Cognitive Psy and Its Applications

Main objectives

1. Understanding the role of **human capabilities and limitations** in the design of products, work places and large systems.
    - main areas of **Human Factors**
    - main theories and findings on **Human perfomance**
2. Understanding where in the process to apply knowledge
3. Understanding the **methods** used to analyze human performance
4. Practicing to identify possible **problems in human-machine interaction**
5. Practincing to apply knowledge to **analyze**, **create**, **improve systems**
6. Practicing **presenting new ideas** and **solutions**.

Introduction to Human Factors (HF)

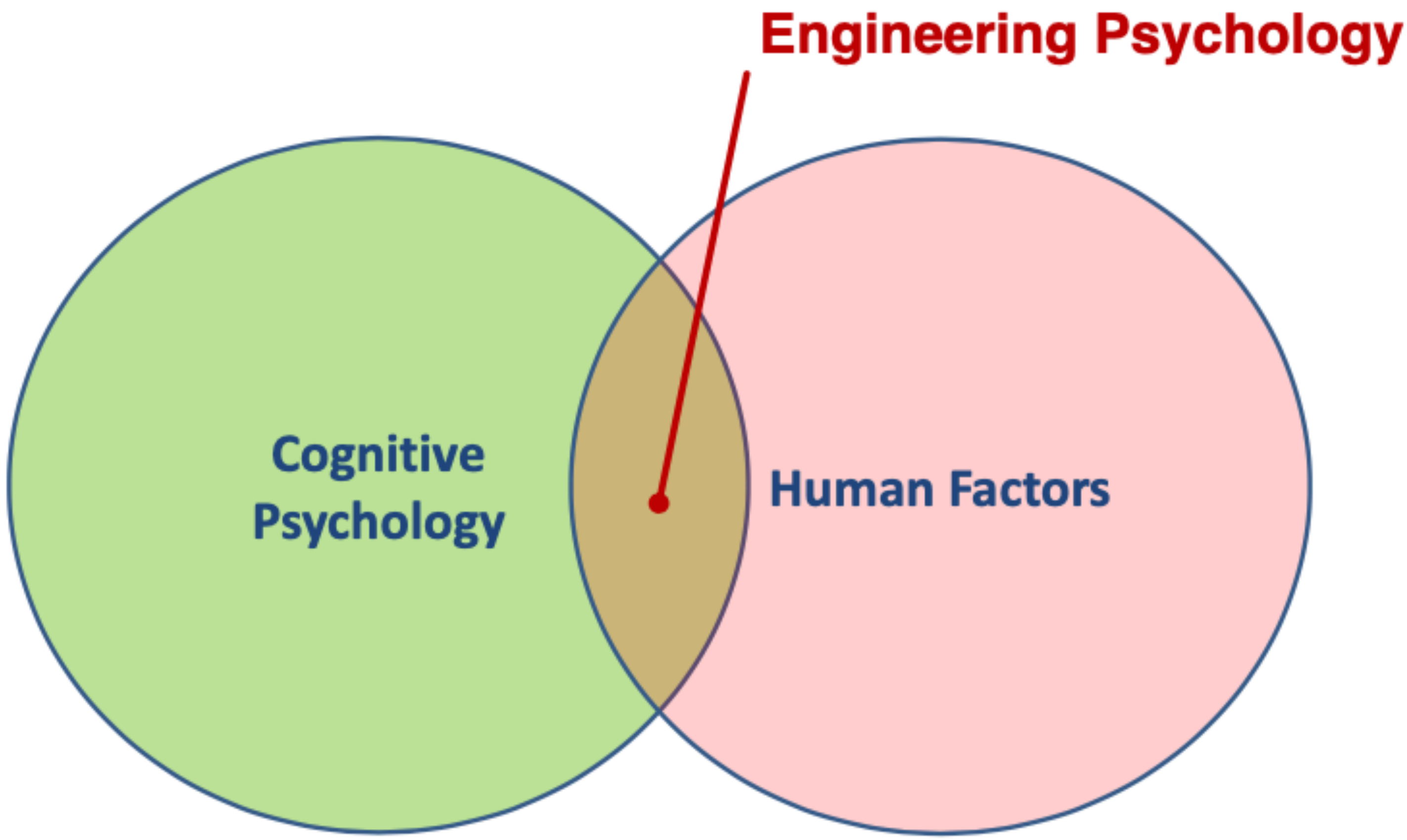
It is the situation when things go wrong that triggers the call for diagnosis and solution, and understanding these situations represents the key contributions of human factors to system design.

Cognitive Psychology **uncovers the laws of information processing and behavior** through experiments by answering fundamental questions with any required application. It mainly focuses on the **information processing capacities of the brain**.

HF is **directly applied** and it is used to apply knowledge by **designing systems that work** and to **accomodate the limits of human performance**.

The **goals** of HF us to make the human interaction with systems one that enhances performance, increase safety and increases user satisfaction and safety. HF involves the **study of factors and development of tools that facilitate the achievement of these goals**. **Productivity** and **error reduction** ->(lead to) **usability**. Overall, it mainly focuses on **physical and psychological perspectives to the problems of system design.**

Engineering Psychology (EP) is a mix of CP and HF and it is the **study of interaction between humans and systems in order to improve performance, safety health and usability**.



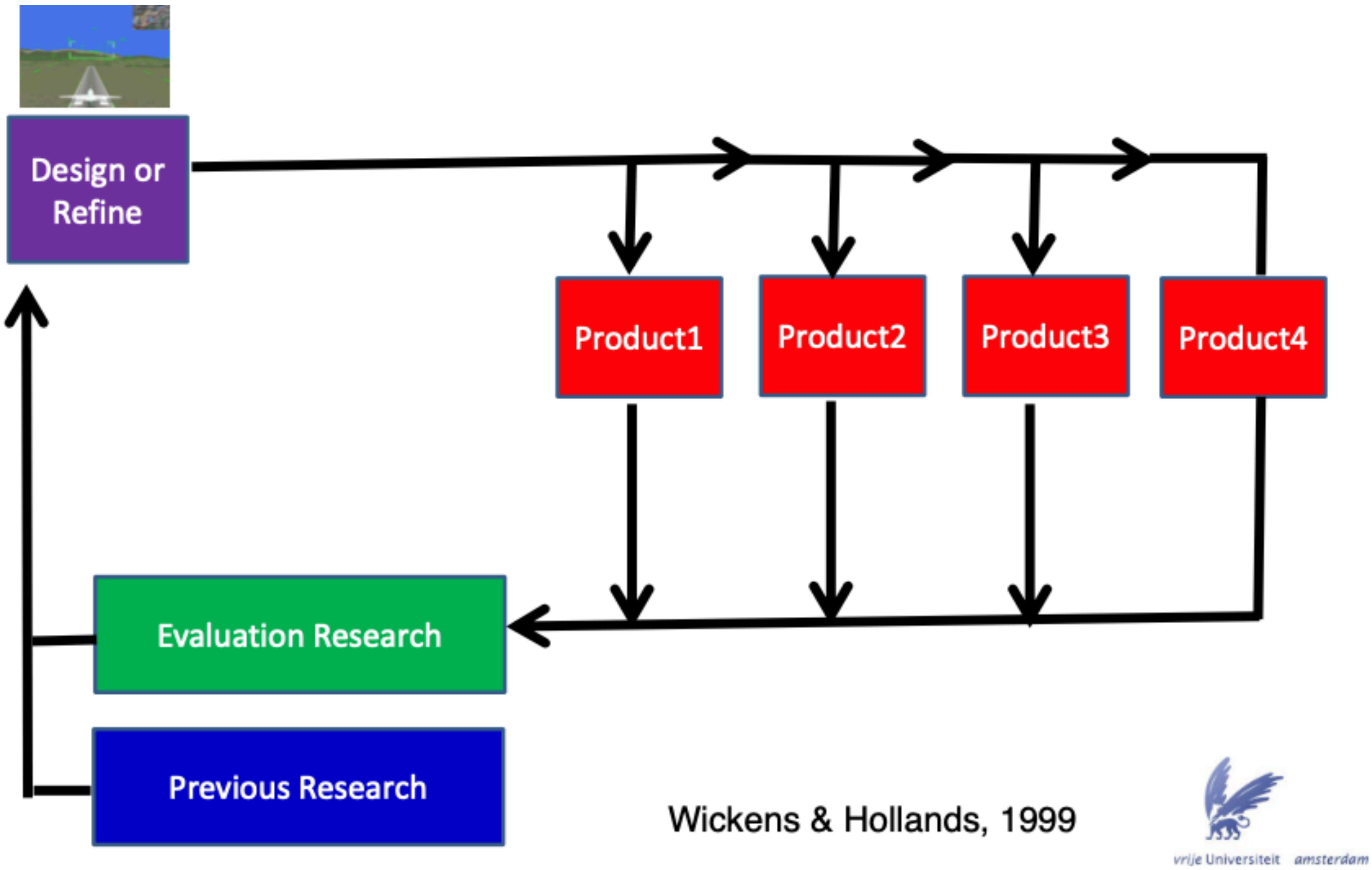
The main **goals** EP are to develop generic knowledge, enhance efficiency, ensure safety, reduce error, assure tasks within the human capability, increase user satisfaction, comfort, improve human performance and reduce costs. **EP** entails the design of machine to accomodate the limits of information-processing capacities of the human brain.

Brief History of HF

- **WWII -** humans seen as operators of sophisticated technologies (like submarines, tanks, etc ...). The main focus was on selection and training; **designing a human to fit a machine**.
- **Last half of the 20th century** - technology advancement brought up a greater physical complexity and in logical too (i.e. operating an aircraft). This rapid development of technology sped up the progress of designing ithe field of HF engineering. This was accompanied by the development of the field of psychology. Humans are now seen as **information-processing systems** = computers, it has inputs and outputs. It also has software running in the brain (i.e. taking care of attention, planning, decision-making, etc...)

Design and evaluation cycle

There are usually different iterations of the same cycle where different products/prototypes are created and tested in different ways. Then, it ends up in the evaluation of each product by ending up with the product will be brought into the market/real world. The design cycle can be entered by HF engineer at any point. The human engineer(HE) can influence the desing process by using previously accumulated knowledge by similar situations.

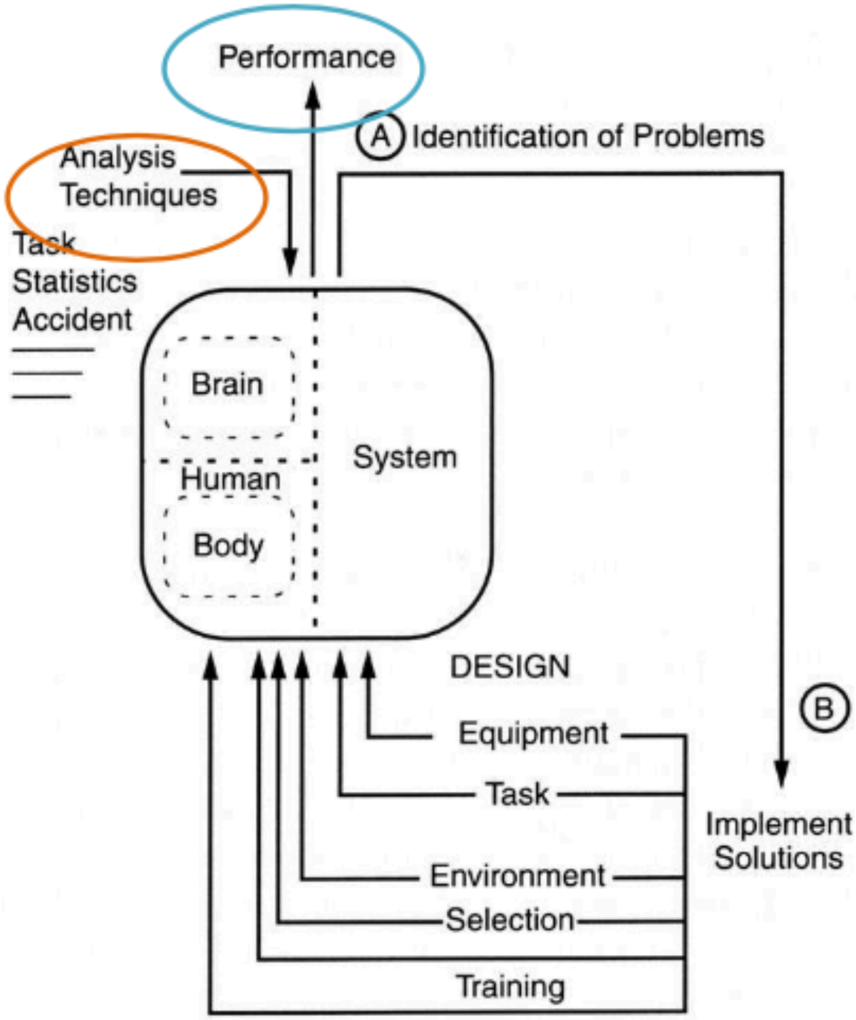


What the HE does in the design process is described in the HF cycle.

The human has a **body and a brain** and it **interacts with the system** that he has to design. Its main role is to **measure performance** of the systems by applying different techniques and **identified solutions when problems arise**. These solutions can be related to the system or to the human, so either the system or the human have to change in order to solve the problem (change the equipment, modified the taks or the environment, improve the training or the selection of the HE). Hence, HF engineers can help in **2 ways**:

- **Problem solving**: the system is functioning and it has been built, so the HE is brought in to solve the occuring problems. This is the most commong and it is called the *cheap or quick fix*, however, it is ultimately the most expensive.
- **The HF engineer is an integral part of the design process from the very beginning**.

The analysis of techniques and the performance are two essential elements in this cycle. The former to understand the function of the project and the other element is used to gauge perfomance.



The 2 formal names for these 2 tasks are **task analysis (for analysis techniques)** and **research methods (for performance measures)**.

Task Analysis

It involves

- describing the full range of tasks that the user performs,
- describing the physical aspect of the process (i.e. use of tools and instruments) and
- describing all the cognitive tasks (i.e. reliance on attention, memory or decision making)

Note: it also involves understanding the **goal** of the system and there may be different ways to reach it.

Research methods

1. Explore the literature to understand the state-of-the-art research regarding the problem
2. Do an experimental reserach (in a controlled environment)
   - Lab study (much more controlled than the field study) or field study (i.e. measurements on the field)
3. Descriptive reserach (less/not controlled)

    - observations, incidents/accidents analysis, surveys and intervies

Experiments

The benefits of using an experimental approach is to discover a **causal relationship** by manipulating the confounding variables and the one of interest. However, the **drawbacks** is that certain situation may not be realistic enough. so not applicable to the real world. In addition, the population may not be representative and in addition the power may be low (the **power analysis** is conducted to determine the smallest sample size that is suitable to detect the effect of a given test at the desired level of significance). It is also possible that if there are more realistic scenario lead to more potential confounds variables and so more difficulty to genralize the expriments to a real-world scenario.

Surveys and observations

May pick up general trends and subjective expericen but they will not lead to casual relationship. Misleading solutions might be cause by "suitable" answers by the interviewee. The interpetration of the answers and the questions may also lead to incorrect results. Observations and surveys are very good at understanding the preferred solution by the user but they might not provide with the optimal solution because it may lack in introspection of what the exactly the causes of the problems are.

Benefits of HF

- Prevention of accidents (i.e. less loss of human life)
- Prevent compensation payments (i.e. payments due to human errors causing accidents)
- Reducing costumer support (which is also a money investment)
- Better management of emplyees and higher job satisfaction
- Higher productivity and efficiency
- Lower costs for training personnel

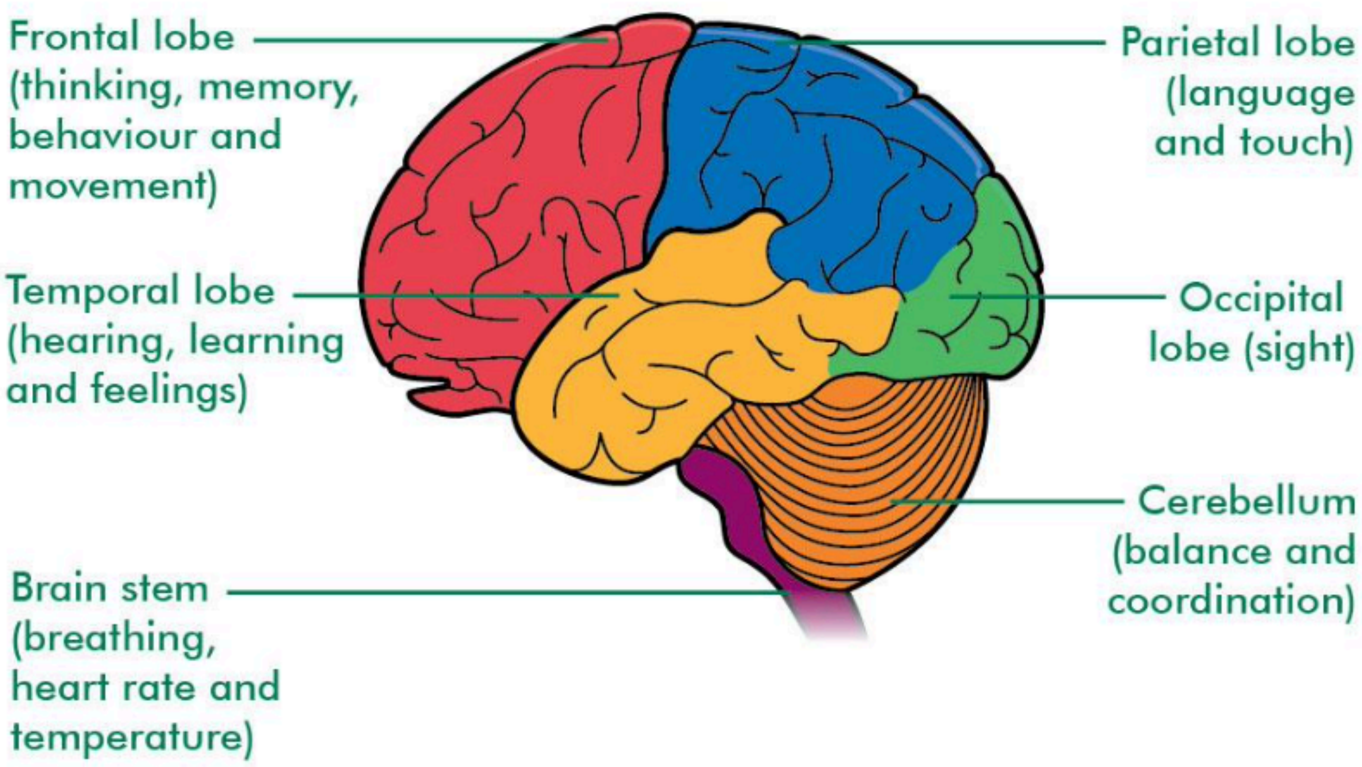
Costs of HF design

- **Can be relatively low if** HF engineers are involved for consultancy or testing or reviews.
- **More expensive** is HF engineer are part of the desing, do the complete task analysis, surveys and experimental research.

