THE DEVELOPMENT OF AUTOMOBILE SPEEDOMETER DIALS

A BALANCE OF ERGONOMICS AND STYLE, REGULATION AND POWER

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Mitchell, 331–366
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Abstract

This paper explains the historical development of analogue and digital speedometer dial designs using the linguistics theory base of pragmatics, which asks researchers to explain a visual design by describing its purpose as well as how its various visual features meet people's needs, how people read dials and how people use dials to coordinate with one another or machines. The paper is useful for researchers interested in methodologies for studying the development of language-like visual communication, and for those interested in the history of information graphics, machine interfaces or speedometer dials in particular. A range of dial designs from the early 1900s to the current day are described and analyzed. In this paper, results show that drivers read speedometers to avoid fines, keep safe, change gears, set cruise control or record high speeds. Designs also, however, serve marketing and aesthetic purposes. Features of analogue displays are described with the paper concluding with a taxonomy of dial features. The entire system of speed containment could be improved since even with easy-to-read dials, drivers continue to speed. Dials that work with satellite systems to continually display the current speed limit may be the way of the future.

Introduction

This paper provides a case study of how the linguistics theory base of pragmatics can be used to explain the development of visual standards. In particular, the paper looks at the visual design of speedometer dials, which have developed in response to improved understanding of driver, safety and market needs, and changing visual styles, laws and technology. Linguistics provides a helpful theory base for understanding a design such as a speedometer dial since the design is closely attached to particular meanings and as such can be said to be *language-like*.

The linguist Harley (2001) said that "Pragmatics is concerned with how we get things done with language and how we work out what the purpose is behind the speaker's utterance" (337). He further explained that the field has two main branches, the first of which is how we extract meaning from language by drawing inferences, and the second is how we work together to maintain conversations. Another linguist, Clark (1996) said that the most useful way to study language use is from both social and individual perspectives.

These explanations from pragmatics are also obviously useful for the study of visual languages. A pragmatic approach to studying visuals is concerned with how we get things done with a particular design and how we read that design. In the particular case of speedometer dials, a pragmatic approach asks how individuals read and use the dials, and how the dials help people to coordinate with one another and with their vehicles.

A pragmatic approach is also helpful in understanding how a visual design develops over time. Such an approach looks at the initial need for the visual, how the visual meets the need and then how designers incrementally modify the visual over time as the design environment changes (e.g., technology changes) and designers come to better understand user needs.

Mitchell (2008) has provided a methodology for studying the development of designs from a pragmatic approach, which involves the following:

1. Selecting a category of visual communication and identifying the social situations in which it is used
2. Formulating open questions about the visual form...and the situations in which it is used
3. Collecting examples of the visual communication
4. Selecting research tools to study how the design is used
5. Writing descriptions of the visual communication and the situation in which it is used

6. Selecting methods for and conducting analyses
7. Discovering themes within the data and applying existing theories as appropriate (4).

This paper applies this methodology to explaining the development of speedometer dial designs. Chosen examples range from the earliest designs to the digital head-up displays (HUDs) available today. The selection could not be all inclusive but is meant to be representative of what designers have created over time and in different cultures to meet a range of needs. Examples were taken from Holland (1999), museum collections, scholarly articles and online sources. Individual selections were made based upon their historical significance and differences from one another. Key questions driving the research are as follows: For whom was the design made and for what purpose? What symbol sets, visual variables (shape, size, etc.), reference points and scale does it use? What is the underlying technology? What are the technological and cognitive affordances and limitations of the design in meeting user needs?

The paper begins by describing the types of marks that appear on speedometer dials, and then presents a range of designs for later discussion. Next the paper reviews literature on how people use speedometers, and then discusses how various visual variables work to meet driver and market needs. Unless otherwise noted, drawings in the paper are the author's and are close approximations of manufacturers' designs. The paper ends with a taxonomy of dial features.

Speedometer marks

To describe speedometer designs, a first step is to look at the set of marks on each dial. For analogue speedometers such as that in Figure 1, the set may be described as *multi-modal written* and *technologically mediated.*

The set of marks is multi-modal written since it consists of a dial shape, scale marks, numbers, letters, a needle and contrasting colors. The design is also technologically-mediated since the needle moves in response to accelerator pressure and the given terrain. For digital speedometers, the medium is written (consisting of numbers) and technologically mediated.

In composing a dial, the aim is to create a design that best meets the needs of several audiences, which include various drivers (e.g., on-road versus race drivers), authorities, car buyers and sellers and others such as design critics. As shown in Figures 2–5, designers have tried a variety of solutions for meeting those needs.

Figure 2 presents examples of early dials, Figure 3 presents examples of circular dials from the 1950s and 1960s, Figure 4 presents examples of linear dials from the 1950s through 1970s, and Figure 5 presents some current dials.

