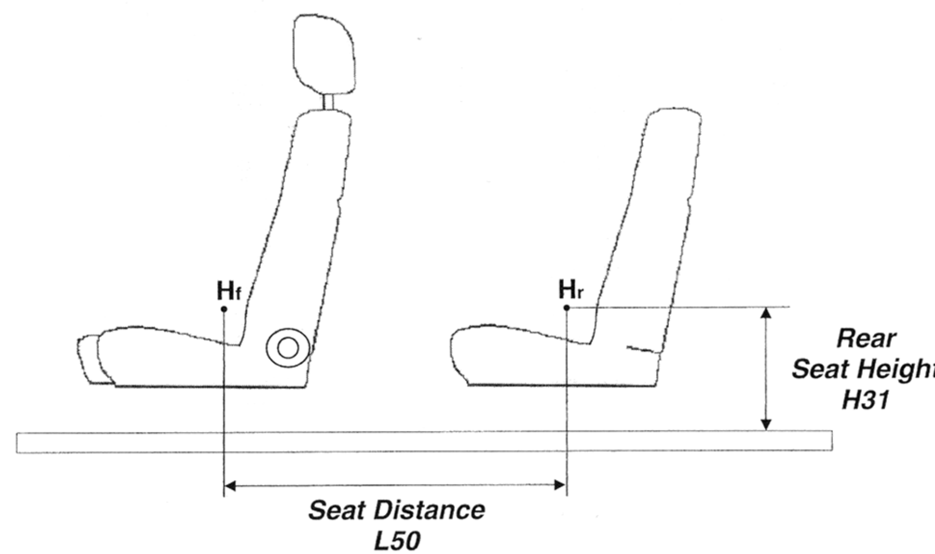
Table 2 Simulator configurations tested

Parameter	Configurations tested
Roof rail height	Base configuration +4 cm
	Base configuration +2 cm
	Base configuration
	Base configuration −2 cm
	Base configuration −4 cm
Sill height	Base configuration +2 cm
	Base configuration
	Base configuration −2 cm
Rear seat height (H31)	Base configuration +2 cm
	Base configuration
	Base configuration −2 cm
Distance between the H-points of the front and rear seats (L50)	Base configuration +4 cm
	Base configuration



Movement Comfort

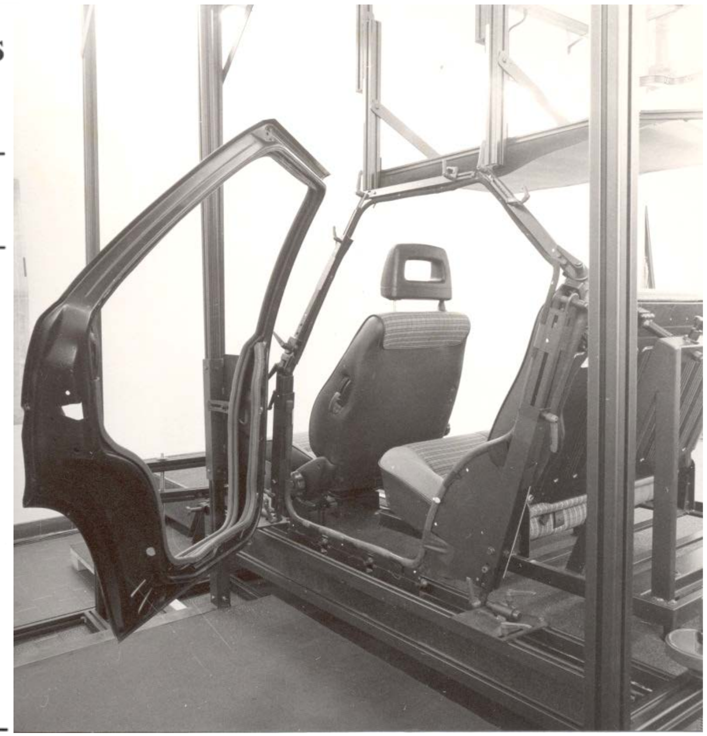
A study of automobile rear seat ingress and egress by Giacomin and Quattrocolo used a parametric door frame and seating buck to create a variety of physical situations to test.



Movement Comfort

Table 4 Number of times each part of the simulator was cited as hindering ingress/egress

Simulator component	Number if times cited in the questionnaires
Roof rail	117
Front seat	105
Sill	63
Door	61
Wheel arch	45
Rear seat	32
Rear pillar	24
Lower front pillar	15
Upper front pillar	14

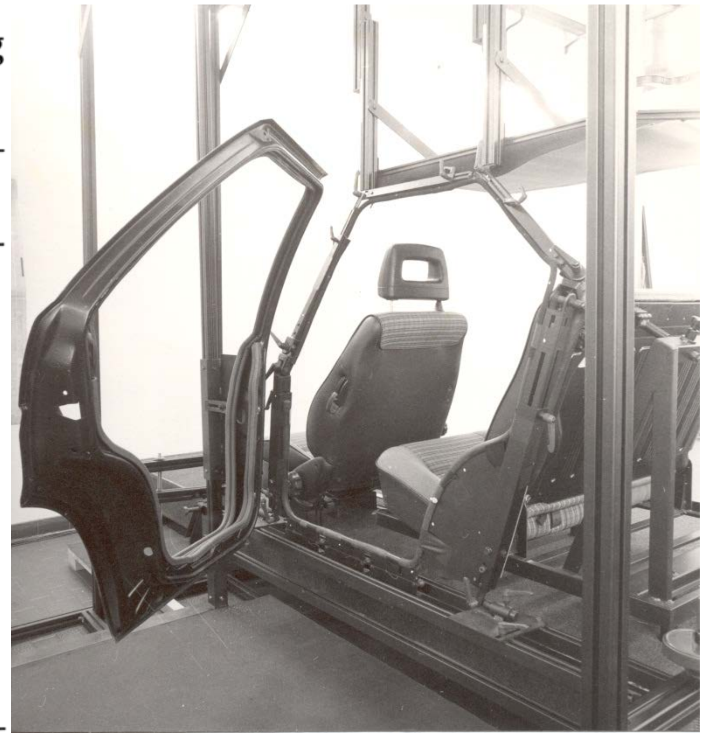


A simple checklist questionnaire permitted the identification of the most problematic vehicle structures as well as the effected human body regions.