Nevertheless, involving HF engineers in the early stage of the design project is cheaper because the system built will be better and will not need more fixes in the future.

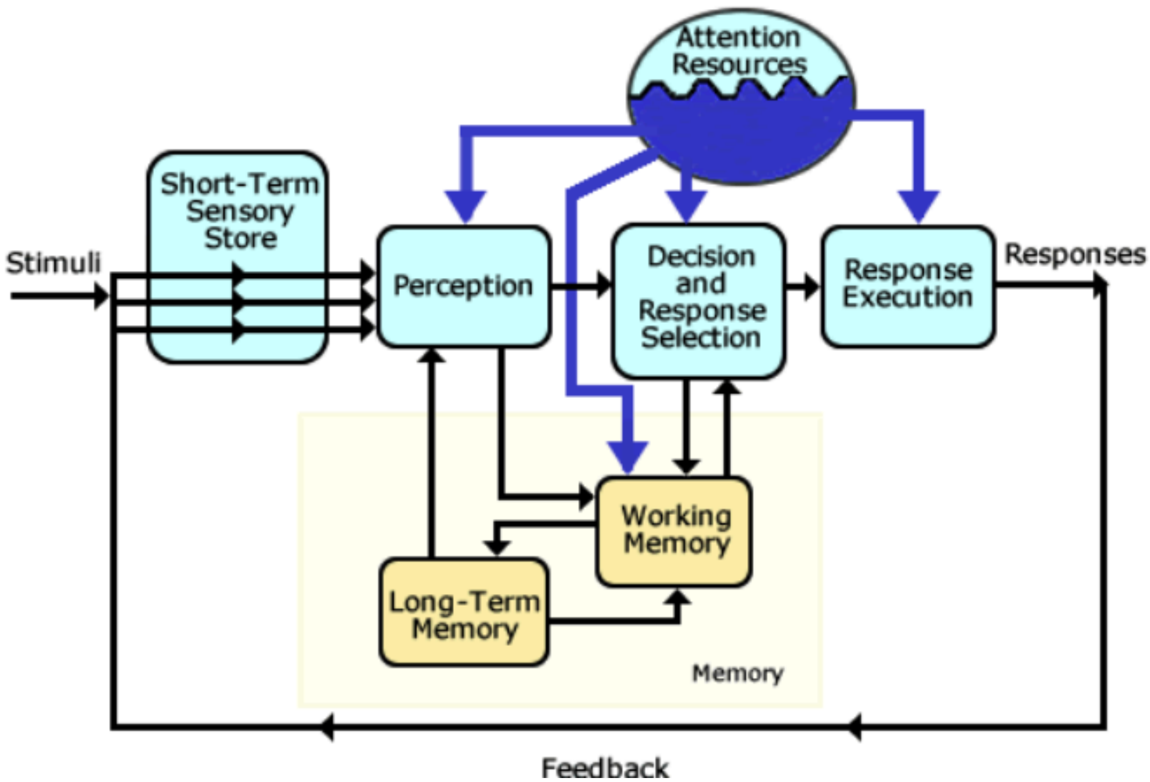
Human information processing

Brain structure and functioning



Human information processing

Information enters from the senses and it is kept in the short-term sensory store. Then, the input is perceptually analyze and then it goes over other processed of decision and response selection and response execution. All these processes need attentional resources which are allocated to all those stages in different ways depending on the tasks. At the same time, we need two types of memory to produce continuity in our information processing stream; the working memory, limited in capacity and stores the information that we need in the moment, meanwhile, the information that is needed in the futre is stored in the long-term memory.

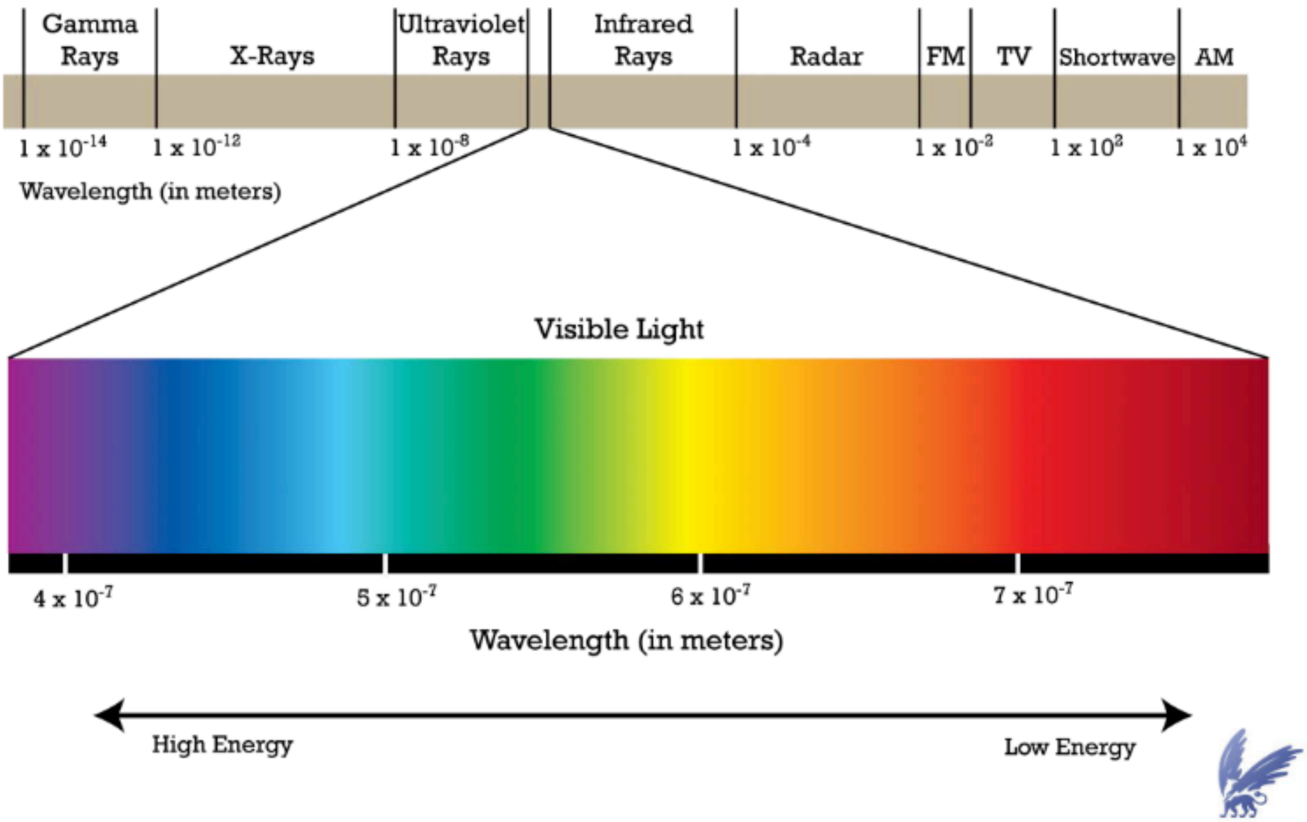


Example: Visual processing

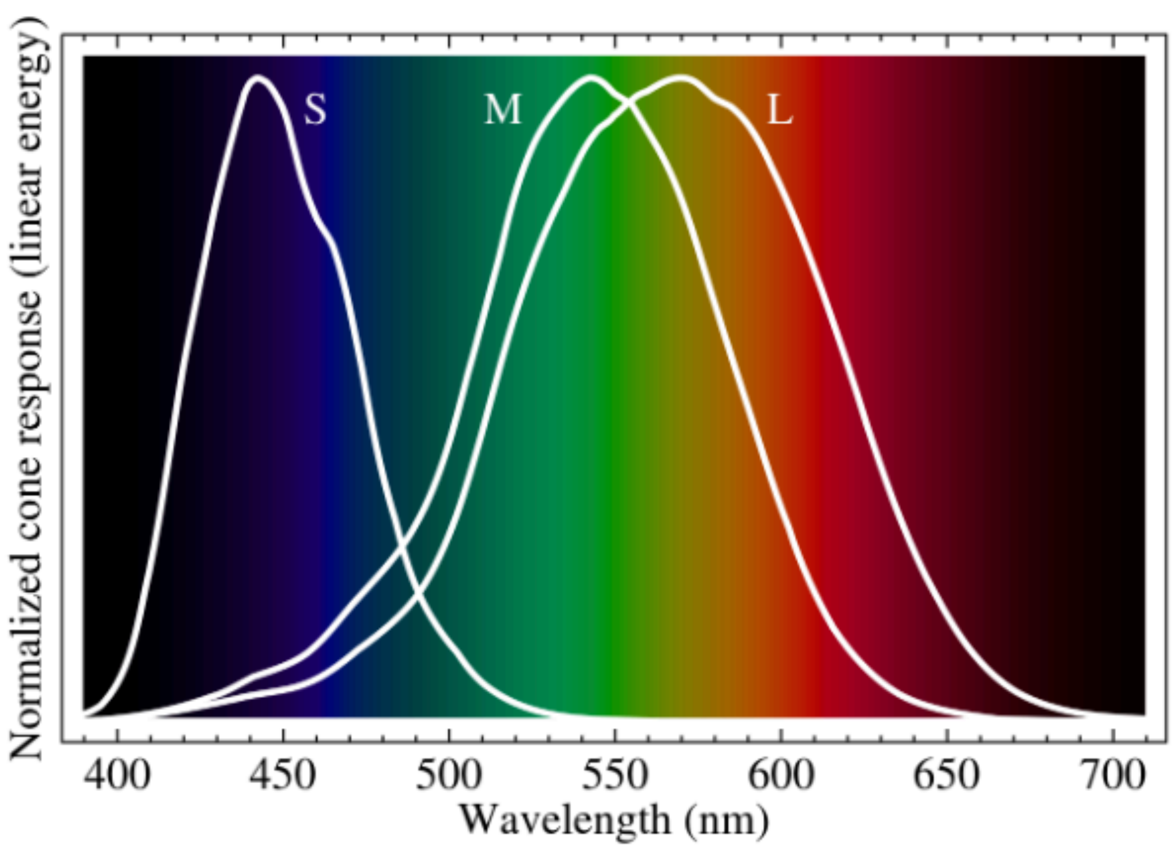
About 50% to 60% is devoted to visual processes. Most of the designed systems are also visual, and the visual domain is the most important part of the artificial systems that are being designed.

Sensation

Our eye are not sensible to all the spectrum of light. This intrinsic limitation has to be considered when designing visual systems.

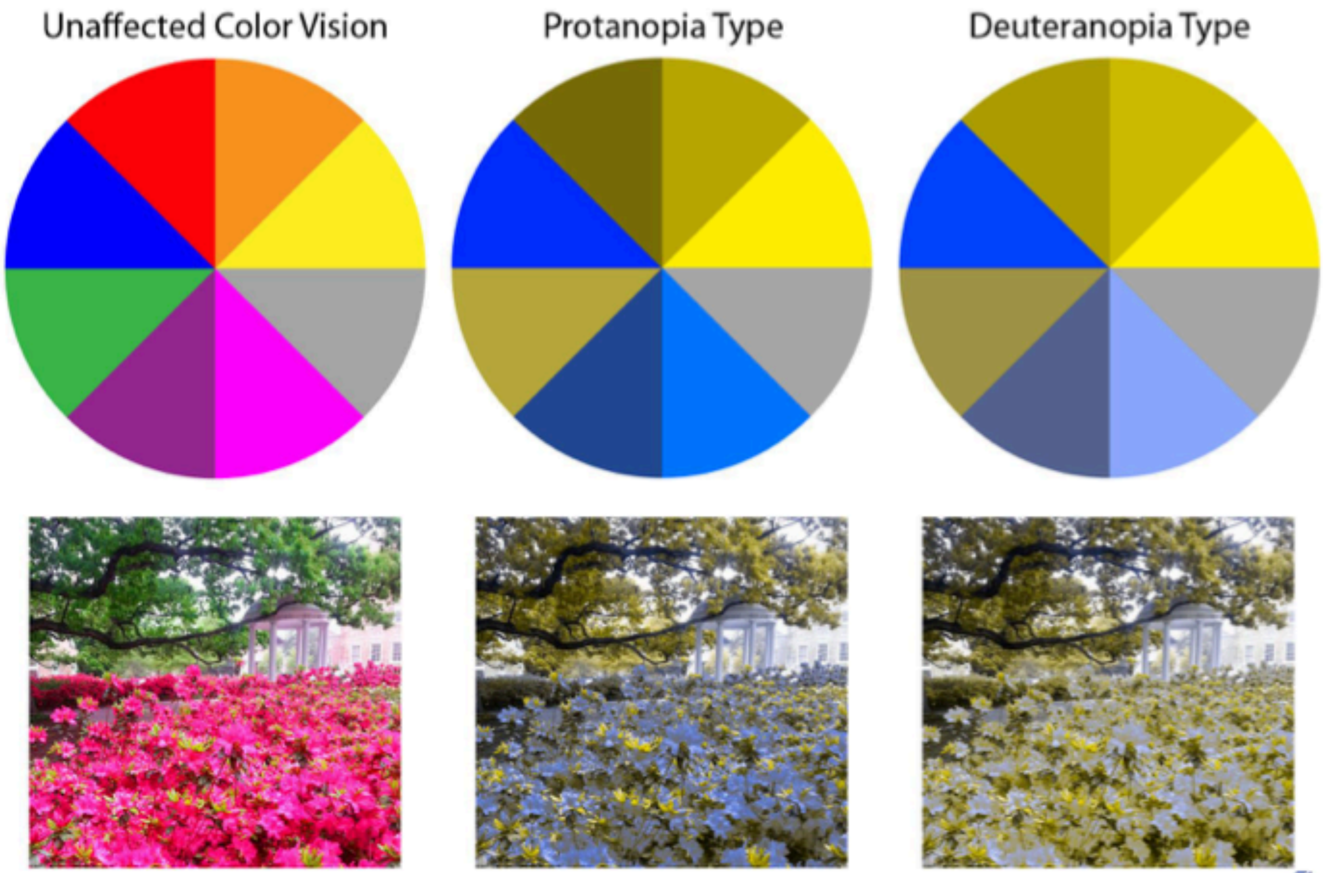


Most people have three types of cones in the retina which are devote to process different parts of lights in the spectrum of visible natural light; blue, green and red cones.



However, not everybody has these three cones and they might suffer of different variations (pratonopia = loss

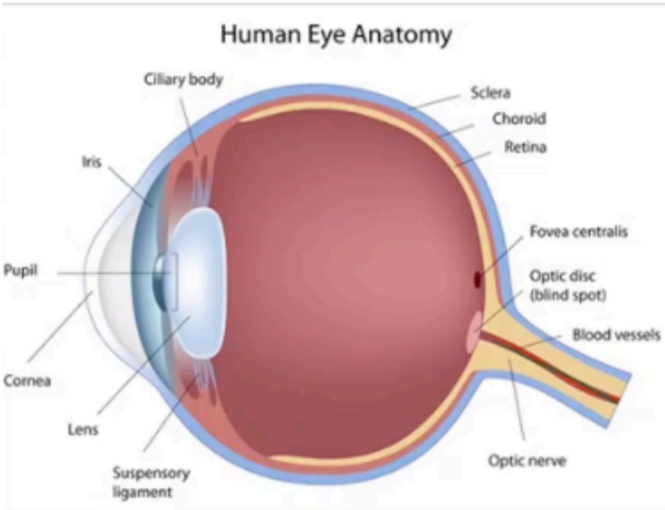
However, not everybody has these three cones and they might suffer of different variations (pratonopia = loss of red cone, deuteranopia = loss of red and green cones)

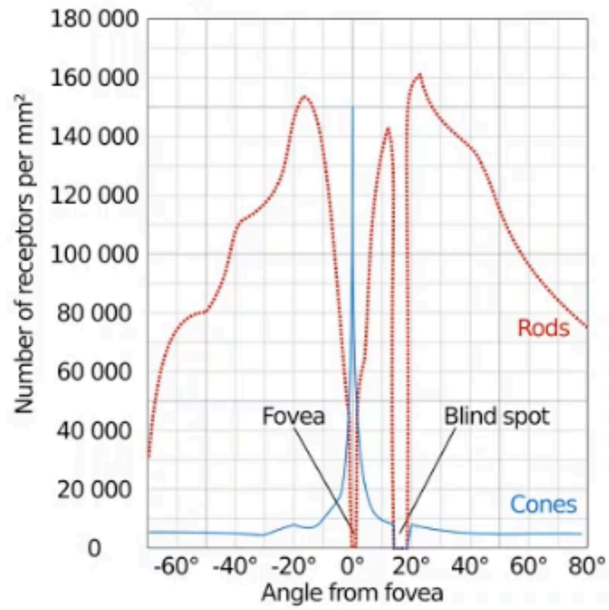


These variations must be taken in consideration when designing digital system.