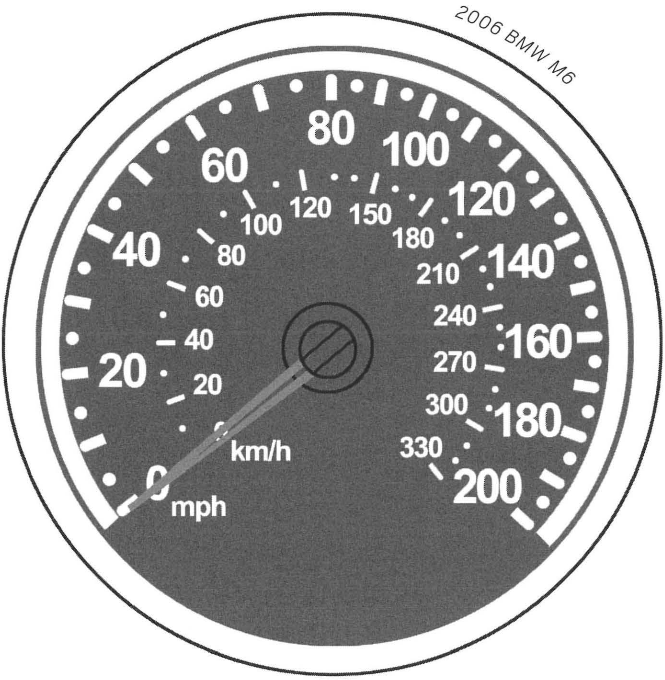


FIGURE 1:
ANALOGUE SPEEDOMETER

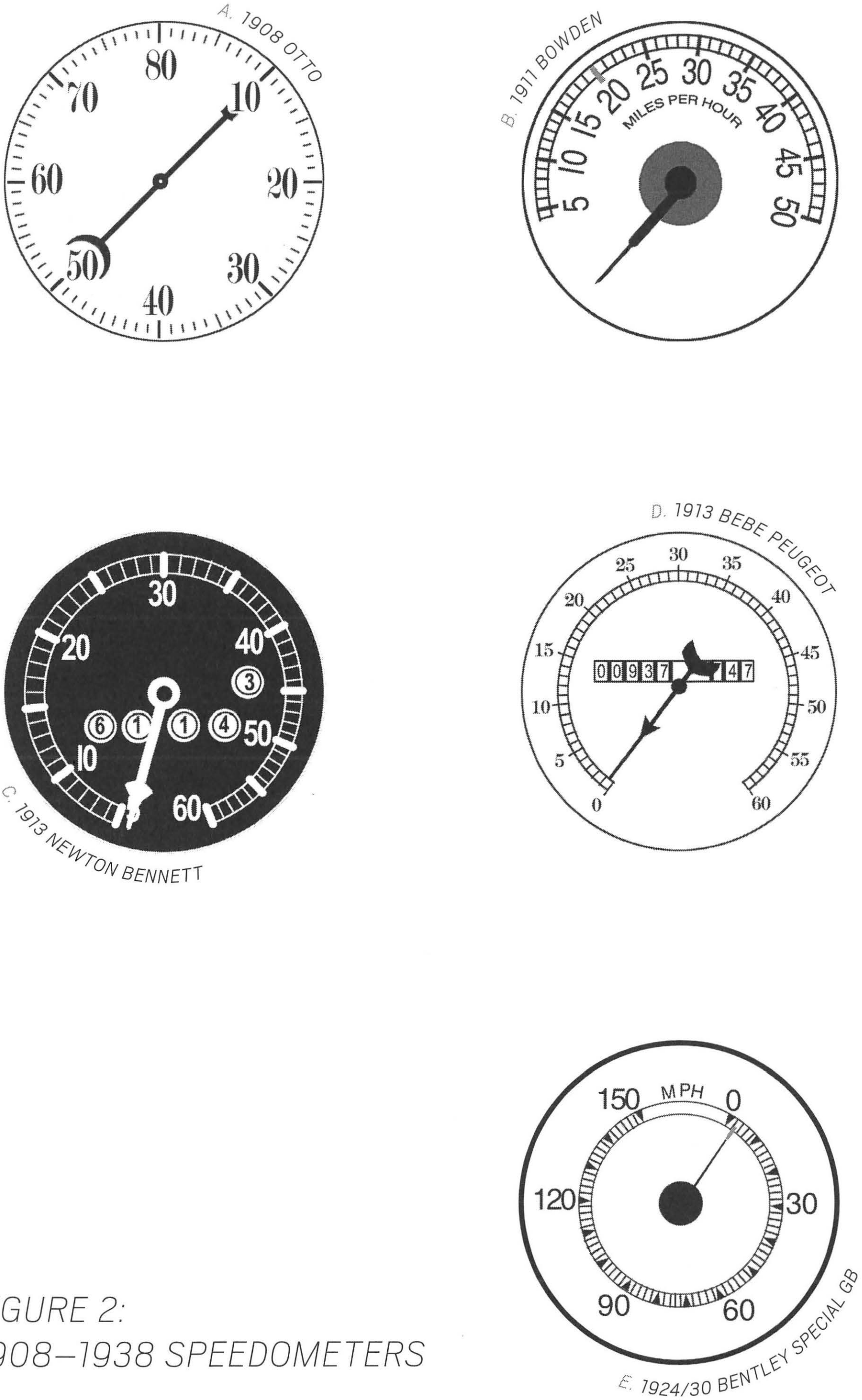
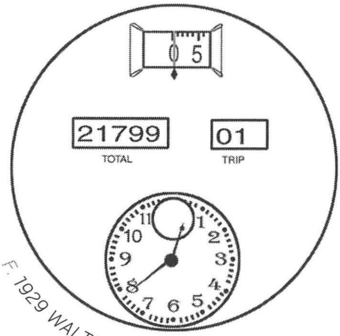
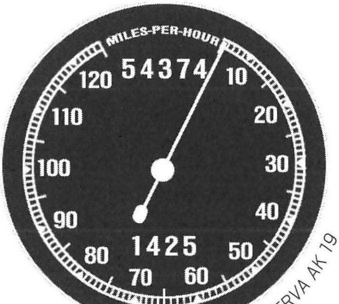


FIGURE 2:
1908–1938 SPEEDOMETERS

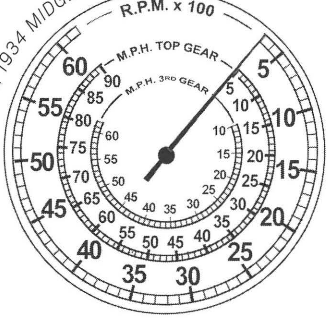


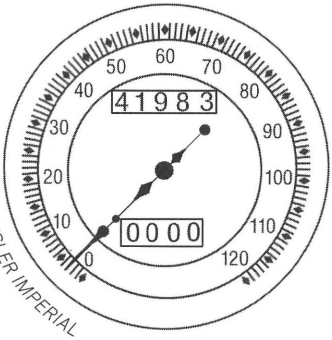
F. 1929 WALTHAM WATCH CO.



G. 1930 MINERVA AK 19

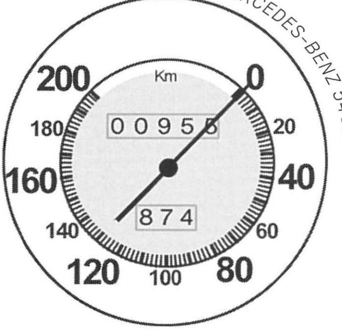
H. 1934 MIDGET PA

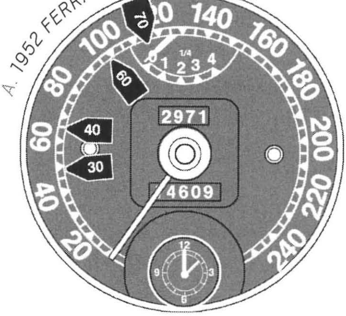




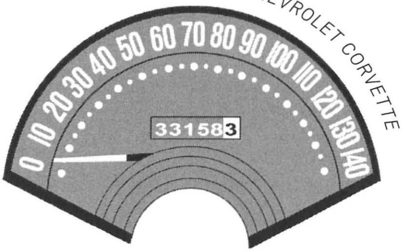
I. 1937 CHRYSLER IMPERIAL

J. 1938 MERCEDES-BENZ 540K



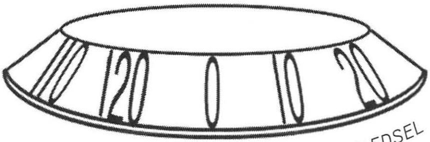


A. 1952 FERRARI 212 INTER

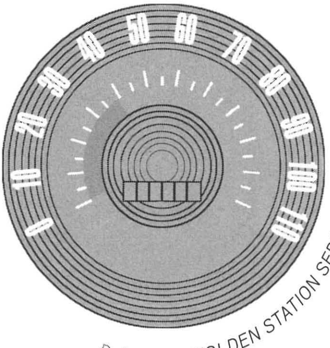


B. 1957 CHEVROLET CORVETTE

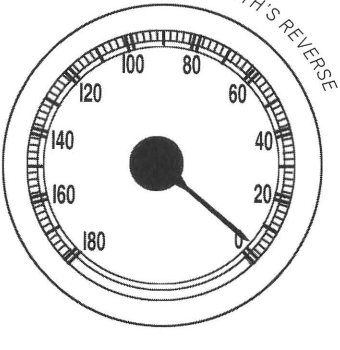
FIGURE 3:
1950s AND 1960s
CIRCULAR
SPEEDOMETERS