Movement Comfort

Table 5 Number of times each body part was cited as hindering ingress/egress

Body part	Number if times cited in the questionnaires
Head/neck	26
Right foot	17
Left foot	12
Left thigh	10
Right thigh	9
Right shoulder	5
Upper back	3
Left shoulder	3
Lower back	2



A simple checklist questionnaire permitted the identification of the most problematic vehicle structures as well as the effected human body regions.

Design Classic: The Dyson Ball

Launched in 2005 the Dyson Ball is designed to move on a ball in order to steer smoothly around furniture.

Besides the comfortable three dimensional turning movement, the ball also contains the motor thus helping to achieve a lower centre of gravity for the complete device for even better manoeuvrability.

Design Classic: Tolomeo Desk Lamp

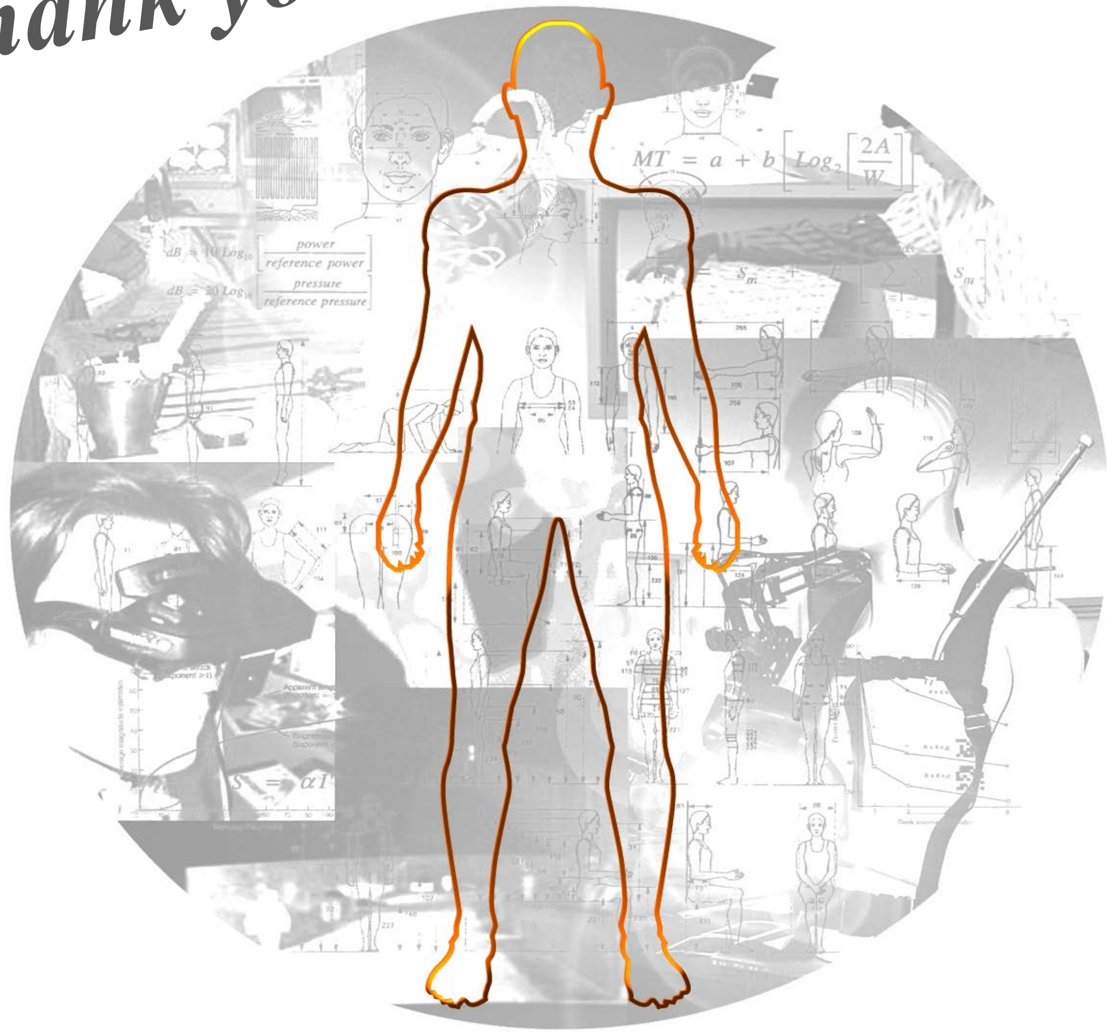
The Tolomeo desk lamp is an icon of design.

It won the Compasso d'Oro design prize in 1989.

It was designed by Michele De Lucchi and Giancarlo Fassina in 1986 for the Artemide company.

Tolomeo is the Italian version of the name Ptolemy.

Thank you.



MT = a + b Log2 [2A/W]
dB = 10 Log10 [power / reference power]
dB = 20 Log10 [pressure / reference pressure]