Most cones are concentred in an area in the middle of the retina, called *fovea*, where most of our color information is retained. In the peripheries, the cones are less present but there are indeed *rodes*, which are in charge of processing emotions and they have no sensitivity to colors. 1st observation: **eye movements to see colors by directing the fovea to the object of interest**, and 2nd observation: **the periphery is necessary for processing emotions** (i.e. it helps to detect danger). The **blind spot**, which is 20 degrees from the Fovea, does not have any rods or cones, this is because the optical nerve is not present at that specific area in the retina and so there are no specific receptors there.

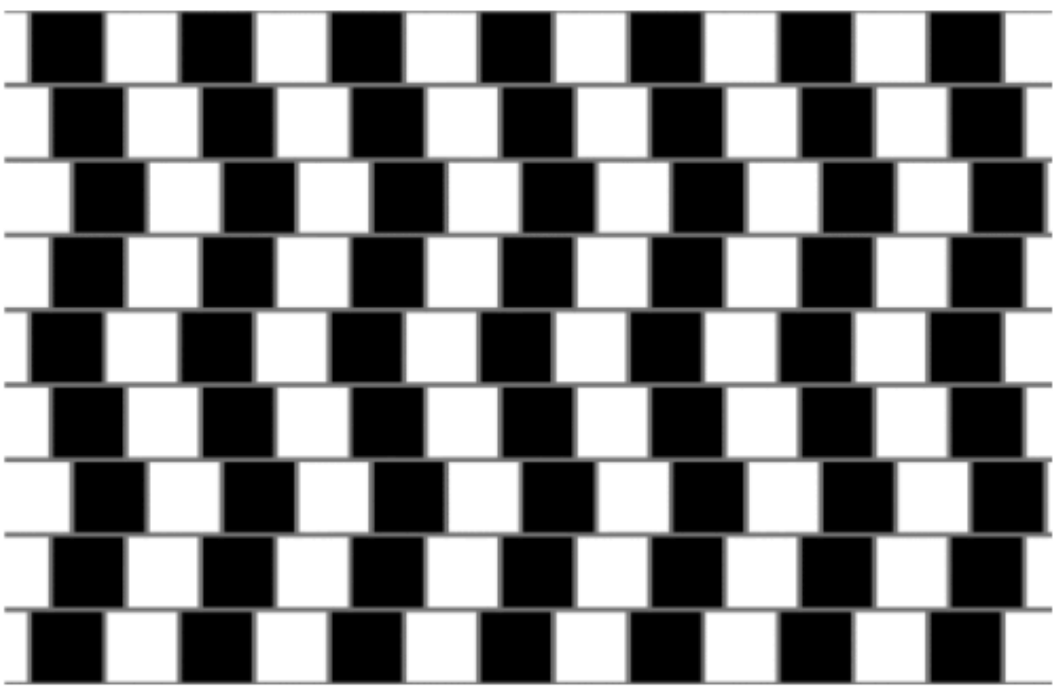
Center vs Periphery





Perception

It has to do with interpretation of our sensorial (visual) input (i.e. visual illusion). The lines below are parallel!



Another imporant part of our perceptual system is solving the **inverse problem**: our visual project are in 2D

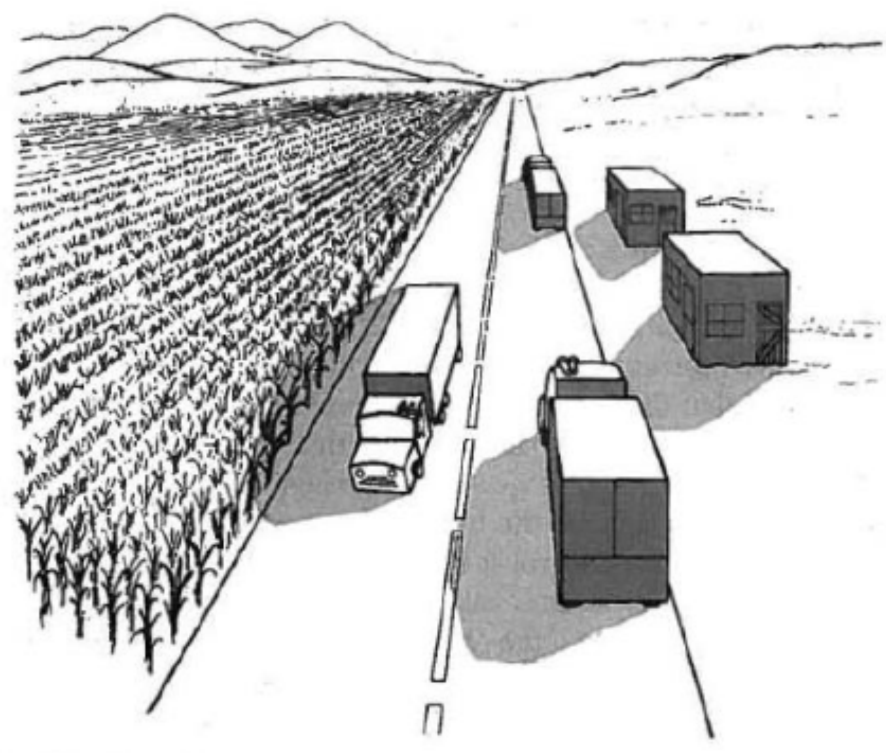
Another imporant part of our perceptual system is solving the **inverse problem**, our visual project are in 2D while we perceive the world in 3D. So, we take the best guess to transform the 2D input to a 3D input. We do that by:

Perceiving depth through:

- *Accommodation*: how much we have to bend our lense to fixate the object
- *Convergence*: how much our eyes are looking in paraller or towards each others can tell us how far an object is
- *Binocular disparity*: the differences in the images that both our eyes receive.

Depth cues:

- linear perspective
- relative size
- interposition
- light and shading
- textual gradients



Perception is not a passive process; we interact with the world around us! **Affordances** helps the human to understand the usability of an object better.

8 Gestalt laws of grouping

(we cover the 3 most important ones and mention the others)

Law of proximity

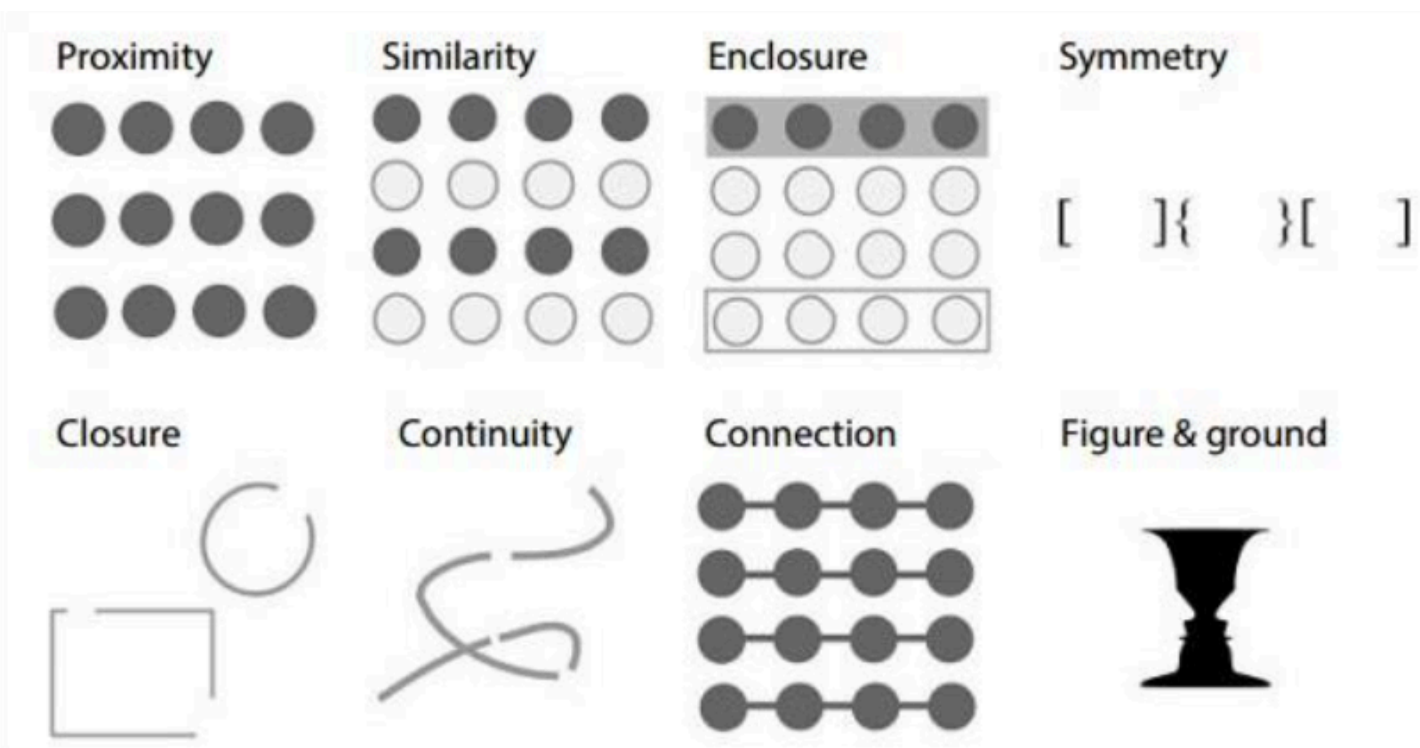
Grouped objects belong to different groups

Law of similarity

Similar object are grouped together by their characteristics (i.e. contrasts); seeing rows instead of a matrix

Law of closure

Not complete objects might still be perceived as completely shaped (i.e. WWF logo).



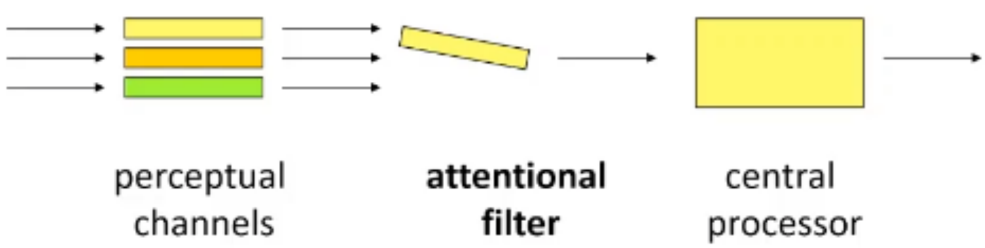
We try to provide the most plausible explanation of an image by predicting it (**prediction**). **Predictions** can be

We try to provide the most plausible explanation of an image by predicting it (**prediction**). **Predictions** can be made in different ways:

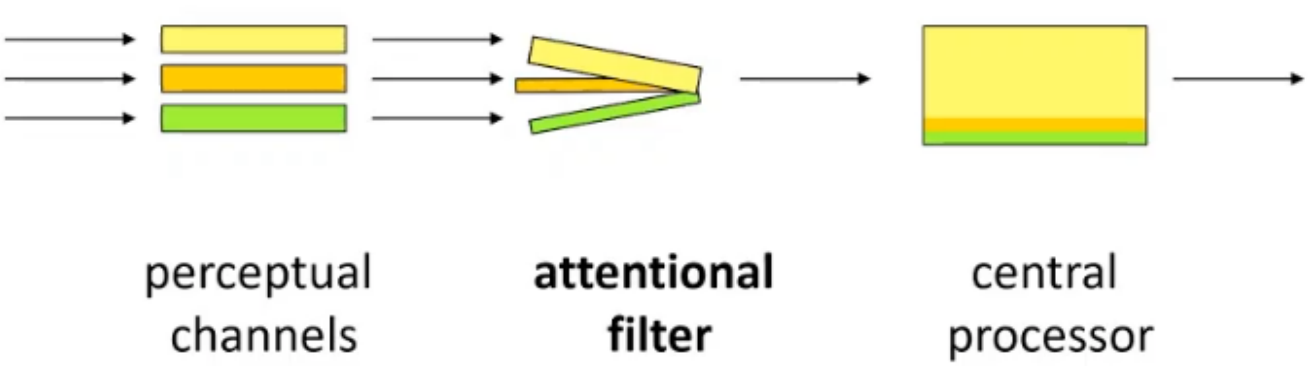
- Autocorrelation between two pictures
- Inferring which part belong to which part of the object
- Priming by immediate previous experiences (i.e. seeing faces)

Attention

Without attentions we are functionally blind!Perception provides us with the basic understanding of the the environement (i.e. objects, the scene, etc ...), but the further processing requires **selection**. **Attention** is a mechanism that allows us to apply selection. Attention can be seen as a **bottleneck** since we have a limited capacity and we have to select the inputs that are useful for us in the moment. The attented inofmration is then use for further processing. **Attention** is defined as the **selection of information** and which **information is processed** compared to which one is **ignored**. Selective attention was first analyzed in *audition*, i.e. focusing on one people talking at a party without getting distracted (*cocktail party effect*). So, attention in audiotion can be studied very effectively. Another example of study is the **diachotic listening technique** (Cherry 1953); shadowing/pay attention to the message in one ear. The experiment concluded that it is **impossible to shadow information from one ear** and **pay attention with the other one**. Overall, detailed aspects such as language, indivual words and semantic content are unnoticed. Successively, a **filter theory of attention** (Broadbant 1958) was developed. This theory suggested that the bottleneck to the filter can be placed very early on in the stream of information process (**early selection**), and the auditory input can be already filtered out by physical dimensions (i.e. location or loudness).



With more developments, a **filter attenuation theory** (Treisman, 1960) stated that relevanta information can pass through the filter, but channel that are less relevant will be attenuated. So, priority is assigned to the different inputs.



Other theories (Deutsch & Deutsch 1963) proposed that the bottleneck filter is placed after the central processor and it happens after the simulus-identification (**late selection**) (i.e. name the color of a certain ink when the ink is incongruent with the meaning of the word).

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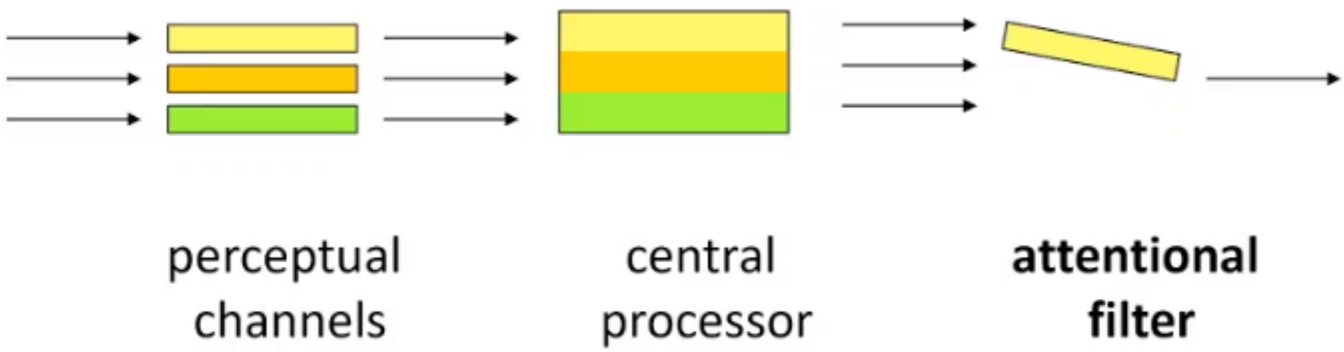
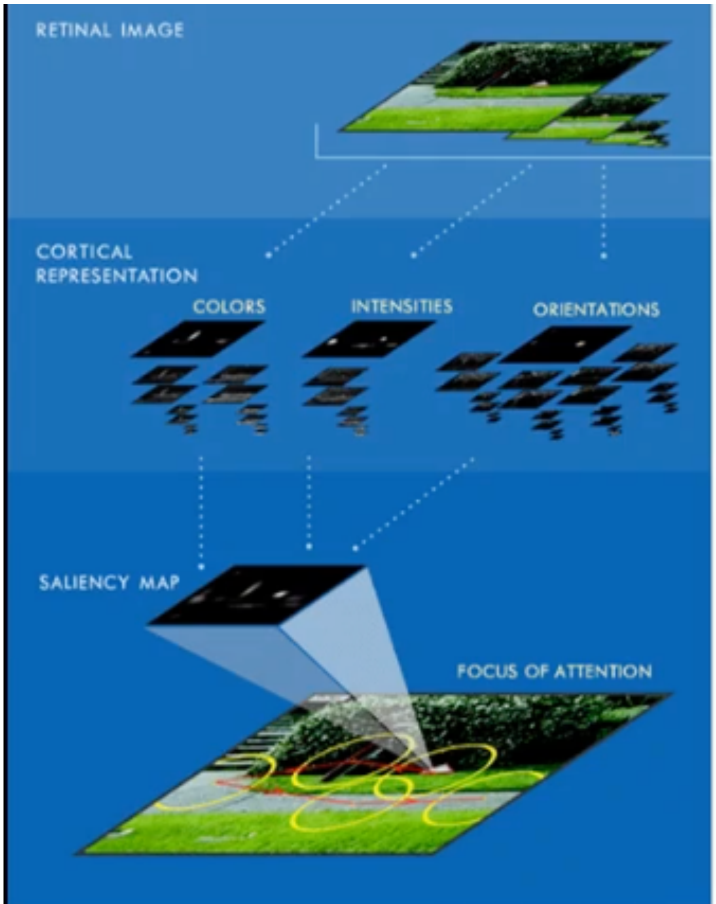


So, for things that have already assigned priority it makes sense to apply the filter only later on.