C. 1958 FORD EDSEL

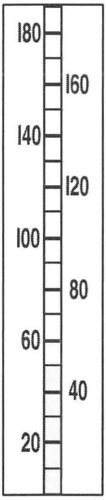


D. 1961 EK HOLDEN STATION SEDAN



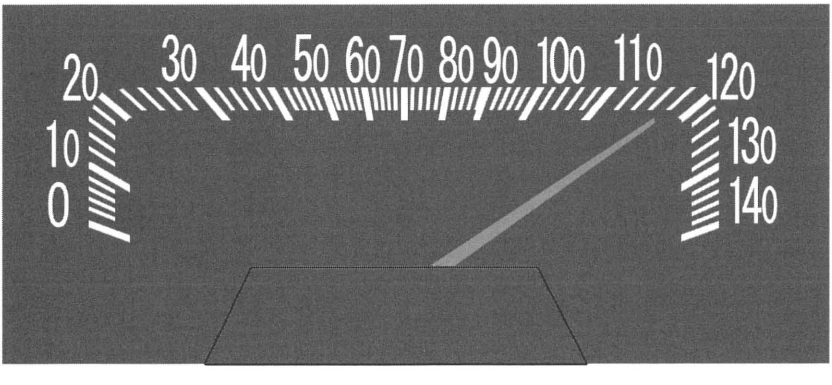
E. 1965 SMITH'S REVERSE

FIGURE 4: 1950s–1970s LINEAR SPEEDOMETERS



A. 1958–1969 MERCEDES BENZ HECKFLOSSEN

B. 1959 FORD GALAXIE FAIRLANE 500



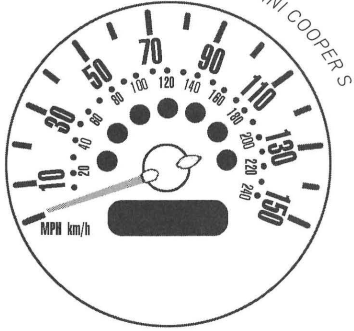
C. 1974 DODGE MONACO

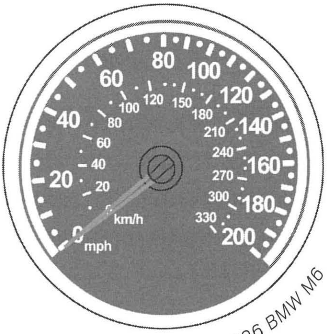
FIGURE 5:
CURRENT ANALOGUE
SPEEDOMETERS

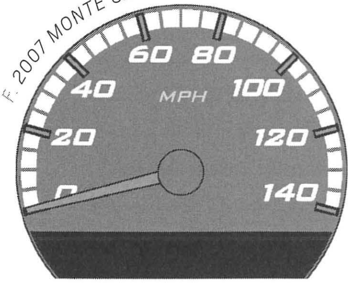
A. 2003 TOYOTA MATRIX

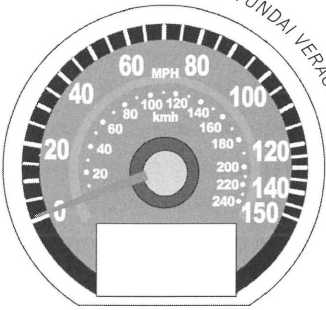
B. 2003 TOYOTA RAUM

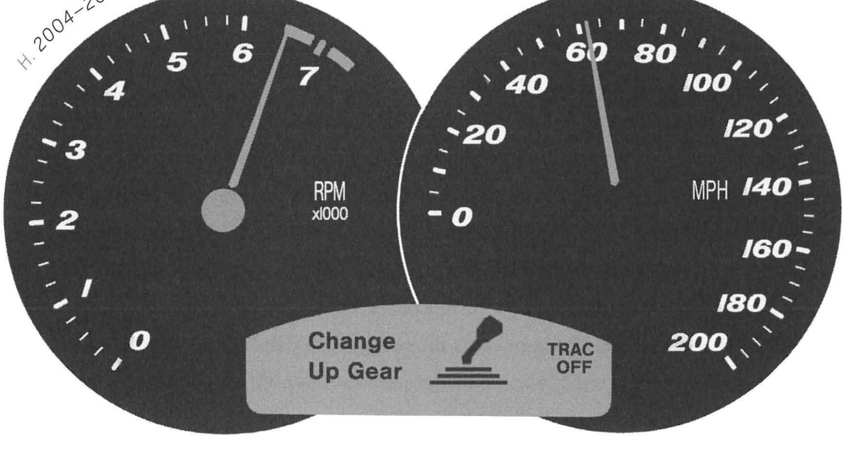
C. 2004 AUDI S4


D. 2005 MINI COOPER S


E. 2006 BMW M6


F. 2007 MONTE CARLO


G. 2007 HYUNDAI VERACRUZ


H. 2004–2006 HOLDEN GTO

Speedometer use

Although the first practical automobile appeared in 1885 with Benz's invention, the first automobile speedometer did not appear until 1902 with Schulze's patent of the eddy current (magnetic or mechanical) speedometer. Speedometers only began to become a standard feature in cars in 1910 (Siemens VDO Automotive AG, 2002) after many localities had already begun setting limits. Limits were imposed on trains and then on cars. In the United Kingdom, *The Locomotive Act 1861* limited speed to 12mph (19km/h), then *The Locomotive Act 1865* reduced it to 2mph (3.2km/h) in cities, towns and villages, and 4mph (6.4km/h) everywhere else. In 1895, *The Locomotives on the Highway Act* raised the speed limit to 14mph (22.5km/h) (Chapman, 2007). In 1901, the State of Connecticut limited speed to 12mph (19km/h) and 15mph (24km/h) for city and country driving respectively. Authorities required limits for safety and preserving roads since "hard rubber tires destroyed the dust binder on macadamized roads, creating ruts and eventually ruining the roads" (State of Connecticut, 2007, ¶16).

According to Sandoro (Hartley, 2002), drivers began installing speedometers to protect themselves from fines. He said, "At the time, police were on bicycles or motorcycles and their timing (of drivers' speeds) was done unscientifically with a stop watch. When speedometers were put in cars, the driver would often put a plaque on the back of the car saying that it was equipped with one so the police would not be so quick to give them a ticket" (¶11). Some early drivers installed one small speedometer dial for themselves and positioned another larger one for police to read at a distance (From speedometer to modern instrument clusters, 2005).

Avoiding fines continues, of course, to be a reason for speedometer use, but drivers also have other reasons. Green (1983) surveyed thirty-two US drivers to learn when and why they looked at their speedometer. He found that they used it when they saw a police car, when in various speed zones (e.g., a school zone), when shifting and when setting cruise control.

In another study, Denton (1969) observed thirty people driving under various speed conditions. He found that many people thought that they used their speedometer more than they actually did. For example, upon seeing a "reduce speed now" sign, twenty-four subjects said that they looked at their speedometer, but during observation only eight did. Denton concluded "use of the speedometer may be determined to some extent by the spare mental capacity available" (451). He suggested that drivers perhaps need "a more readable display not requiring a shift of attention from the road" for locations such as roundabouts in which "traffic behavior is changing fairly rapidly" (451).

From a safety perspective, the primary purpose of speedometers is to help drivers limit their speed, yet speeding still occurs. To understand why people speed, Gabany, Plummer and Grigg (1997) took an approach designed to decrease potential threat to subjects and improve the chances of getting truthful answers, and asked the subjects why they thought that *other people* engaged in speeding. Results suggested five reasons, which are "ego-gratification," "risk-taking," "time pressures," "disdain of driving" and "inattention" (31). For all reasons except inattention, it is possible that some drivers use their speedometers while speeding. For example, when speeding for reasons of ego-gratification or risk-taking, drivers may want to report their speed and so would read their speedometers. Indeed, some have even posted on the Internet pictures of their speedometers registering high speeds. Drivers who speed due to time pressure or disdain of driving may keep their excess speed within a narrow range above the limit to minimize risks of receiving fines or having accidents.

Speeding due to inattention may also be explained as speeding due to *unawareness*. In a survey of twenty-five drivers, Kumar and Kim (2005) found that "84%...reported that they are sometimes unaware of the current...limit. 40% reported that they are sometimes surprised that the...limit is different from what they thought [and] 68%...reported that they sometimes catch themselves inadvertently exceeding their desired speed" (1). Kumar and Kim have reasoned that such speeding occurs because roadways do not provide a constant display of the speed limit and speedometers do not draw drivers' attention to speeding.