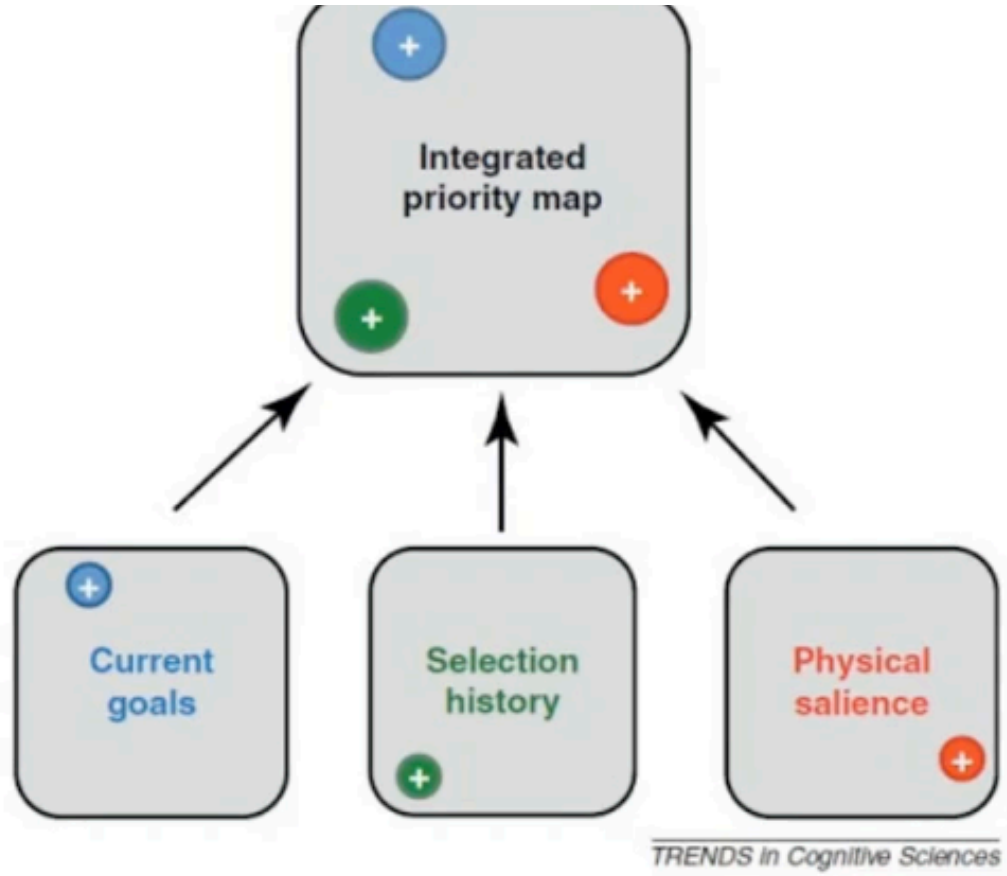
In general attention can be seen as selection of information and with the invention of brain imaging attention was discovered to have not specifically related to the stimulus input but it has to do on how the information was gated; if the the individual attending the information or not the visual cortext behaves differently. So, to **direct visual attention** it is possible to **spatially** select (i.e. selectivity of location, for example, stree sign) or by **feature-based** selection (i.e. based on features such as color, orientation or size, for example, traffic lights).

Information processing in the visual search is driven by attivation of one of the features in the feature maps (like color, orientation or size). This was suggested and studied by the work of Itti & Kock, 2001. They discovered that first the images are decomposed in parallel into several feature maps (i.e. color, intensity and orientation), then, for each of the feature maps the most salient location is computed and then fed to the **master salient map.** This master saliency map represent the location of the current feature maps and then the current salient locations are selected and the focus of attention si redirected to these locations.



Itti & Koch, 2001

However, we are not only driven by these kind of **bottom-up inputs**, salient location, but we can also redirect our attention on command. So, there is also a **top-down influence** on our vision attention, which consists in redirecting our attention where desired. In addition to bottom-up and top-down influences , there is also another force that may playing a role in redirecting our attention which entails the **expected rewards** of an object or image that may attract our attention; since we got a reward by looking at it in the past, i.e. starbucks coffee cup, now we recognize it first in the frame we are looking at. It was discovered (by Anderson, Laurent & Yantis 2011) that learned reward value directly modulates the visual salience of reward-associated stimulus features, causing more attentional capture. So, **the force controlling our attention are now 3-folds**:



Scene context/history also controls attention, expectation where things should be in a scene (i.e. we do not expect to see a car flying, so if we see one, our attention would be caught by it).

So, at the end, **attention is a competition among current goals, physical salience, selection history and scence context**. Moreover, **eye movement** converge to what we are paying attention to.

Memory

Different types of memory exists:

- **Iconic memory**: the information is preserved between 0 and 250ms. Very fragile representation usually replaced by other information.
- **Visual working memory\short memory**: 250ms - seconds, we need the processes of reharsal to protect it from interference.
- **Long term**: hrs - days - years, stored passively, it is retrievable.

(By Sperling, 1960) Perceptual representations(**iconic memory**) are :

- easily overwritten by new stimuli
- can decay quite quickly

Meanwhile, **visual working memory** :

- Stores information for a few seconds so that it can be used in the service of the ongoing cognitive tasks
- Can survive eye movements, eye blinks and other interruptions
- It a maintain a **limited amount of information** (about 4 items) in an "on-line" or readily accessible state.

In the end, **working memory** (WM) has functionally dissociated mechanisms fro the maintenance of information (i.e. the central executive). Recent studies suggested that WM works as a **gradient**; WM can be found in the brain as a **neuro-persisten activity** (firing of neurons), and depending on the task we involve different brain areas differently, so it is a **content-specific** activity. WM has **capacity limitation** and it it related to different areas, i.e. controlateral dealy activity.

Long-term memory has no capacity limitations.

Eye Tracking

It is is a **complex physiological measure** of information processing with a long history and many applications in research.

The human eyer performs 100-200 movements per minute depending on the task and aim; these movement patterns can be characterzied by the durations of the eye fixations. Such activity is necessary for positioning of **the fovea**, the most sensity part of the retina and focusing on it on the observed object. The **fovea** is the area of the highest visual resolution, maximal visual acuity. By studying eye movements and their dynamicas we can assess visual stress, the process of certain taks solving and mechanisms of visual perception itself.

Monitoring techniques for eye movements

Camera recording

A sequence of eye positions is recorded during visual performance, and each frame indicates eye position in a 40ms interval. To analyze the results, each image in enlarged and projected onto an auxiliary screen, making it more convinient to track the sequence of eye movements. The center of the pupil on each frame is marked by a dot; then, these dots are connected by lines. BY following these lines it is rather easy to analyze eye movements during a task. Next, the trajectory of the eye movement is matched with the test picture and analyzed.

This method may be applied to studying eye movements of a driver; in this case, it is the bright corneal reflex that is tracked, but not the eye itself. The main advantage of this method is that the traffic situation is also reproduced in the recorded movie at the same time. Accurate matching of the bright spot and the road in the shot is achieved by the setting of translucent mirrors in front of the driver's eyes. They separate the optical flow into two parts, one of which reaches the driver's eyes, whereas the other is directed towards the camera. Analyzing data across fames and following the way the driver's gaze (marked with a black cross) moves, it is possible to see where the driver is paying attention to (i.e. traffic lights, road signs, cars etc...). From changes of the car position on the road, we can also assess the driver;s reaction to the situation and his/her response time to changes in the environment.

Electrooculography

It is used in cases where **constant recording of eye position** is needed. The electro-biological field, which surround the eye, is recorded. By placing four nonpolarizable electrodes around the eye, it is possible to record the change in eyeball position relative to the head. As the eye is an **electric dipole**, where the cornea is positively charged, whereas the retina negatively, an electrical potential, that changes during the rotation of the eye arises in the surrounding media. The results of the experiment are assessed on the oscillographs screen or recorded on paper tape. **Main advantage** of this method is that allowes the expriment to be carried out over a long time and does not distract the subjects attention from the visual task. **Oculography** makes it possible to carry out the experiment at control a human's state at a distance (e.i. an experiment for a pilot in the aircraft). **Multipurpose electroencephalograpich equipment** make it possible to combine the indices of human visual activities with many other physiological parameters of the human's state. However, when the objects are small (e.i. playing chess), a a proper measurement method is needed. Oculography has limited use, because of its low resolving power.

Contact recording

Methods used for eye movement where small objects are involved and with high resolcing power. A special suction cap with a small mirror is fixed on the eye, each time before placing the cap on the eye, the eye is anaesthetized using tetracaine (so, the procedure is not painful or harmful). The rotation of the eye changes the mirrors orientation in relation to the beam of light, and, being reflected to a different angle, the beam is projected onto a screen. Its displacements are recorded by a camera. This method is also used to study the strategies for search of an object among many similar ones. One of the **disadvantages** ofthis method is that it can be used while working in the dark only.

Electromagnetic method

This method still works with a suction cap. In addition, a special electromagnetic sensor - a solenoid reel of thin wire - is fixed to the cap instead of the mirror and it serves as trasmitting antenna. So, when the recording device is switched on and it produces an electromagnetic field; in the receiver, electromagnetic waves are again transformed into electric current, which controls the trace of the oscilloscpe beam and the recording device. The eye movements change the intensity of electric current in the receiving antenna that causes corresponding beam displacement on the oscilloscope and equivalent registration onto the tape of the recording device. In parallel, it is possible to perform recordings on the magnetic tape, and this allows the dynamics of the subject's eye movements to be reproduced when necessary.

Our eyes move by fixed points and saccades, they only move smoothly when looking at moving objects. Eye movements are perpetually changing and depend on the external image and conditions of perception. For example, in the process of reading our eyes are moving with constant stops - fixations. However, if the reader reads in conditions of following the moving beam, such thath the reading speed will arise, the eye will slide down the lines and the number of stops will considerably diminish. However, no eye movements can compensate for a deficit in visual information; proper perception of a visual scene are mipossible without peripheral vision.

Eye movement reserach is closely connected with the problems of psychological engineering: the ergonomic arrangement reduces the opertor's time for processing visual information and improves his work reliability. The main task of psycological intercafe is to find the best variant of the interface between a man and a machine; the mechanism of eye movements are of immense values to solve this problem.

Decision Making

Decision making

Deciding is a process of selecting a response option among several alternatives; the decision is the outcome. Decision mkain is important in many fields, but specifically in medicine.

Types of decision making

Decision making under certainty

- The decision maker *knows with certainty* the consequences of every alternative (e.i. choosing food at the canteen)

Decision making under risk

- The decision maker *knows the probabilities* of the various outcomes (risk) (e.i. watching a lecture)

Decision making under uncertainty

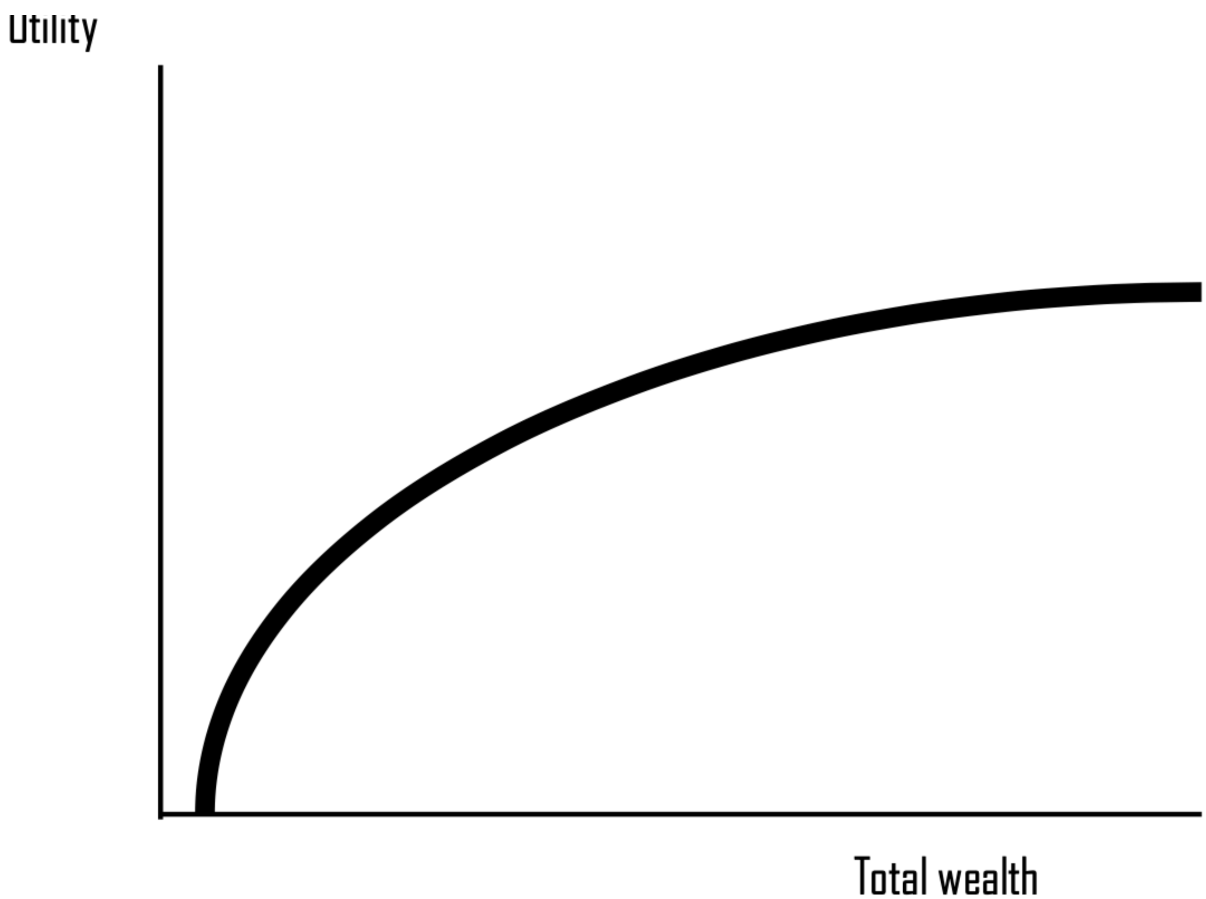
- The decision maker *does not know the probabilities* of the various outcomes (e.i. lottery, choosing a faculty, a job etc...)

Expected value

When the outcomes are risky the EV is calculated

$$EV = \text{value of payoff} \times \text{probability}$$

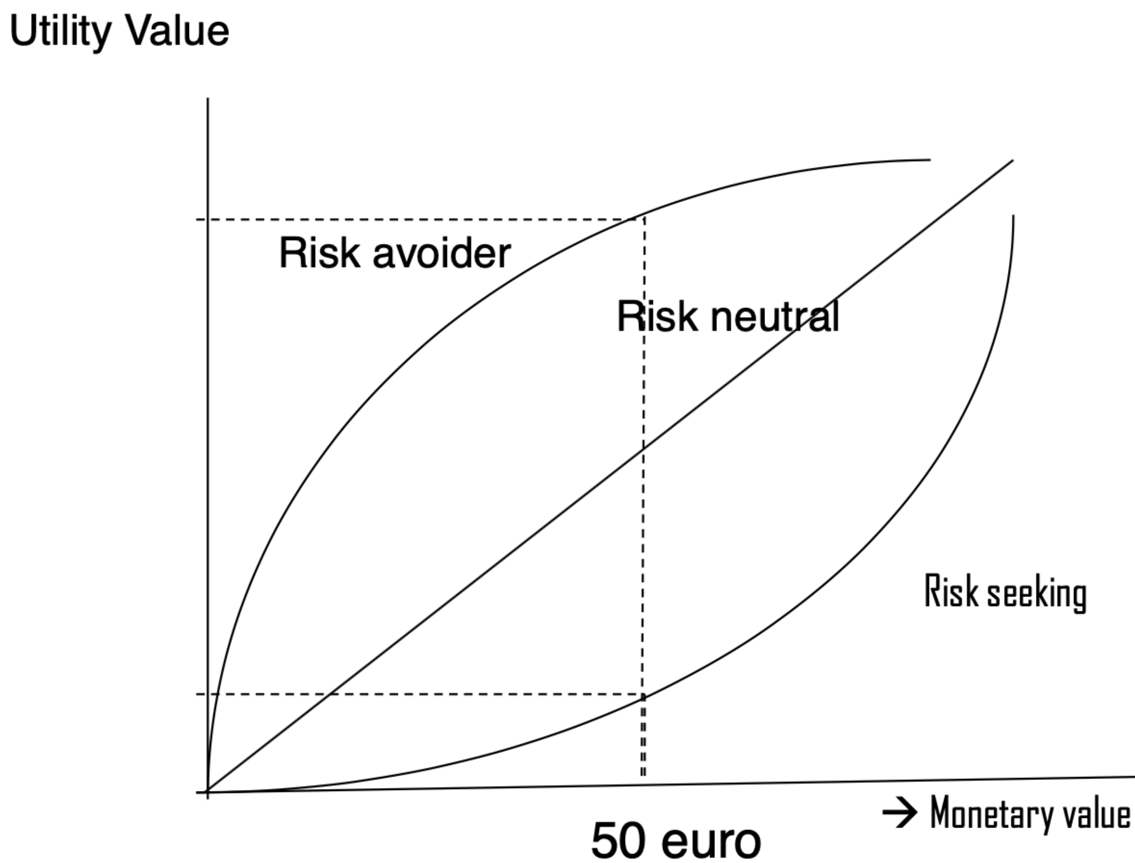
In theory, the choice with higher expected value ir preferred. However, in practice is different. It is not about the mathematica value of the money, but it is about poeple's utility of the money. The value increases at a decreasing rate. In other words, the meaning of money changes depending on how much money one owns. This means that utiliy is not s imply linear function of the value defined by money.



Expected utilty theory

We make decisions based not on monetary values, but based on utility values. **Utility** is defined as **usefulness** (goodness). This utility function is not only for wealth but also for people's attitudes.

The utilty function for different person might also be different (e.i. risk avoider, risk neutral, risk seeking)

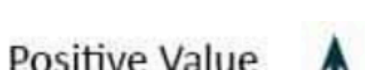


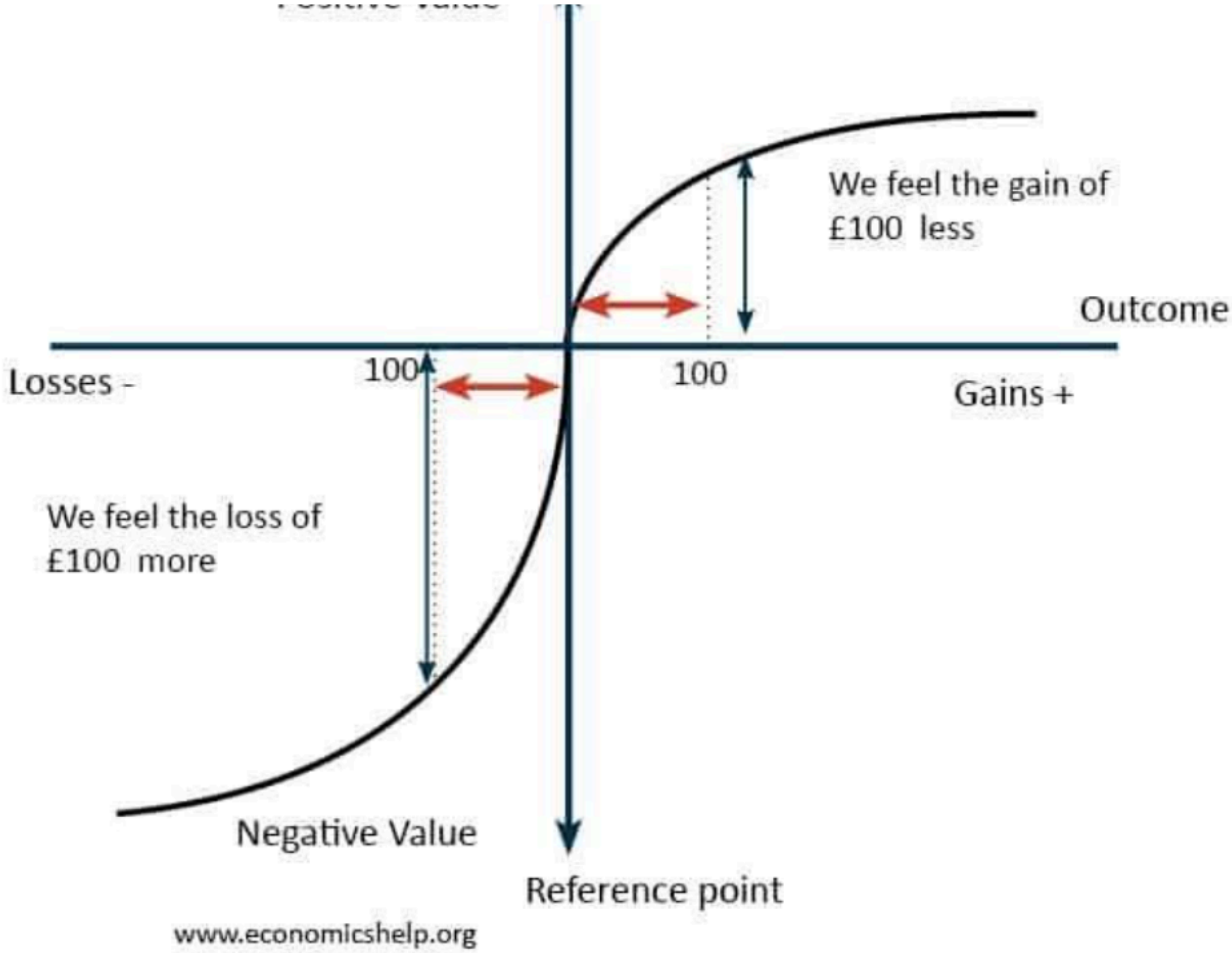
Nevertheless, criticism debated that utility has no meaning to most people and that the utility function was reported to have several exceptions as well.

Prospect Theory

The preferences for choices do not depend on overall wealth and attitudes only. In fact, preferences are reference point dependent; it depends on how the outcome is defined (e.i. gains and losses), just like perception (where the carriers of utility are likely to be gains and losses rather than state of wealth).

The prospect theory functions are very different whether you frame the outcome as gains or losses, and it shows that people are very risk aggressive when they gamble with profit, however, risk takers are also prone to gamble a lot when the outcome is phrased as losses (with the goal of getting out of the game and a quick and profitable manner).





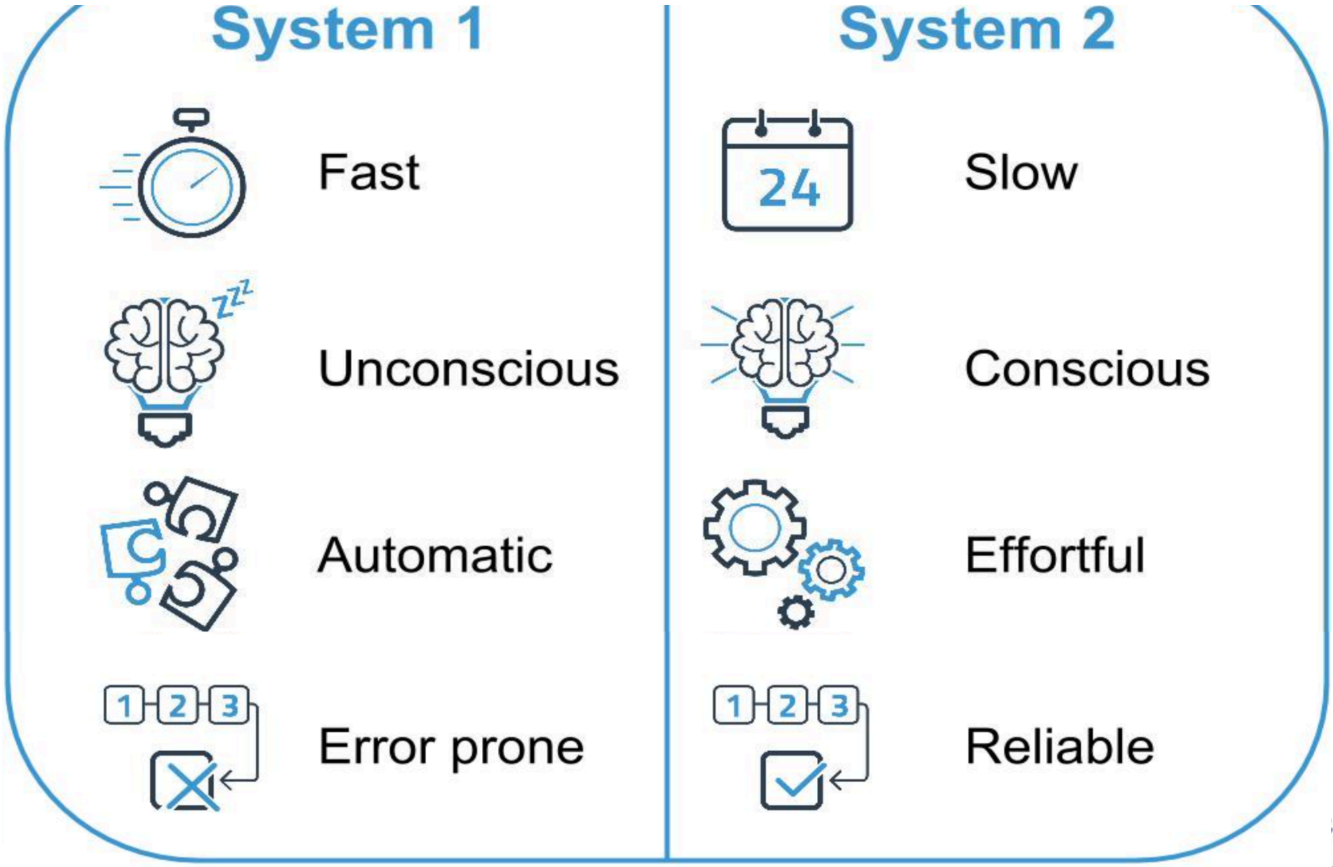
Overall,

- risky prospects can be framed in different ways, as gains or as losses
- changing the description of a prospect should not change decisions, but it does, in a way predicted by Prospect Theory
- framing a prospect as a loss rather than a gain, by changing the reference point, changes the decision

Dual-process thinking

The prospect theory led to discover that we have two different reasoning systems:

- Heuristic system (**system 1**)
- Analytical system (**system 2**)



Heuristics and biases

- A **cognitive bias is a systematic error in judgement**
  - Systematic deviation from the norm
- A very large number of cognitive biases have been identified
  - E.g. **availability bias and confirmation bias**

Availability Heuristic

The probability of an event is evaluated by the ease with which it comes to mind (e.i. frequent events or memorable events). For example, if somebody coughes in front of you, the first things that comes to mind is that that person has covid.

Inattentional blindness

If your system is enganges in looking for certain information sepcifically, it might be biased towards it and ignore other sort of information.

The solution to prevent these kiund biases is to **reflect, reconsider and slow down**.

System 1, which generated the error, and System 2, which failed to detect and correct it. (D. Kahneman, 2004)

Knowledge rather than reasoning skills is important in the diagnostic process! (Prof. Geoff Norman)

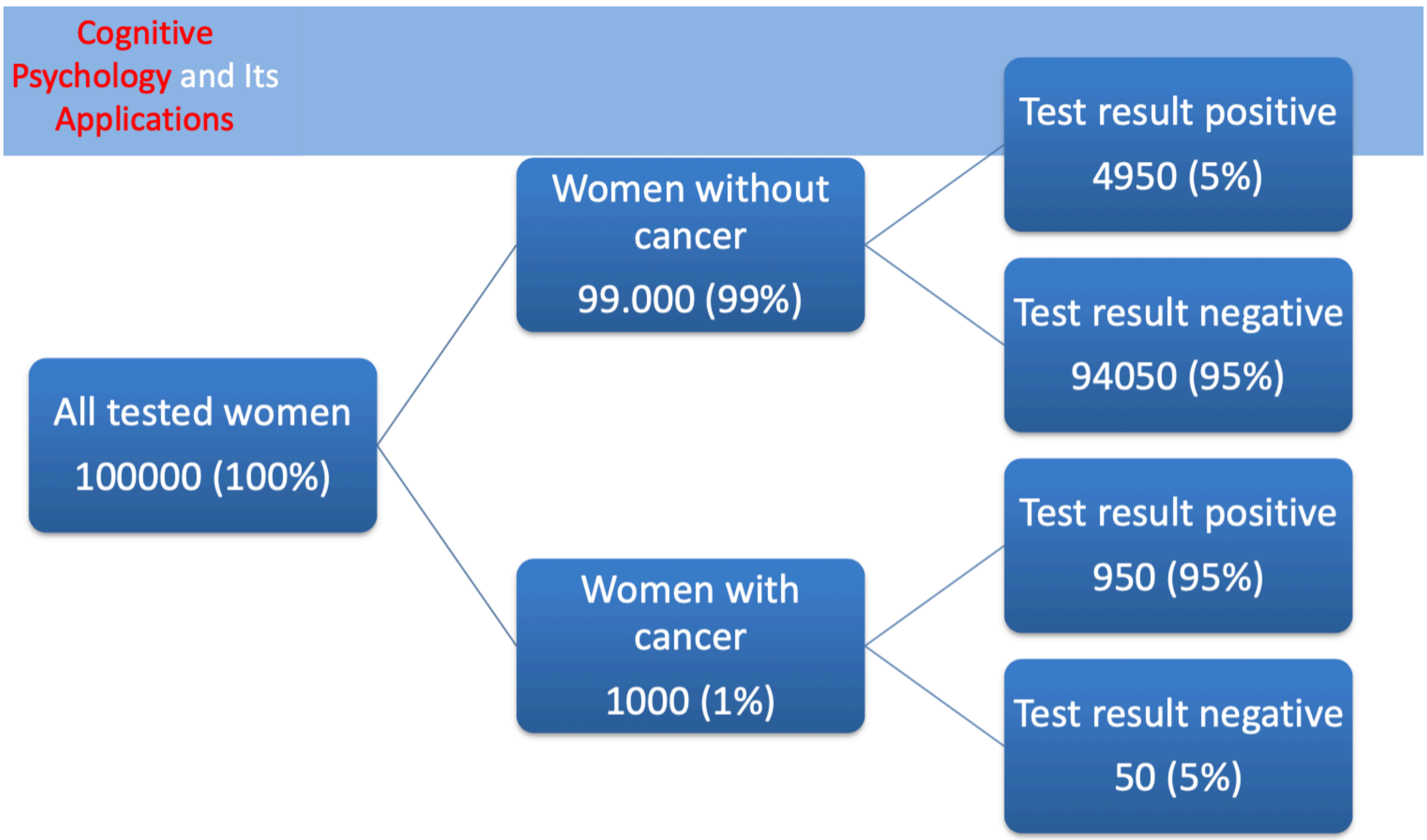
If you have not heard about myasthenia gravis, you cannot cognitively debias your way into that diagnosis. In the *realm of expert performance, knowledge is king*. (Dr. Gurpreet Dhaliwal)

Bayes' Theorem

Theory provides the probability that a hypothesis (H) is true given certain observations(E): conditional probability.

$$P(H|E) = \frac{P(E|H)}{P(E)} P(H)$$

e.i.



P(H) = P(cancer) = the **prior probability** that somebody has cancer = 0.01

P(E) = P(Test+) =. the probability the test will be positive = $0.99 \times 0.05 + 0.01 \times 0.95$ = 0.059

P(E|H) = P(Test+|Cancer) = the probability that the test is positive given the woman has cancer = 0.95

Bayes' theorem = given the test is positive, what it the probability this woman really has cancer ?

$$P(cancer|test+) = \frac{0.95}{0.059} 0.01 = 0.16$$

- It is important to take the prior probabilities into account (if the prior probability is 0.5, then, the bayes' theorem output is the same as the test result (still, by referring at the example above))

- Interpretation of the test results sohuld always be considered in a certain context

Promise of AI

- Increasing numberof diagnoses thata computer can bette rdiagnose than physicians, mostly visual diagnosis.
- Physicians and computers make different mistakes, so together they will be even better!
- It wil same time that doctors can use differently!

Limitations

However, there are some limitations:

- Deep learning algorithms do not generalize to other settings/images than they were trained on.
- The algorithm does not include context
- Integration of the algorithm with the doctor
- Liability (who is responsible to make the decision in case a computer is doing the task?)

Signal detection theory

It is a means to measure the ability to differentiate between information-bearing patterns and random patterns that distract from the information. In the field of electronics, the separation of such patterns from a disguising background is referred to as signal recovery. In ohter words is a means for separating discrimination and decision in detection, recognition, and matters of life and death.

The following confusion matrix shows all the possible decisions that can be made when the signal is present or absent.