Bringing the above research together, drivers read speedometers to avoid fines, keep safe, change gears, set cruise control or record high speeds. As a tool that simply presents a car's current speed, speedometers do not prevent drivers from speeding. The current system of legal punishments prevents much speeding, but does not prevent speeding due to unawareness. The most basic technological solution for such speeding is cruise control, but it is useful only along relatively straight stretches of highway. Other technologies will be discussed later in the paper.

Speedometer designs also serve marketing and aesthetic purposes. One design variation that serves more of a marketing than a safety purpose is the highest speed indicated on the dial. For all cars except those driven in countries with no or few limits, the maximum dial speed is much higher than that allowed on public motorways, indeed it is often more than twice as high. Most countries have motorway limits that range from 70 to 130 km/h (43–80 mph), but as shown in Table I, speedometers indicate top speeds of up to 280 km/h and 160 mph.

CAR	TOP SPEED (KM/H)	MAX. SPEED ON SPEEDOMETER (KM/H)	TOP SPEED (MPH)	MAX. SPEED ON SPEEDOMETER (MPH)
2007 Audi TT	251[a]	280		
2007 BMW 6 Series E64 Convertible	250[b]	260		
2007 Chevrolet Monte Carlo			145[a]	140
2007 Chevrolet Uplander			111[a]	120
2007 Mercedes Benz A-Class 170	~188[c]	240		
2007 Mercedes Benz SLK	~230[d]	260		
2007 Mitsubishi Outlander			115[a]	140
2006 Nissan Altima SE-R			150[a]	160
2007 Pontiac G6 Sedan			112[a]	140
2007 Porsche Cayman	259[a]	280		
2005 Toyota Camry	211[a]	220		
2007 Volvo V50 station wagon				
5 speed geartronic	215[e]	260		
5 speed manual	220[e]	260		

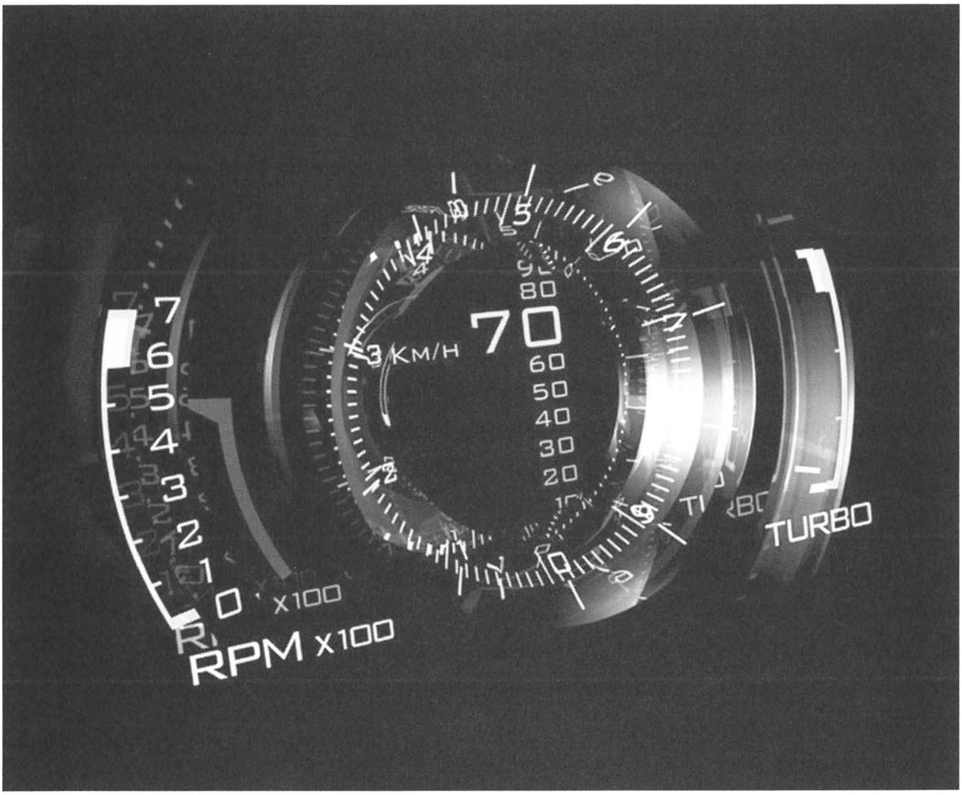
Table 1: Examples of top speeds and maximum speedometer speeds

NOTES: **a** Car specifications directory, 2007. **b** BMW Heaven, 2007. **c** Mercedes Benz Australia, 2007a. **d** Mercedes Benz Australia, 2007b. **e** Volvo Car Corporation, 1998–2006.

Regarding worldwide speed limits, Nepal and the Isle of Man are the only two countries having no limits. There are also no limits in the Indian states of Uttar Pradesh and Kerala (Speed limit, 2007), and along the German autobahn, there is only an advisory limit of 130 km/h along three-quarters of the road network. On those parts without a limit, the average speed is 150 km/h (93 mph) (Autobahn, 2007). In Austria and the United Arab Emirates, the world's highest limit of 160 km/h (99 mph) is being tested along some stretches of road (Speed limit, 2007).

Most drivers will never attempt these high speeds, but cars are still designed to reach them and speedometers list them. Apparently, cars are designed for high speeds because limit-free portions of the German autobahn allow such speeds. Therefore, designs made for German conditions influence what is used around the world. Another reason for designing high-speed cars has to do with the desire for power. Garfield (1977) wrote, "Many of us won't accept simply any machine; we want the newest, most powerful, most advanced model—whether lawnmower or

FIGURE 6: CONCEPT CAR SPEEDOMETERS



A. 2006 SAAB AERO X
(GM MEDIA ONLINE, 2007)

B. 2007 CITROEN C-CACTUS (JALOPNIK, 2007) automobile" (364). Speeds listed on speedometers therefore act as aids for safety and legal compliance, but also for power and competition. Many speedometer designs for cars on public roads are a compromise between these needs.

Some speedometer designs are made purely for marketing reasons. These designs are for concept cars, which are often radical prototypes made to test customer reactions to new ideas. If ever produced, the cars would require changes to make them cost-effective, safe and usable. Figure 6 shows unique speedometers from two recent concept cars, the 2006 Saab Aero X and the 2007 Citroen C-Cactus.

The Saab Aero X, an environmentally friendly car powered by ethanol, has no standard dials but displays information on "glass-like acrylic 'clear zones' in graphic 3D images" (GM Media Online, 2006, ¶ 5). According to the marketing literature, the green lighting of the dials reflects Saab's aviation background and aims to provide maximum clarity. The unique speedometer design is created through a vertical linear arrangement with large font presentation of the current speed.