Signal (true state)

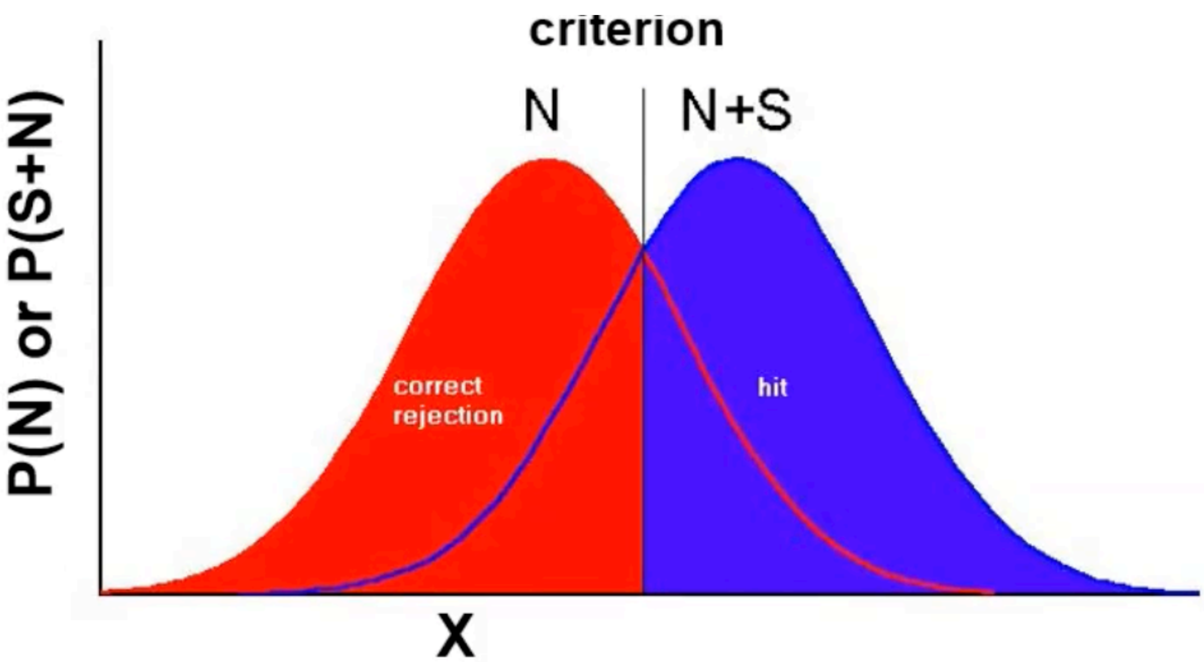
Response (Decision)	present	absent
Present	Hit	False alarm (FA)
Absent	Miss	Correct rejection (CR)

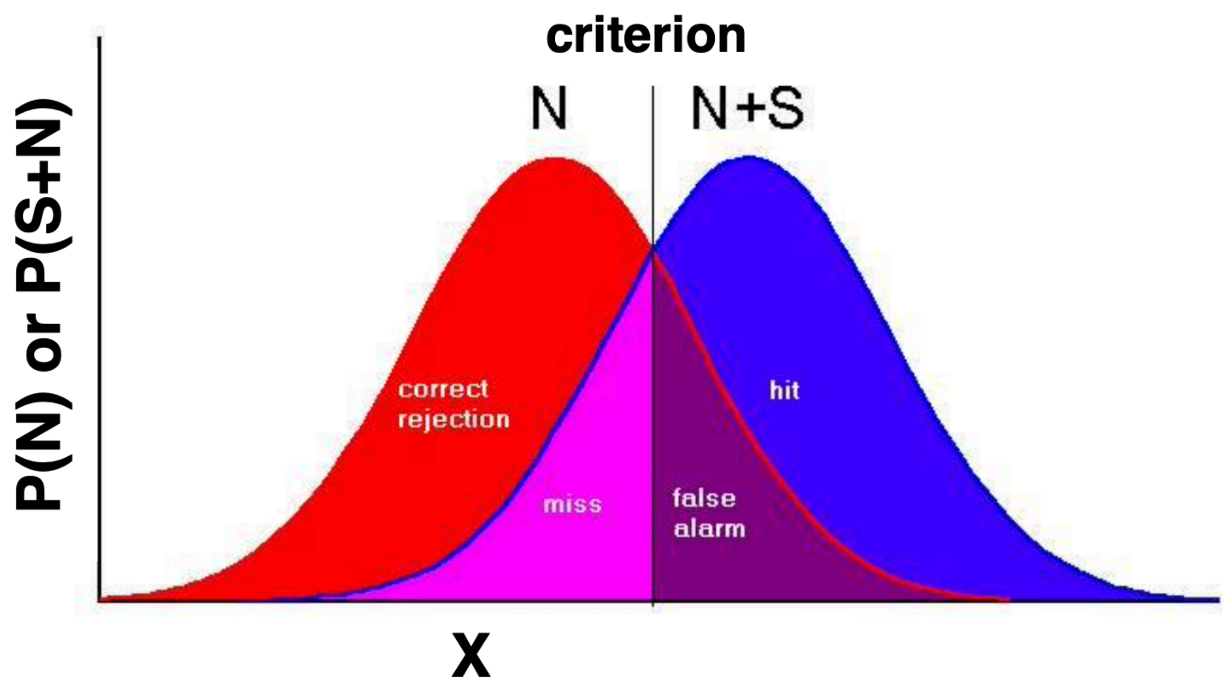
Assumptions

- **Decision variable** (x) : anything used in order to make a decision. So, if a signal is absent only noise contributes to x; if a signal is present, both noise and signal contribute to x.
- The value of the decision variable will vary from trial to trial, whether the signal is present or absent. This variation takes the form of a normal distribution.
- It is difficult to make a decision since the values of x stems from the N + S (noise + signal) and the noise (N) distribution overlap.

On the x-axis, the evidence X. On the y-axis, the probability.

The confusion matrix above can then be visualized in the distributions below:





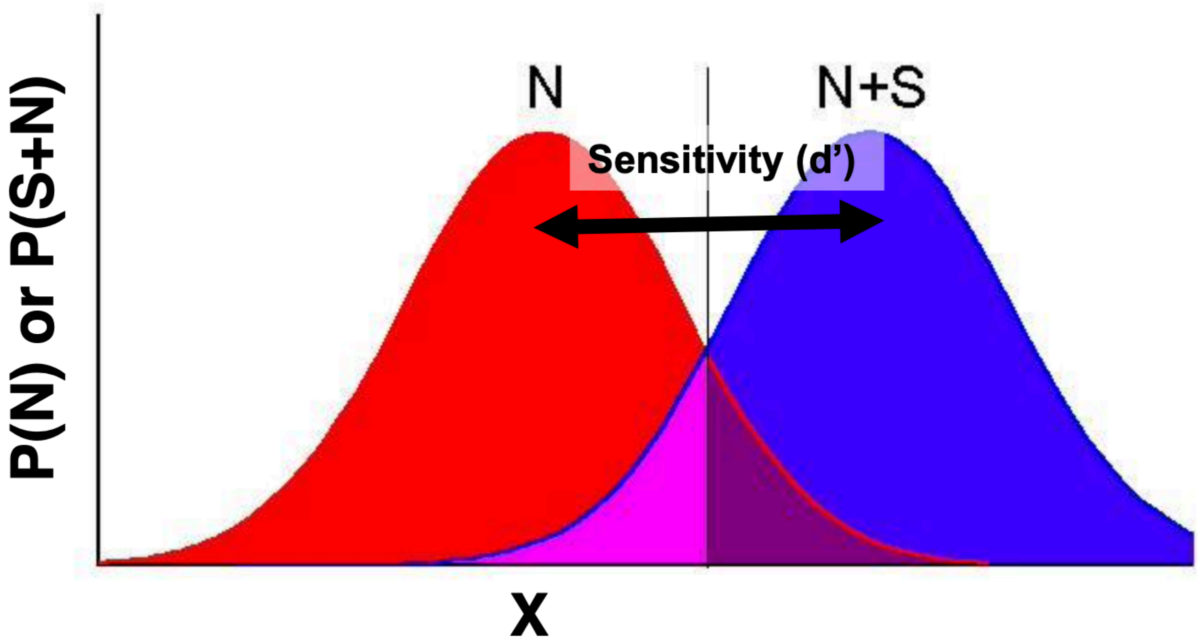
This is a way to visualize how much probability is associated to each of these outcomes.

Measure of sensitivity d'

(Different from the sensitivity of the test)

It is defined as the distance between the means of the *N* and *N* + *S* distributions *in terms of their standard* *deviations* (both normal with same std. deviations). This assumption about their std. deviations make it very easy to calculate the distance between the means of the *standardized N* and *N+S* distributions.

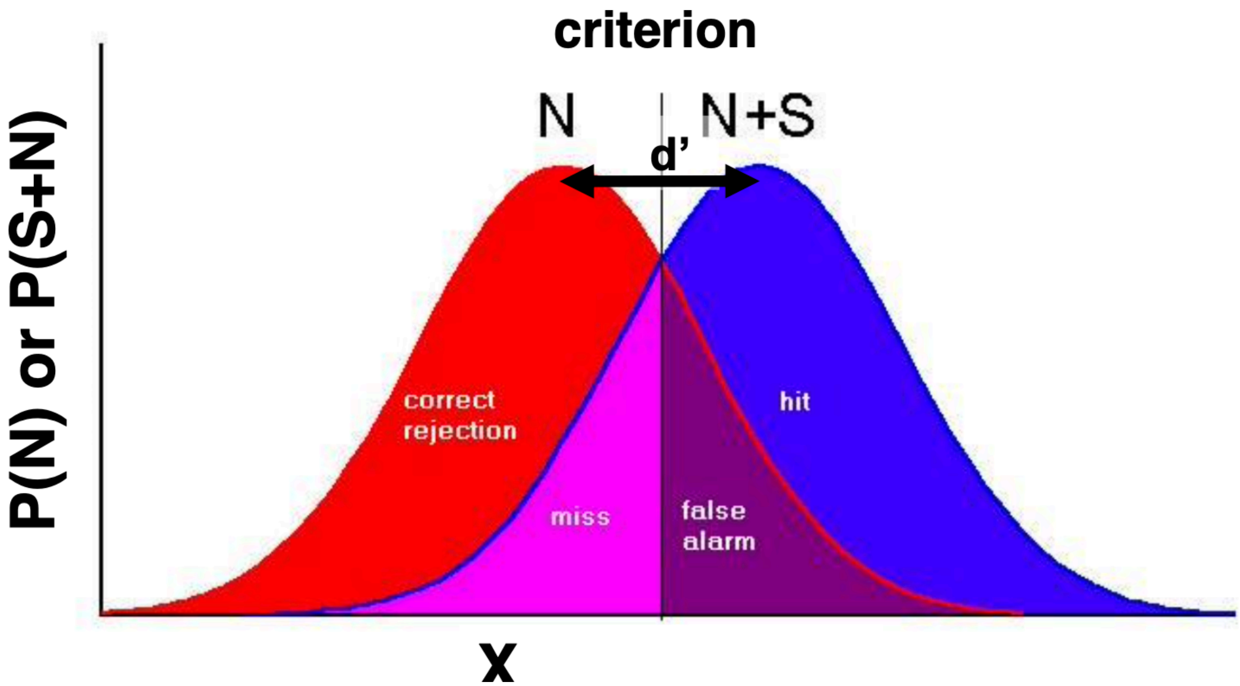
d' = the difference between the z-scored proportion of hits and the z-scored proportion of FA = $\mathrm{z(proportion\ Hits)}$ - $\mathrm{z(proportion\ FA)}$.



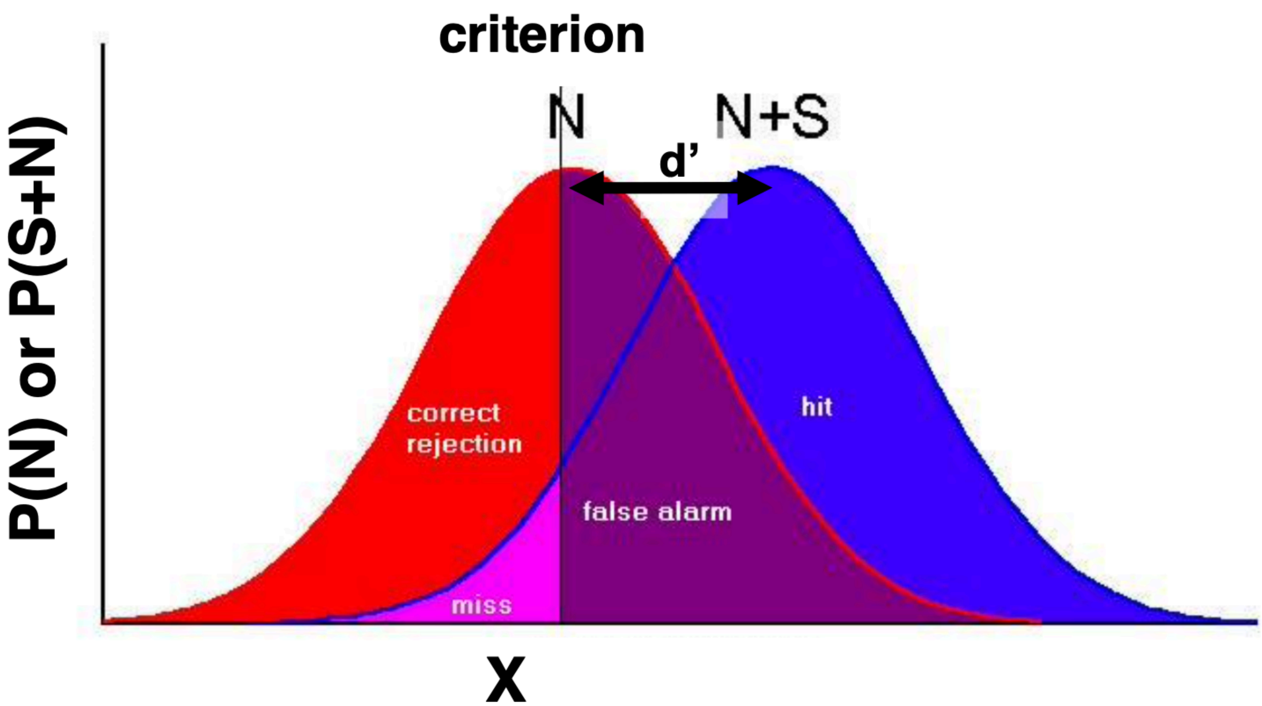
When the sensitivity reduces, the distributions overlap more and it can either be that the signal is weaker or less sensitive observer shifts *N+S* distribution to the left.

The sensitivity is independent of criterion settings (bias).

The crierion is **neutral** in between *N* and *N+S* distributions.



If I need less evidence to say "yes", the criterion is moved towards the left and si called **lenient (or liberal)**.



If the criterion is moved towards the right, there is the need for more and more evidence to say "yes". This criterion is called **conservative**.

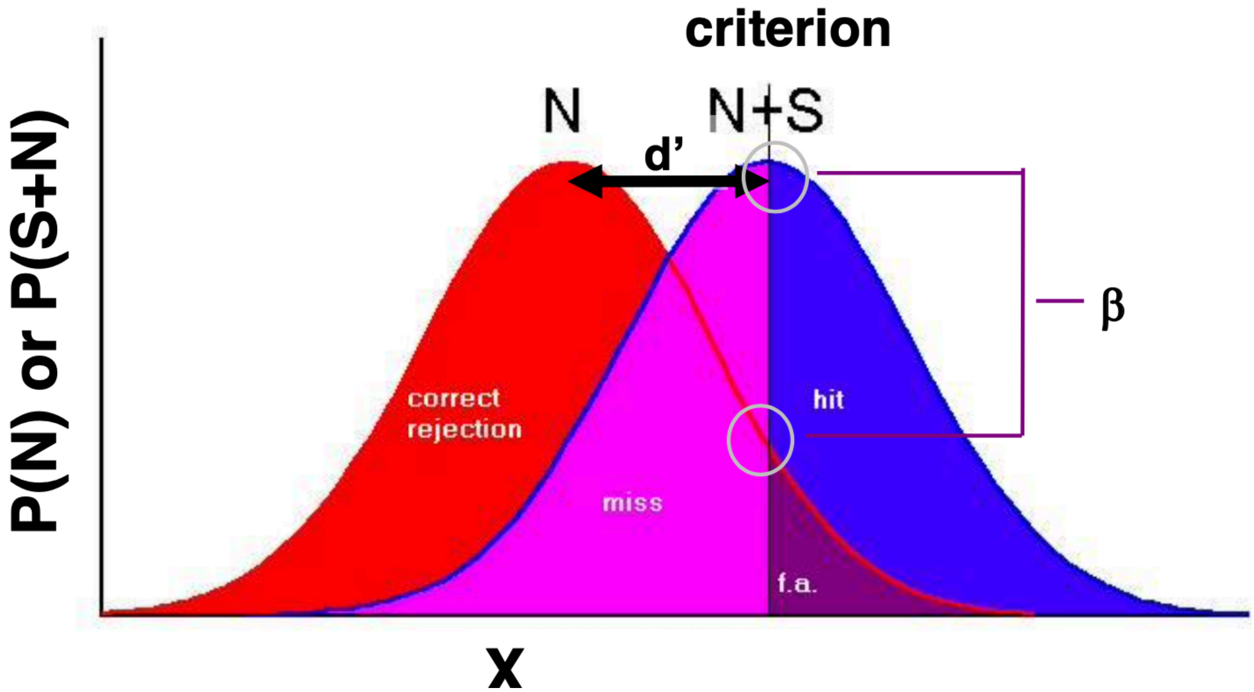
β**:** a measure of criterion setting: the ration of y-values of the *N+S* distribution at the criterion and the *N* distribution at the criterion:

$$\beta = \frac{f(z_{criterion}|N+S)}{f(z_{criterion}|N)}$$

$f(z_{criterion}|N)$

$z_{criterion}$ is the line "criterion".