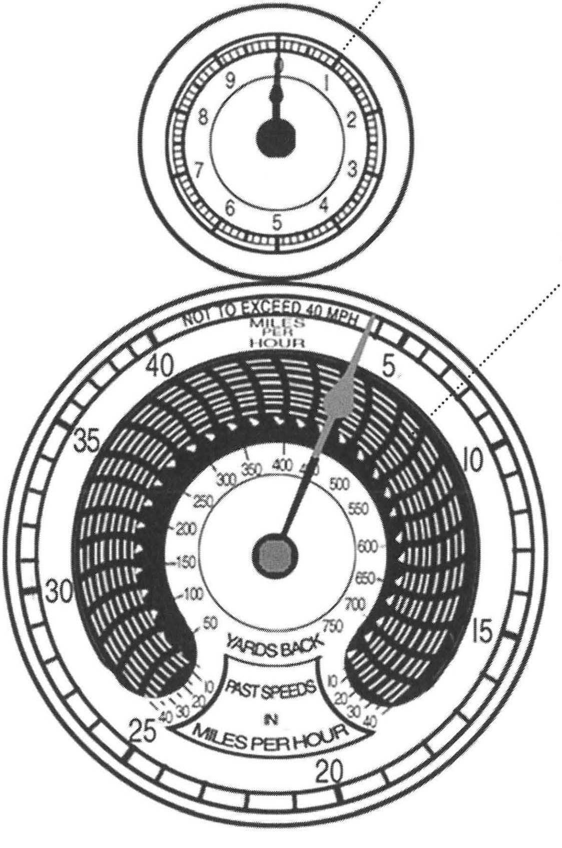
The Citroen C-Cactus, another environmentally friendly car, has a diesel-hybrid drivetrain with low fuel consumption and CO_2 emissions. The car has a top speed of 150 kph, which Citroen (2007) said "contributes to...good environmental performance...[and] reflects Citroën's efforts to develop a green vehicle...in which the motorist is in harmony with his/her surrounding environment" (¶24). The speedometer is unique in that it is placed around the steering wheel hub and has a scale that rotates around a fixed point.

While the designs of the Saab Aero X and Citroen C-Cactus speedometers are both eye-catching, as shown, neither follows ergonomic design recommendations.

Discussion of speedometer design features starting with analogue dials then moving to digital readouts follows. The analogue design features discussed are dial shape, reference point placements, scales, typefaces, number placements, needles and color. The paper also discusses dials that provide additional assistance in controlling speed, and what design would be easiest to read and therefore safest.

Dial shape and technology

As shown in Figures 2–5, most analogue speedometer dials are circular or arc-shaped, but some are linear. Early designs were circular because of their technologies, which were based on centrifugal or magnetic (eddy current) force. One of the earliest speedometers, the 1904 Cowey (*figure 7*) was circular and contained unique features.



Analogue trip meter

Visual record of
speeds reached over
the last half mile

FIGURE 7:
1904 COWEY "RECORDING SPEED INDICATOR"

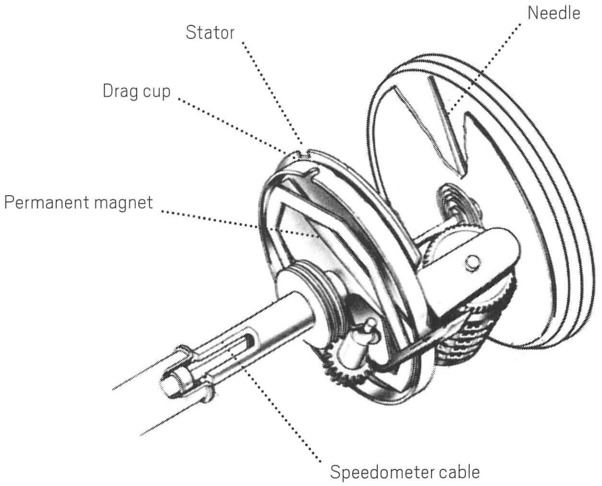


FIGURE 8
MECHANICAL SPEEDOMETER

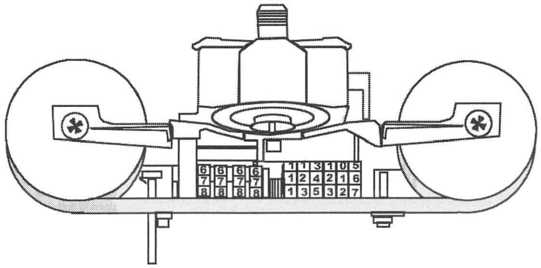


FIGURE 9
RIBBON SPEEDOMETER

While modern cars typically have a digital trip meter, the 1904 Cowey's was analogue. The Cowey also included a device to record speeds reached over distances of 50 to 750 yards, which in the early days of motoring might have appealed to designers or driving enthusiasts interested in learning the car speed capabilities in various situations.

Another design, the 1911 Bowden (*figure 2b*), measured speed based on the movement of metal balls that swung out from a rotating shaft to create a centrifugal force. Although useful, the mechanical (magnetic or eddy current) speedometer proved to be more accurate.

Figure 8 illustrates mechanical speedometer technology. Such speedometers have a multi-strand wire (speedometer cable) that transfers the drive from the gearbox output shaft to the speedometer dial. The output shaft is directly attached to a circular permanent magnet that is housed in a shallow aluminum *drag cup*. Along the shaft is a steel stator, which when the car moves, is driven by electronic eddy currents set up by the rotating conductive cup. The faster the cup turns in response to an increase in speed of the gearbox output shaft, the greater the torque on the stator. The stator is connected to a hairspring, which in turn is connected directly to the speedometer needle. The larger the torque on the stator, the greater the force on the hairspring and the greater the movement on the speedometer needle.

An improvement on the mechanical design was the mid-1950's electronic speedometer (Siemens VDO Automotive AG, 2002). This device has a magnetic transducer positioned somewhere on the final output shaft of the gearbox after the overdrive unit, which eliminates the need for a cable.

Early variations on circular dials were window dials, which showed only a portion of a dial's speeds and had a moving scale and stationary pointer. One example of a window dial is the 1929 Waltham (*figure 2f*), which had numbers silk-screened onto the lip of the speedometer's aluminum cup. These numbers rotated past a fixed point on the dial. The speedometer assembly was placed vertically inside the car with the lip, not the face of the cup, visible to the driver. Mroz (1998) reported that even when a magnifying glass was used for the window, drivers had difficulty reading the numbers, which would have been moving (perhaps only slowly) much of the time. Some of the dials contained no lamp so they could be read only in daylight. The speedometer window presented a range of only about 10 mph.

The vertical speedometer of the 1958–1969 Mercedes Benz models (*figure 4a*) used ribbon technology, which was an attachment to the drag cup of a mechanical speedometer. On these speedometers (*figure 9*), the pointer is a colored tape that winds from one drum to another as speed changes. On the Mercedes Benz speedometer, yellow ribbon marked speeds up to 50km/h, a red-yellow combination marked speeds from 50 to 60km/h, and red marked speeds above 60km/h. About this device, van Eijck (1999) wrote, "...the vertical strip-type speedometer...proved hard to read and was roundly criticized by the motoring-press..." (¶3). Neither vertical nor horizontal linear designs proved to be popular and are seldom used in modern cars.

Although the circular shape of early dials was technologically determined, this shape offers many advantages over linear dials. For example, circles save dashboard space, and compared to linear designs, can display finer increments of speed around the circumference within the same amount of space. Further, on circular dials the indication of speed is visually redundant since it is marked by two visual variables, angle and position. On linear dials, speed is indicated only by position.

Reference points and direction of movement

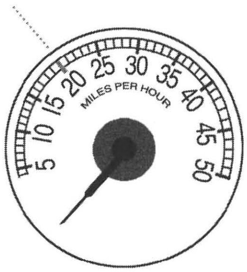
Another important issue in the design of circular dials is where to place the key reference points, which are the initial, top and maximum highway speeds. As seen in Figure 2, the placement of the initial speed on early dials was either at the top (from 12:00 to 2:00) or in the bottom left quadrant (from 7:00 to 9:00). Eventually, placement in the bottom left quadrant became the standard. While initial speed placement at the top of the dial was based on clock design, placement in the bottom left quadrant was based upon a combination of factors, which are presented in Figure 10, using the 1911 Bowden speedometer as a model.

On the Bowden, the 4mph start was placed between 8:00 and 9:00, and the 50mph maximum listed speed was placed between 3:00 and 4:00. A red mark highlighted 20mph, which was presumably the maximum speed limit at the time.