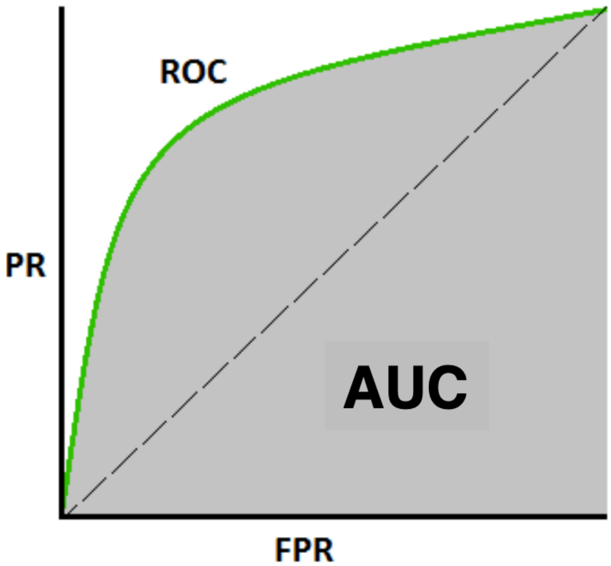
Note: β = 1: neutral criterion; β < 1: lenient criterion; β > 1: conservative criterion.



d' and ROC/AUC curves

Signal (true state)

present	absent



$$\text{TPR / Recall / Sensitivity} = \frac{TP}{TP + FN}$$

$$\text{Specificity} = \frac{TN}{TN + FP}$$

$$\text{FPR} = 1 - \text{Specificity}$$

$$= \frac{FP}{TN + FP}$$

ROC/AUC is useful for comparing models (also saliency models).

Transportation, distraction and multitasking: driving

Motivation

Why transportation?

Transportation involves the interaction of a human with the artificial system. Milions of people are traveling every day. Our brain has not evolve the process the information at high speed perfectly, so, it is interesting to see how to track and control information at very high speed. One of the main concerns while travelling is safety, since many people travel at high speed. Costs of life and material costs are also elements to consider during travelling. These things have to be taken in consideration when designing a good transportation system and transportation vehicles.

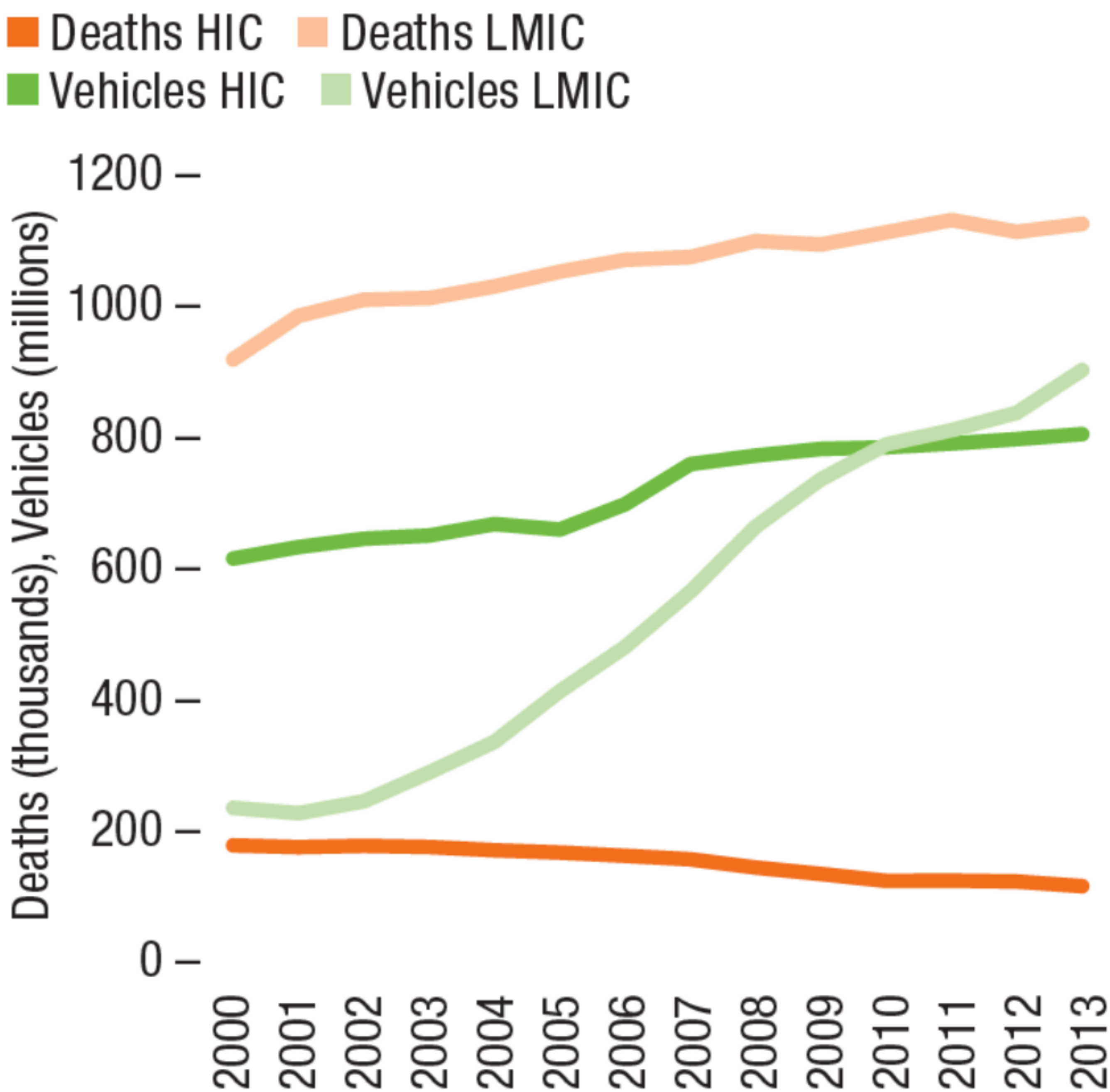
Why driving?

Driving safety is of world's importance and many people drive nowadays.

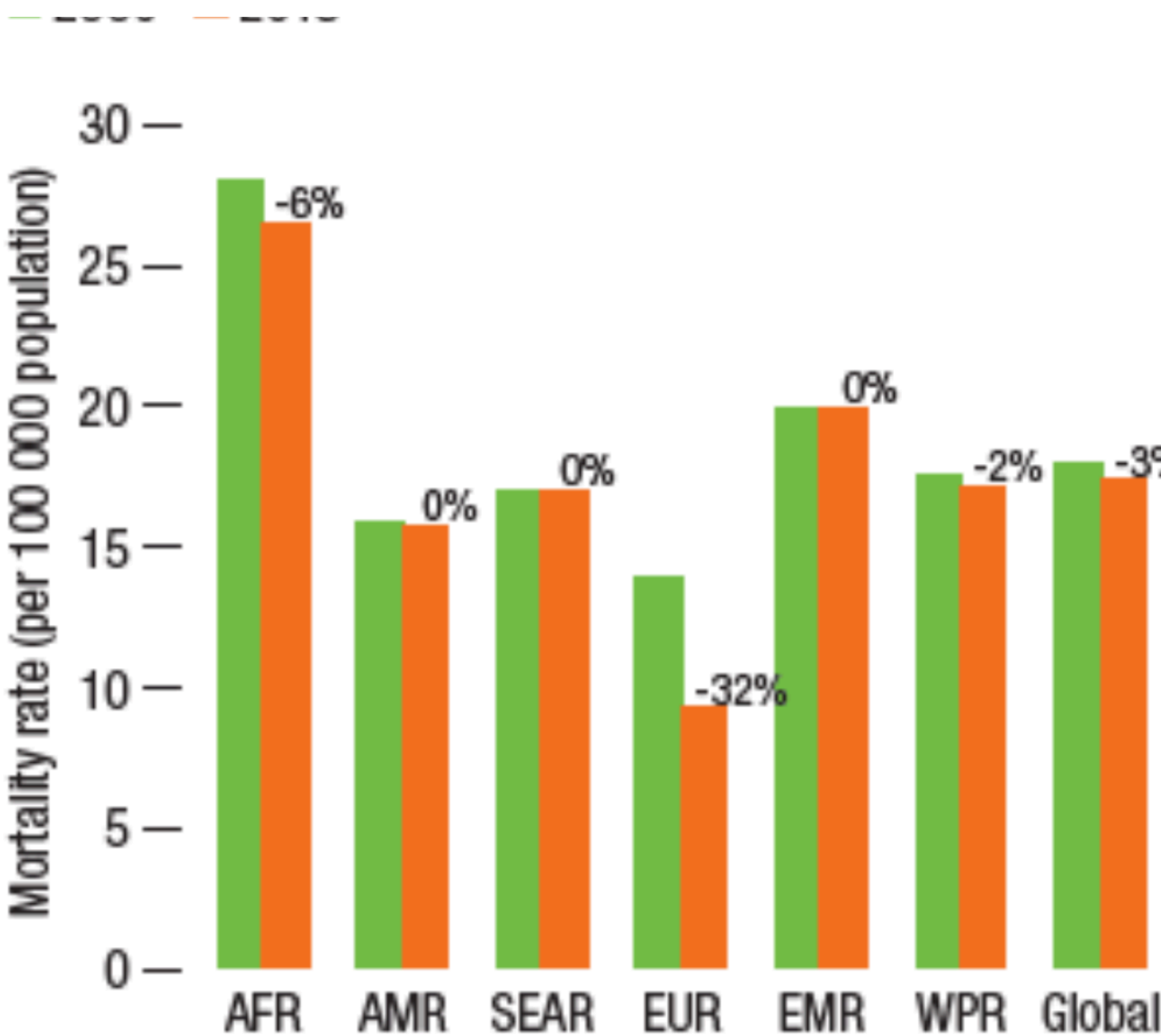
According to WHO:

- ~1.25 million people died from road traffic injuries in 2013, with another 20–50 million people sustaining non-fatal injuries as a result of road traffic collisions or crashes.
- road traffic injuries are the ninth leading cause of death globally, and the leading cause among people age 15–29 years. Almost 60% of road traffic deaths occur among people aged 15–44 years.

By looking at some data, we notice that in low-income countries (LMIC) as the number of vehicles is increasing, the number of deaths is rising too. On the other hand, in high-income countries, as the number of vehicles is the number of deaths is rising too. On the other hand, in high income countries, as the number of vehicles is increasing the number of deaths is decreasing. This leads to think that either the cars of the infrastructure in LMIC is poor or not safe, or people to not obey to the rules or the rules are not enforced.



In addition, we can see that only in EUROPE the deaths rate decreased from 2000 to 2013.



So, there is a lot of room for improvement to decrease the mortality rate and the accidents in road traffic.

Overall, >90% of accidents in traffic are due to human error.

Task analysis

Assessment of driving performance can be based on **strategic, tactical and control aspects**

Strategic

– Choice of route

– Choice of travel time

Tactical

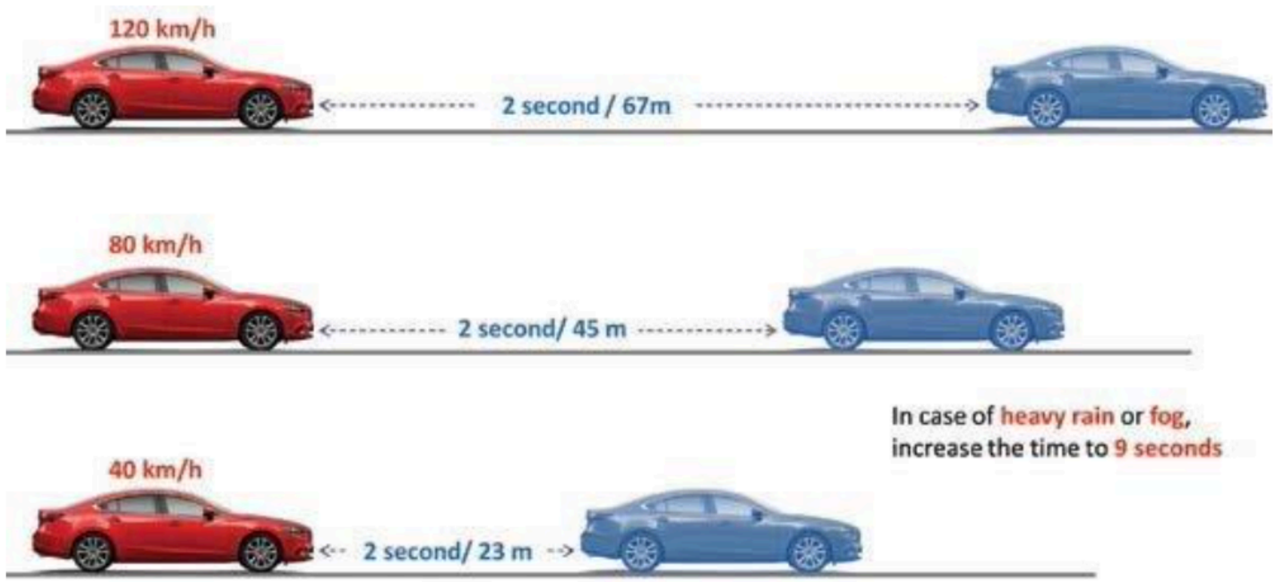
–Choice of speed

–Lane choice, overtaking

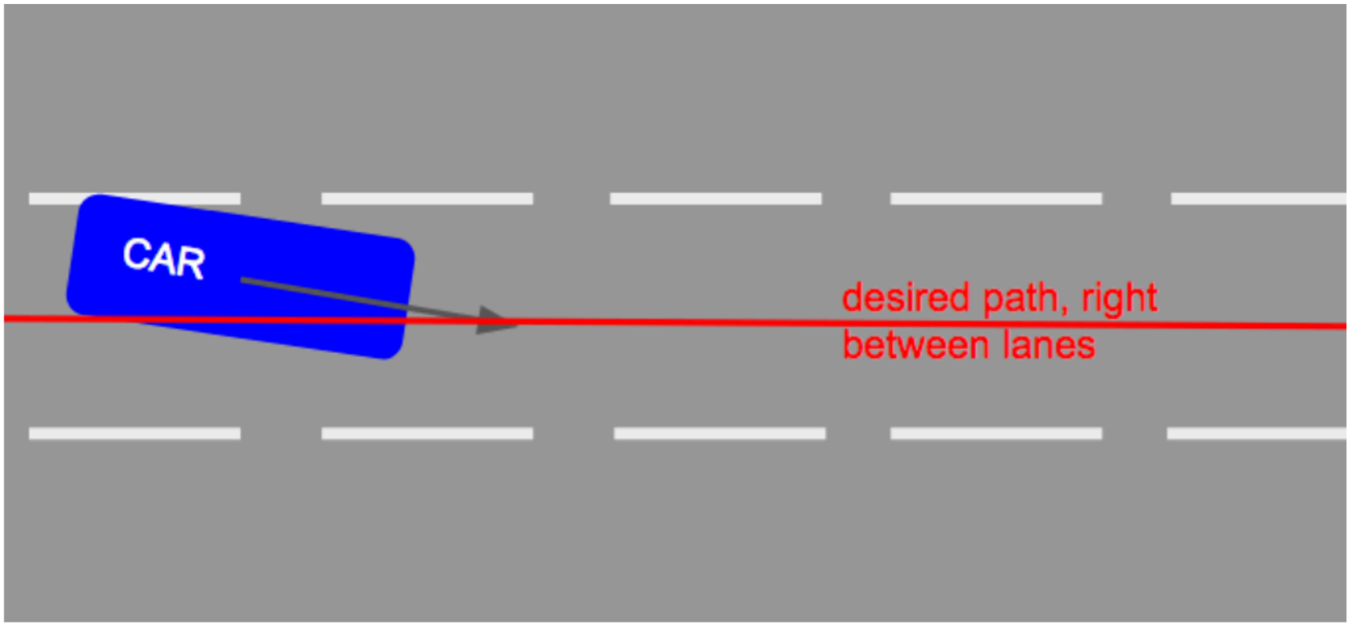
–Taking turns

Control

–Longitudinal (speed, distance between cars)



–Lateral (position of the car in the road/lane)