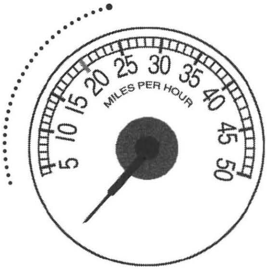
Reference point placement on the Bowden offered several advantages. First, this design followed both the direction of conventional clock movement and left-to-right reading order. Next, since the most common speeds are on the left of the dial, the movement from lower to higher speeds increases from a lower to a higher position. Lastly, the design is aesthetically pleasing since it is symmetrical.

Most modern dials follow this same pattern for reference point placement. However, it is useful to note here that a design that has been singled out as following good ergonomic principles, the Toyota Raum (*shown in Figure 2b and again below*) also follows this pattern. The Raum was created following principles of universal design. According to Misugi, Kanamori and Atsumi (2004), universal design "is

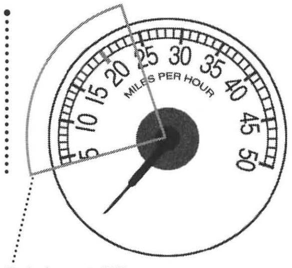
Scale mark for key reference point of 20mph is colored red to provide good contrast.



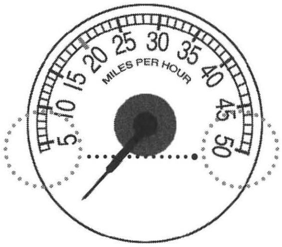
Follows conventional clockwise movement



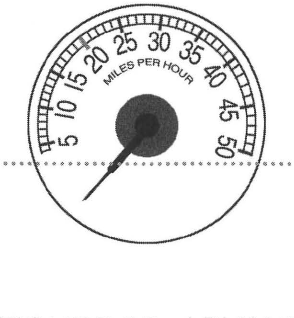
Higher speeds (within the recommended range) are higher on the dial



Follows conventional left-to-right reading order across the dial



Scale is placed along the upper portion of the circle, which is appropriate for a device that is viewed from above



Has a symmetrical design

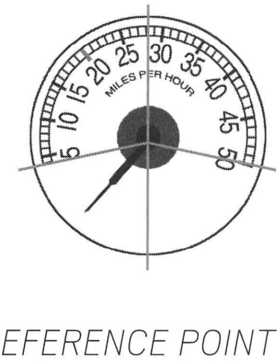
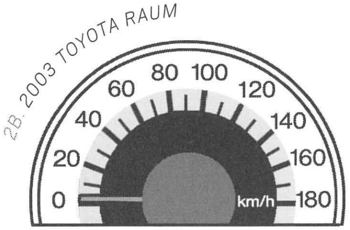


FIGURE 10: ADVANTAGES OF REFERENCE POINT PLACEMENT ON THE 1911 BOWDEN SPEEDOMETER

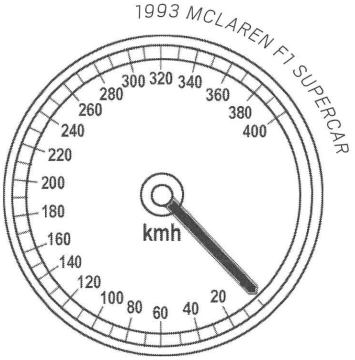


defined as providing a service or designing an object or location in such a way that it can be easily used by many people, regardless of physical characteristics such as gender, age or disability" (¶1).

In addition to its useful reference point placements, the Raum offers meter numbers set in a typeface that has "superior readability even when viewed slightly blurred," which takes into consideration the needs of "slightly far-sighted elderly drivers." Further, the meter numbers have a background of "white bands for easy recognition" (¶16). During development, the designers "confirmed" the speedometer with users over thirty times. On this dial the current Japanese speed limit of 100km/h (Speed limit, 2007) is placed near 12:00.

On a speedometer, 12:00 was a poorer choice than 6:00–9:00 for the start of measurement partly because it goes against our linguistic representation of speed, in which speed increases and decreases along the vertical dimension. In language we say things like, "She sped *up*," "She slowed *down*," "He drives at *high* speeds," and

FIGURE 11
4:00–5:00 STARTING POSITION



"He is going at a *low* speed." When a dial starts at 12:00, the visual representation of speed moves in the opposite direction to the linguistic.

Another issue in speedometer design is the direction in which the needle should move to indicate higher speeds. The clockwise choice obviously came from the well-established pattern of clock movement. In the speedometer's history, however, at least one design moved counter-clockwise. This was Smith's reverse speedometer, installed in a 1965 Cobra (*figure 3e*). The Cobra had a British sports car body and an American hot rod engine, and was known as the first American muscle car (Campbell, 2005). Its unique concept appears to have inspired its unique dial.

Racing car speedometers provide an opportunity to look at the pragmatics of reference point placement. On the 1993 McLaren F1 Supercar (*figure 11*), the dial's starting point was placed between 4:00-5:00, which was useful for racing. To provide an idea of speeds expected by such a car in a Formula 1 or Grand Prix race, in 1998 the average speed in the fastest Grand Prix was 237.591 km/h (147.633 mph), the highest speed along a straight line during a Grand Prix was 356.5 km/h (221.5 mph) and the highest practice speed was 244.413 km/h (151.971 mph) (Atlas F1 News Service, 2000). Therefore, this design aimed to place the most common racing speeds towards the top of the dial, in the area between 9:00 and 1:00.

Some modern speedometers have asymmetrical positioning of the starting and ending points. For example, the 2004–2006 Holden GTO (*figure 5*) starts at 9:00 and ends at 5:00 and the 2003 Toyota Matrix (*figure 5*) begins at 6:00 and ends at 9:00. Both designs allow the scale to fit around an information area, and both produce a unique look.

In summary, the most typical reference point arrangement on circular speedometers is a symmetrical design with a 7:00–9:00 starting position, the maximum motorway speed limit near 12:00 and a 3:00–5:00 maximum speed. Current asymmetrical arrangements are chosen so as to place the scale around dashboard information areas, provide a unique design or even associate a design with racing.

Scales

Speedometer scales vary in relation to their number and type. Many dials have dual scales, typically representing speeds in mph and km/h (*see figure 5*). At least one speedometer (the 1934 Midget PA in *figure 2h*) used dual scales for representing speeds available in different gears. In this case, one scale was for third and the other for top gear. Designers typically visually differentiate between dual scales

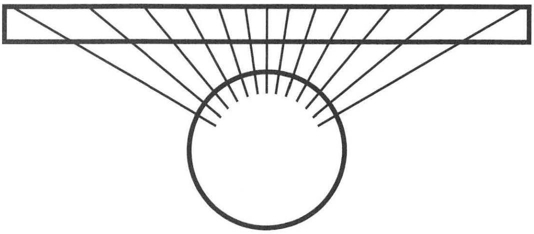


FIGURE 12
PROJECTION OF CIRCULAR
SCALE ONTO A LINE

by coloring them differently, and use a smaller typeface and fewer scale marks on inner scales.

Woodson, Tillman and Tillman (1992) have recommended that dials use a single scale whenever possible because it reduces reading error. With LCD dials, dual scales for km/h and mph may no longer be needed since the technology can allow drivers to choose their preferred system. This solution was followed for the 2007 Chevrolet Monte Carlo speedometer (*figure 5f*).

The scales on most speedometers are what Stevens (1951) termed *ratio,* which is a scale that has a true zero point and organizes items from less to more by equal increments. While all car speeds *are measured* by equal increments, *visual representations* of increments may be unequal. For example, scale marks on the 1904 Cowey (*figure 7*) were unequally placed because the pointer did not move at a constant rate with the speed. As other examples, the scales on the 1959 Ford Galaxie Fairlane 500 and the 1974 Dodge Monaco (*figure 4*) have scales that project a semi-circular scale onto a horizontal line, which represents equal units of speed with unequal spacings (*figure 12*).

As on the 2004 Audi S4 design (*figure 13*), some speedometers have two different ratio scales so as to keep the most often used speeds on the left of the dial while saving space for presenting higher, less-used motorway speeds on the right and maintaining a symmetrical design.

One Hyundai speedometer (*figure 5g*) used the unique combination of three different ratio scales, two of which were placed at the end of the scale to fit in the little-used ranges of 120–140 and 140–150 mph.

Numerical increments on speedometer scales vary mostly according to when the speedometer was designed. Through the 1930's, increments of 5 or 10 were more

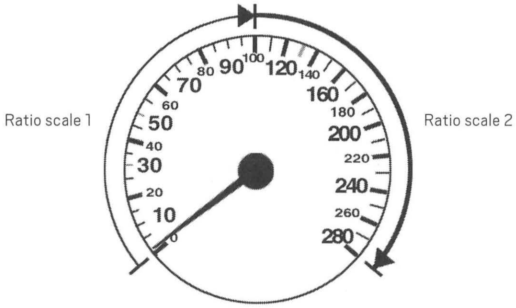


FIGURE 13
SPEEDOMETER WITH TWO RATIO SCALES
(2004 AUDI S4)

typical, although the 1924/30 Bentley Special (*figure 2e*) had increments of 30mph. Starting in the 1930s, increments of 20 became more common. To save space on the dial, the speedometer on the 2006 BMW (*figure 5e*) used increments of 30 in its km/h scale for the speeds of 150 and over. The retrospective design of the 2005 Mini Cooper (*figure 5d*) has an unusual selection of numbers on its mph scale since it begins with 10mph and then proceeds in increments of 20mph, so the numbers on the dial are 10, 30, 50, etc.

Oborne's (1995) review on the ergonomics of numerical increments said that "a system that progresses in 1s or 10s is the easiest to use" (143) simply because people are used to counting this way. Woodson et al. (1992) have said the fewest errors are made with intervals of 1 through 10 with the next best being 2, 4, 6, 8 and 10, and that intervals of 3, 6 and 9 or 4, 8 and 12 can be confusing. Therefore, speedometer dials with increments of 10 or 20 are likely to be the easiest to read.

While recent dial designs have fewer and simpler scale marks, earlier dials tended to have one mark for each mph and more decorative marks resembling those on some clocks such as track lines and combinations of lines, dots, triangles and diamonds. For functional dials, Woodson et al. (1992) recommended using simple marks and avoiding "dots..., thick marks, marks joined by a heavy base line, [and] long marks spaced closely together..." (392). According to Oborne (1995), "the major scale marks...should be emphasized, and the British Standards Institute (1964) suggests that each major marker should be two times the length of the minor marker" (143).

Typefaces and placements of numbers

While some early speedometers used serif typefaces, sans-serif faces are more common on all designs. The typeface may be regular, bold or italic. For instruments, simple typography is recommended (Woodson et al., 1992).

On most modern speedometers, numbers are placed straight up, which is another ergonomic guideline for stationary scales (Woodson et al, 1992). On earlier designs, numbers were sometimes straight up, angled (e.g., Chevrolet Corvette, *figure 3b*), or angled and turned (e.g., 1952 Ferrari 212 Inter, *figure 3a*).

Although numbers may appear on the inside or outside of a speedometer scale, Woodson et al. (1992) recommended that they appear on the outside so that the pointer does not cover them. This choice was made on the ergonomically-designed Toyota Raum (*figure 5b*).

Speedometer needles

Some early speedometers had decorative needles, but others were more streamlined and similar to those on current speedometers. As previously discussed, on some designs a band of color served as the needle (e.g., 1961 Holden, *figure 3d*). Early designs with decorative needles followed clock designs. Woodson et al. (1992) have recommended that designers avoid "artistic" designs for ease of reading, and that for applications in which users make "quick scanning look[s]," such as in driving, the pointer needs to be wider. In such designs, the pointer's tip should be tapered so that it is the same width as a scale mark and should fall just below the scale mark.

Color

Obviously, strong color contrast is required between the background and graphical elements on speedometer dials. Designers often use a third color, typically red or orange for the needle. According to Woodson et al. (1992), dials for daytime use are best seen if markings are placed on a light background. However, one way to create distinctive designs is through color, so some dials have for example blue, green, red or orange marks against dark backgrounds.

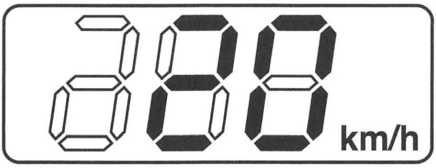


FIGURE 14
DIGITAL SPEEDOMETER
(1988 MITSUBISHI MAGNA)

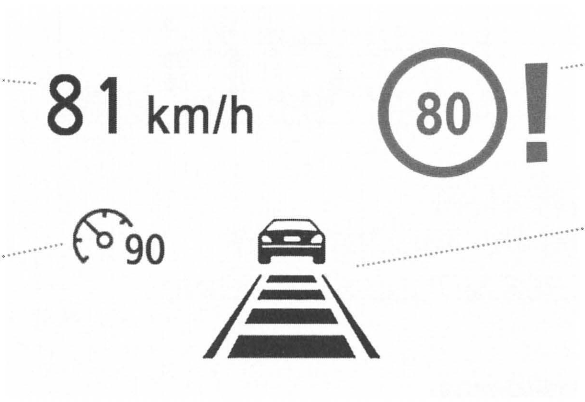
Digital read-outs

In 1986, the first fully digital information system was installed in a Volkswagen (Siemens VDO, ca 2003). In modern digital speedometers, a magnetic sensor is positioned on the final output shaft of the gearbox. An electronic sensor then records every revolution of the magnet. Next, a semiconductor Eprom chip converts the sensor information to a final speed, which then appears as numbers on a backlit LCD display. When more current cars have a digital speedometer, it usually appears in a head-up display (HUD), which is a transparent display of data through a driver's windscreen.

Figure 14 presents an early digital design from a 1988 Mitsubishi Magna in which characters are formed by highlighting parts within a 7-segment framework. These designs are easier to read in sunlight and need a light source to be read in the dark.

According to Oborne (1995), 7-segment characters received criticism because they don't look like drawn numbers and the spacing between numbers can vary (in particular, the number 1 creates a wide gap). People therefore read these characters more slowly and make more errors than with printed and dot-matrix characters. More recent digital displays have acceptable character design owing to higher resolution technology.

A digital speedometer's strengths are that it provides precise reading at any instant (although this is not usually important while driving), uses less dashboard space and can have large numbers for easy viewing. In a 1980 study of speedometer formats conducted with 400 drivers (Simmonds, 1983), drivers provided the most accurate readings when using digital speedometers. According to this study, a "substantial majority preferred...the digital speedometer," but thought curved designs were more attractive. There was also a "significant minority who did not



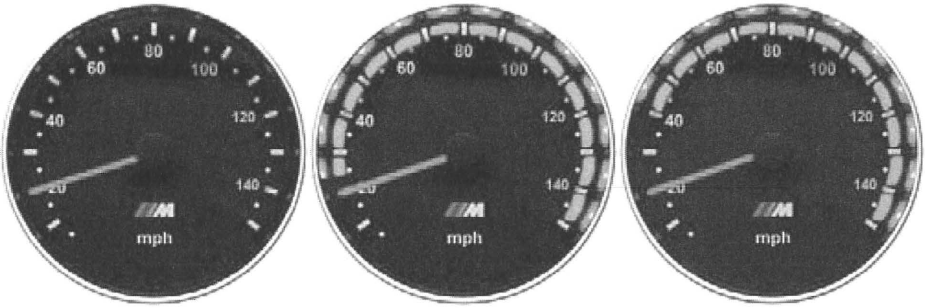
Current speed (displayed in yellow)

Speed marked on road signs (displayed in red)

Cruise control setting (yellow)

Driver-selected lengths to stay behind vehicle traveling in same lane (yellow)

FIGURE 15
HUD FOR SIEMENS VDO ADAPTIVE CRUISE CONTROL AND TRAFFIC RECOGNITION SYSTEM



For a 25 mph limit

For a 40 mph limit

FIGURE 16
DESIGN THAT PROVIDES A CONSTANT READOUT OF THE SPEED LIMIT (KUMAR & KIM, 2005, 2)

like digital instruments" (100). Among the study group, those most preferring digital read-outs were aged over fifty. Some of this group said "that they had been able to read the speedometer clearly for the first time in years" (100).

On the other hand, analogue dials have strengths that for many outweigh those of digital dials. Woodson et al. (1992) noted that analogue dials are often preferable because "the dial...provides...additional information in the form of advance warning, rate of change and/or opportunity to make 'cross-dial' extrapolation [which is because] the pointer position and motion act as...additional qualitative cue[s]...to what is happening" (390). Analogue dials are also a better choice for reading fast changes (Oborne, 1995). Since the majority of cars have analogue speedometers, there is obviously a driver preference for them.

Designs that provide additional assistance in controlling speed

As previously noted, speedometers alone do not control speed. Currently, drivers themselves under the influence of government punishments are responsible for maintaining speeds within limits. While cruise control offers one solution to motorway speeding due to inattention, there are now more sophisticated technologies available. For example, Siemens VDO has developed adaptive cruise control (ACC) and traffic sign recognition (TSR) systems that monitor roads using a global positioning system (GPS), computer technology and camera. These systems will automatically reduce a car's speed under three conditions, which are if they detect a slower-traveling vehicle in the same lane, if the TSR detects a speed limit sign that shows less than the car's current speed, or if the GPS detects that the car has entered an area with a lower speed limit. The systems allow drivers to specify how closely they would like to travel behind any in-lane vehicles. The user display for these systems appears on a dashboard LCD but can also appear as an HUD (*figure 15*).

Kumar and Kim (2005) have designed a speedometer that displays both a car's current speed and the road's speed limit as determined by GPS, or for temporarily hazardous areas such as construction zones, a beaconing system. In this design, speeds above the limit are marked with a band of color (*see figure 16*). When cars exceed the limit, the speedometer either sends an audible warning (e.g., beeps) or presents visual cues (e.g., a flashing needle).

The safest design

So what design works best from a safety perspective? Research in this paper suggests that most drivers prefer an analogue dial, that the design of the 2003 Toyota Raum speedometer most closely follows the principles of ergonomic design, that drivers who speed due to unawareness need a speedometer that provides a constant readout of the current speed limit, and that drivers need either a speedometer that remains in their view at all times (e.g., an HUD speedometer) or one that provides speeding alerts. Such a design could also offer the option of advanced GPS-based cruise control such as Siemens' design. In the future, it is possible that governments may combine GPS with car technology to physically restrict speeds.

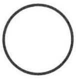
Conclusion

Automobile speedometers appeared at the turn of the century and although many were at first similar in design to clocks, they soon developed their own pattern as a result of greater understanding of drivers' needs, speed limits, the practicalities of fitting the dial onto the dashboard, style preferences and changes in technology. In developing dials, designers have experimented with different positions of reference points; dial shapes; analogue and digital read-outs; the number and shapes of scale marks; multiple and reconfigurable scales; increments, style and placement of numbers; needle designs; moving versus stationary scales; and colors. Figure 22 presents a taxonomy of dial features.

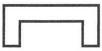
Speedometer designs continue to evolve with inventions such as GPS and head-up displays. Further, just as clocks influenced speedometer designs, speedometer designs are now influencing software applications such as graphical representations of business performance indicators.

DIAL SHAPE

Circular or semi-circular



Vertical or horizontal, linear



Unique

REFERENCE POINTS AND DIRECTIONS ON CIRCULAR OR SEMI-CIRCULAR DISPLAYS

Start 7:00–9:00, end 3:00–5:00,
motorway limit near 12:00

Start and end at or near 12:00,
motorway limit near 6:00

Some early designs,
based on clocks or timers

Asymmetrical

Fits around other information,
information, and maintains
visual ratio scale for high speeds

Start near 5:00, end near 1:00

Racing

Start near 4:00, end near 8:00

Eccentric

Start and end near 6:00,
motorway limit near 12:00

REFERENCE POINTS AND DIRECTIONS ON LINEAR DISPLAYS

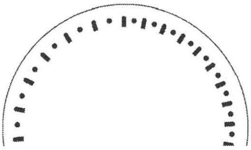
Reading order

Moves upward

TYPES OF SCALES

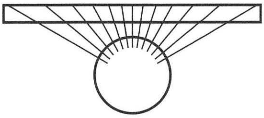
Ratio

Two or three connected ratio scales



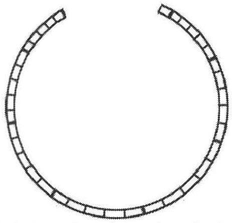
Conserves space, retains symmetry on dials that have high top speeds

Semi-circular ratio scale mapped onto horizontal line



Unique

Uneven



Early design based on early technology

NUMBER OF SCALES

1 (mph or km/h)

2 concentric (one for mph and one for km/h)

2 concentric (each for a different gear)

NUMBER OF SCALES MARKS

1 mark = 1 mph, major mark every 5 mph	*Early design*
1 mark = 2 mph, major mark every 10 mph	
1 mark = 5 mph, major mark every 10 mph	
1 mark = 1 km/h, major mark every 5 km/h	*Early design*
1 mark = 2 km/h, major mark every 10 and 20 km/h	
1 mark = 5 km/h, major mark every 20 km/h	
1 mark = 10 km/h, major mark every 20 km/h	*Racing*
1 mark = 20 km/h	*2nd, minor scale*

SCALE MARK SHAPES

Major scale marks	▮ Line	● Circle	‖ Double lines	◆ Diamond	▲ Triangle
			Some earlier designs		
Minor scale marks	▮ Line	● Circle	*Marks may be joined by single or double track lines* *Identically shaped minor marks may be smaller*		

NUMBERS PRESENTED ON THE DIAL

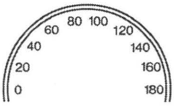
(0), 10, 20, 30, 40... mph	
(0), 20, 40, 60, 80 ... mph	
30, 60, 90, 120... mph	*unique*
10, 30, 50, 70...mph	*unique*
(0), 10, 20, 30, 40... km/h	
(0), 20, 40, 60, 80... km/h	

FONT

Serif	*Early design*
Sans-serif	*Follows ergonomic design recommendations*

PLACEMENT OF NUMBERS

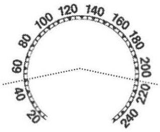
Straight up



Follows ergonomic design recommendations

Angled

Angled and turned



Early design

POINTER

Decorative		*Early design*
Simple		*Follow ergonomic design recommendations*
Band of color		*Unique*

MOVING SCALE VERSUS MOVING POINTER

Moving scale	*Early design, Unique*
Moving pointer	*Follows ergonomic design recommendations*

COLOR

Light background, contrasting graphics and pointer

Dark background, contrasting graphics and pointer

Key reference point may have unique color

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Author note

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