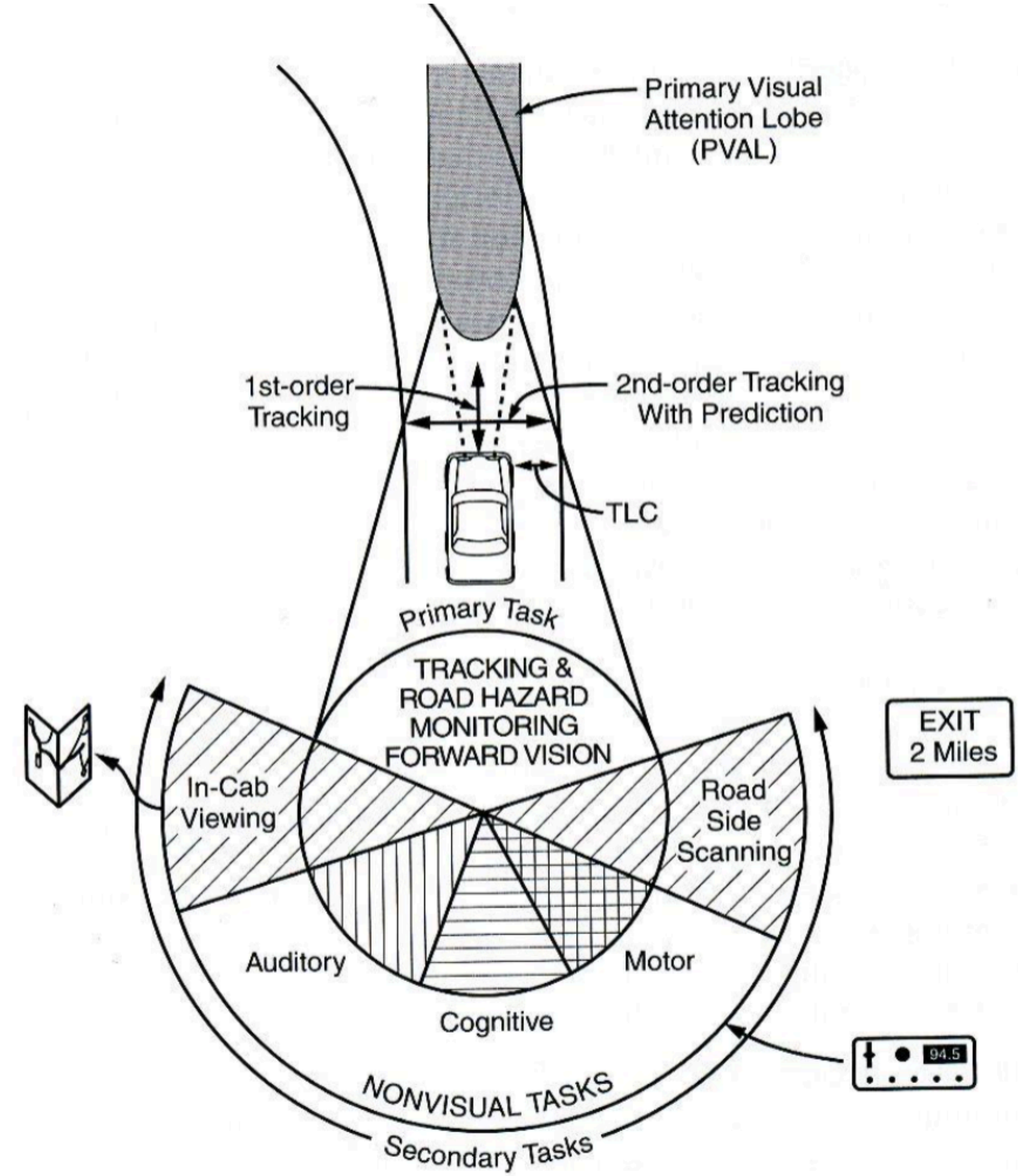
Primary tasks

- Lane keeping and hazard monitoring (**sagety driving**)

Secondary tasks

- navigation, scanning for signs, radio, cell phone, eating...

Driver's information processing stream



Visual tasks

At the top the 2D vehicle control: **PVAL** is imporant for the primary task (driving)

– Longitudinal (1st order)

– Lateral (2nd order)

– Lateral (2nd order)

Non-visual tasks

At the bottom, auditory, cognitive and motor are all competing with the primary task (driving).

TLC = time to lane crossing

Time to contact = distance between the vehicles/ realtive velocities

Critical issues

Visibility

Anthropometry

Anthropometry plays an important role in industrial design, clothing design, ergonomics and architecture where statistical data about the distribution of body dimensions in the population are used to optimize products.

Illumination

Proper illumination is very important at difficult part of the highway. Driving at night is 10x more dangerous than driving during day.

Signage

Aspects to take into consideration when designing a new system are:

Readbility concerns attention and perception (e.i. readable signs etc...)

Clutter concerns the visual search of the sign (e.i. not having conflicting information or a lot of information next to each other).

Redundancy is used to facilitate information processing (e.i. traffic lights)

Consistenty similar to redundancy (e.i. vertical vs horizontal traffic lights)

How to measure visibility?? The general suggestion is that glances should be shorter than 0.8 s, and there should be more than 3 s between glances. Danger roughly proportional to (glance time).

TABLE 17.1 Single Glance Time (Seconds) and Number of Glances for Each Task

	Glance Duration	Number of Glances
Speed	0.62 (0.48)	1.26 (0.40)
Destination Direction	*1.20 (0.73)*	*1.31 (0.62)*
Balance	0.86 (0.35)	2.59 (1.18)
Temperature	1.10 (0.52)	3.18 (1.66)
Cassette Tape	0.80 (0.29)	2.06 (1.29)
Heading	*1.30 (0.56)*	*2.76 (1.81)*
Cruise Control	0.82 (0.36)	5.88 (2.81)
Power Mirror	0.86 (0.34)	6.64 (2.56)
Tune Radio	1.10 (0.47)	6.91 (2.39)
Cross Street	*1.66 (0.82)*	*5.21 (3.20)*
Roadway Distance	*1.53 (0.65)*	*5.78 (2.85)*
Roadway Name	*1.63 (0.80)*	*6.52 (3.15)*

Standard deviations in parentheses; tasks in italic are associated with a route guidance system.

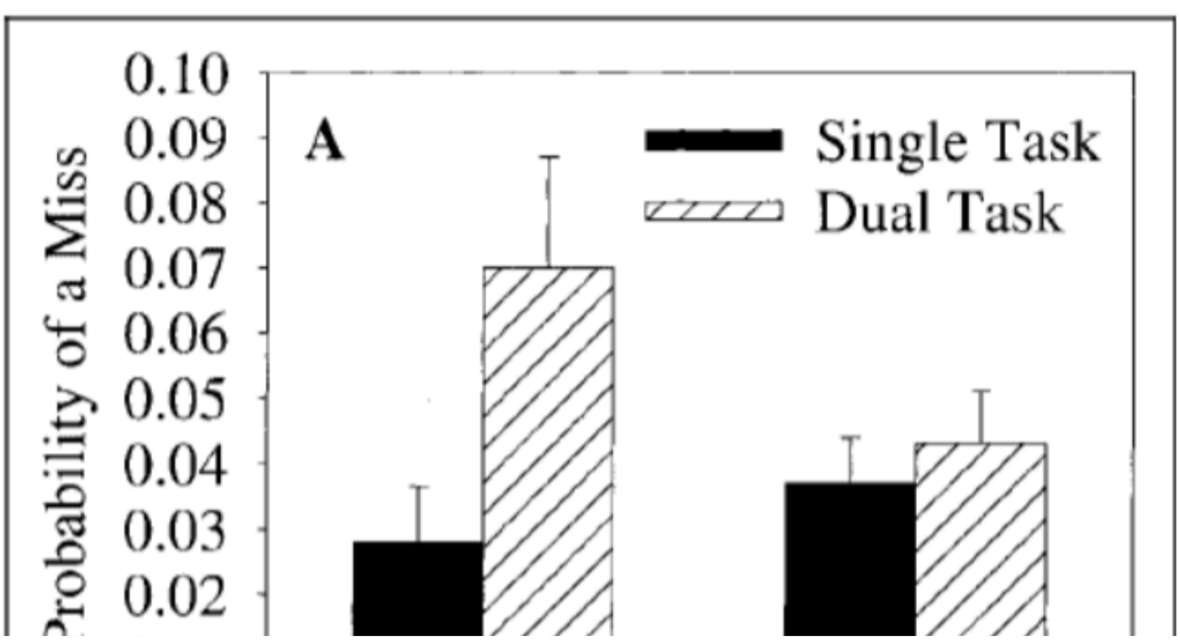
Resource Competition

Three examples of resources that competes with our attention are head-up displays, hands-free cell phones and audio warnings, or speech controls. Also, driving under the **influence of the smartphone**.

How to measure resource competition?

Simulation with

- manual tracking
- detect red light and break (and measuring reacting time)
- single or dual task
- conversation on the phone/control task



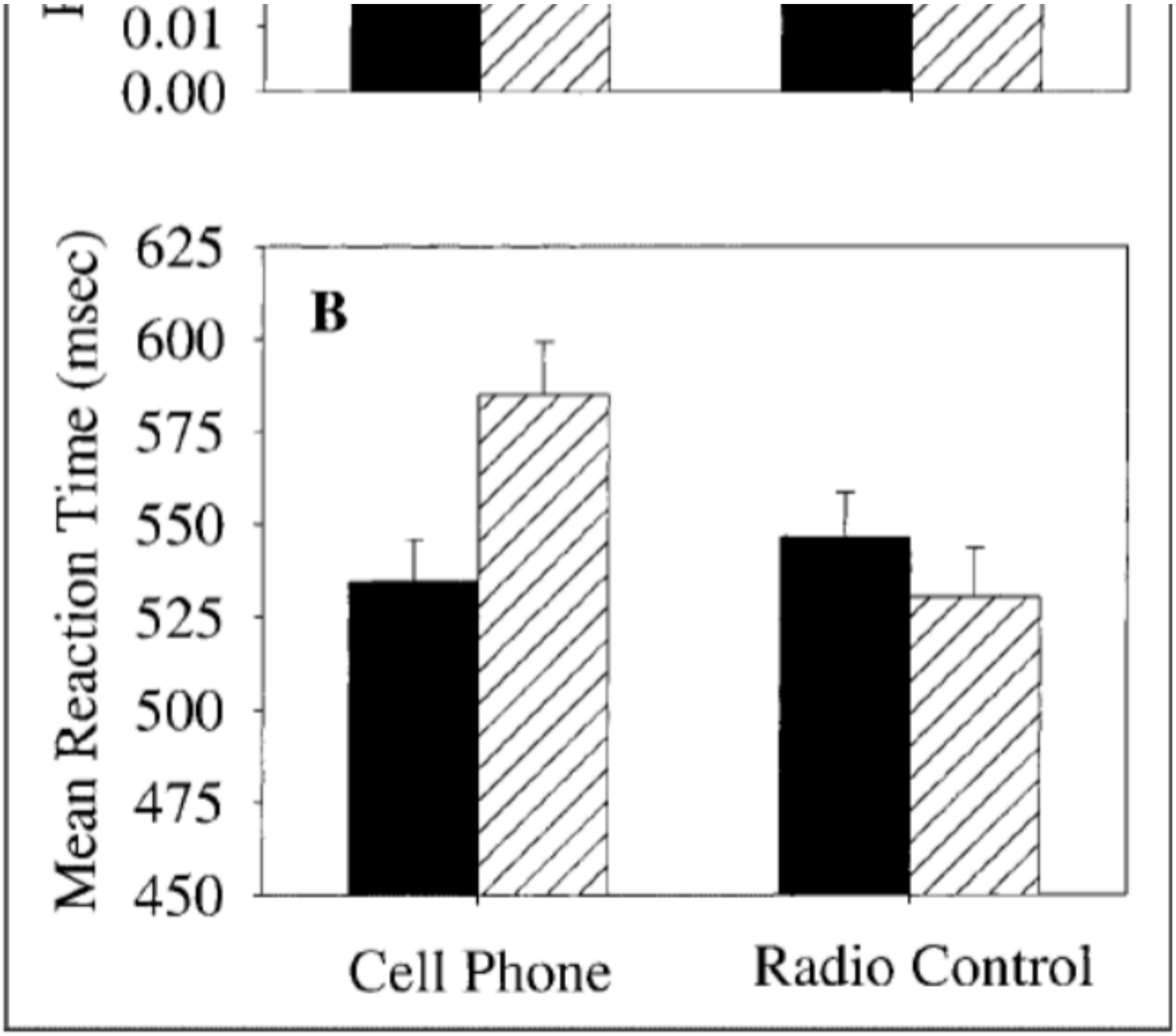


Fig. 1. Probability of missing the simulated traffic signals (a) and mean reaction time to the simulated traffic signals (b) in single- and dual-task conditions in Experiment 1.

This suggests that driving with the phone is very impactful for the reaction time of the driver, or its attention.

Hazards

All of them lead to loss of control

Overcorrection

Coming back in the lane when the control is lost and similar manouvering.

Fatigue

Lack of vigilance or sustained attention on the task. This is the most important cause of accidents during night

Lack of vigilance or sustained attention on the task. This is the most important cause of accidents during night.

Countermeasures

- Rumble strips: strips on the sides of the road that produce a very loud noise when the car goes on it.
- Driver state monitoring: using camera image to measure the driver's fatigues. Then, for example an alarm rings advising the driver to take a break.

Speeding

- Loss of control is more likely
- More difficult to detect the hazard
- More distance raveled before maneuver is made
- Greater damage at impact

People usually engage in speeding because they

- underestimate dangers
- Overestimate driving skills
- inadequante mental model for hazards

Countermeasures

- Cruise control: help to maintain the speed limit
- Safe distance to have enough time to react (around 2 sec to collision, since the reaction time for breaking is 1.5 sec)

Individual factors

- Alcohol use

  – In US cause of 50% of fatal accidents

  – At 0.05%: poorer RTs, tracking, information processing

  – Speed limits, fines, **social pressure**(one of the most effective methods)

- Age and gender
  - young male drivers

    – Inexperience, overconfidence, risk taking

    – Alcohol, fatigue, driving at night

    – Distraction

  - Older drivers

    – Vision problems

    – Reaction time

    – Attention

Safety improvements (summary)

	Driver	Vehicle	Road
Pre-crash	Training, selection, (fitness to drive)	ABS, passive safety, (anticollision warnings)	Roadway design, sig, signs, speed checks, public transport
Crash	Seat belt use	Airbag, active head restraint, vehicle size	Barriers, lane separation
Post-crash	First aid, emergency call	(Automatic emergency call)	Congestion, availability of emergency vehicles

Intelligent systems

- Vehicle control
  - – Lane departure warning
  - – Collision avoidance
- Navigation
  - – Trip planning
  - – Up-to-date information (traffic jams, weather, services)
- Semi of full self-driving mode
  - – Overconfidence in system
  - – Less attention for driving task
  - – Trade safety against efficiency

Automation, control and stress/workload

Automation

An relevant example for automation concerns self-driving cars.

It also happens in automation of diagnosis, by the use of computer vision (e.i. radiology, find different diseases).

<u>Why are tasks automated?</u>

- to prevent human errors
- to save time
- to improve performance

<u>What tasks are automated?</u>

- **Dull, Dirty, Dangerous 3D**
- For multi-tasking, difficult or unpleeasant tasks
- Extension of human capability

Stages of automation

Automation can happen in different ways:

1. Information aquisition, selection and filtering
2. Data integration (e.i. self-driving cars, warning systems)
3. Advisory system (e.i. collision-avoidance sytems)
4. Control and execution of actions

Levels of automation in terms of control

1. The human is in control
2. The system **suggests** different alternatives
3. The system **selects** different alternatives
4. The system **acts** after approval by the human
5. The system **provides limited time** to stop the action
6. The system **acts and inform afterwards**
7. The system **acts and informs when asked**
8. The system is in control

Self-driving cars level of automation

- **Level 0**:Automated system issues warnings and may momentarily intervene but has no sustained vehicle control.
- **Level 1 ("hands on")**: The driver and the automated system share control of the vehicle. (Cruise Control, Adaptive Cruise Control, Parking Assistance
- **Level 2 ("hands off"):** The automated system takes full control of the vehicle (accelerating, braking, and steering). The driver must monitor the driving and be prepared to intervene immediately at any time if the automated system fails to respond properly.

- **Level 3 ("eyes off")**: The driver can safely turn their attention away from the driving tasks, e.g. the driver can text or watch a movie. The vehicle will handle situations that call for an immediate response, like

emergency braking. The driver must still be prepared to intervene within some limited time, specified by the manufacturer, when called upon by the vehicle to do so.
- **Level 4 ("mind off")**: As level 3, but no driver attention is ever required for safety, e.g. the driver may safely go to sleep or leave the driver's seat. Self-driving is supported only in limited spatial areas or under special circumstances, like traffic jams. Outside of these areas or circumstances, the vehicle must be able to safely abort the trip, e.g. park the car, if the driver does not retake control
- **Level 5 ("steering wheel optional")**: No human intervention is required at all. An example would be a robotic taxi.

(Un)reliability of automation

Errors may occur because of the interaction between the user and the system:

- because of system complexity
- Wrong settings are entered
- use outside of the sytem operating range
- the user does not understand the logic of the system

In most case the **user-system combination** is **unreliable**, or the **system** is **unreliable**.

Trust

It is **preceived reliability** which is critical for acceptance of automated systems. Trust is often not well calibrated, so, there are two possibilities: either the user mistrust the system or he/she overtrusts the system.

Mistrust

- failure to understand the system's limitations

Consequences

- ineffiencient and slow system
- many errors because warning are not taken seriously

Overtrust

Giving more control to the system

- Actual reliability is difficult to judge when few errors occur

Consequences (which may be very serious)

- miss a lot of things
- slow detection of failures (e.i. vigilance)
- **poor situation awareness** because user is not actively involved

Other aspects

- Automated tuned to the tasks, so we the right things of the tasks are automated

- Automated tailed to the tasks, so we the right things of the tasks are automated
- Training adapted to level of automation
- Human-system communication is less “rich” than human-human communication
- Preserve job satisfaction

Design of automation

First, **the tasks and function analysis** takes place, then, **the allocations of tasks and functions to humans and systems** occurs. The tasks and functions' allocations are based on the strong points of humans and systems:

- Humans
    - E.g. perceiving unexpected patterns, detection in noise, generalization, improvisation, inductive reasoning
- System
    - E.g. expected patterns, working with details, computations, deductive reasoning, repetitive work, monitoring, using (large) databases

Human-centered automation

The folllwing are important factors to consider when building an automated system and when you want humans to trust the system:

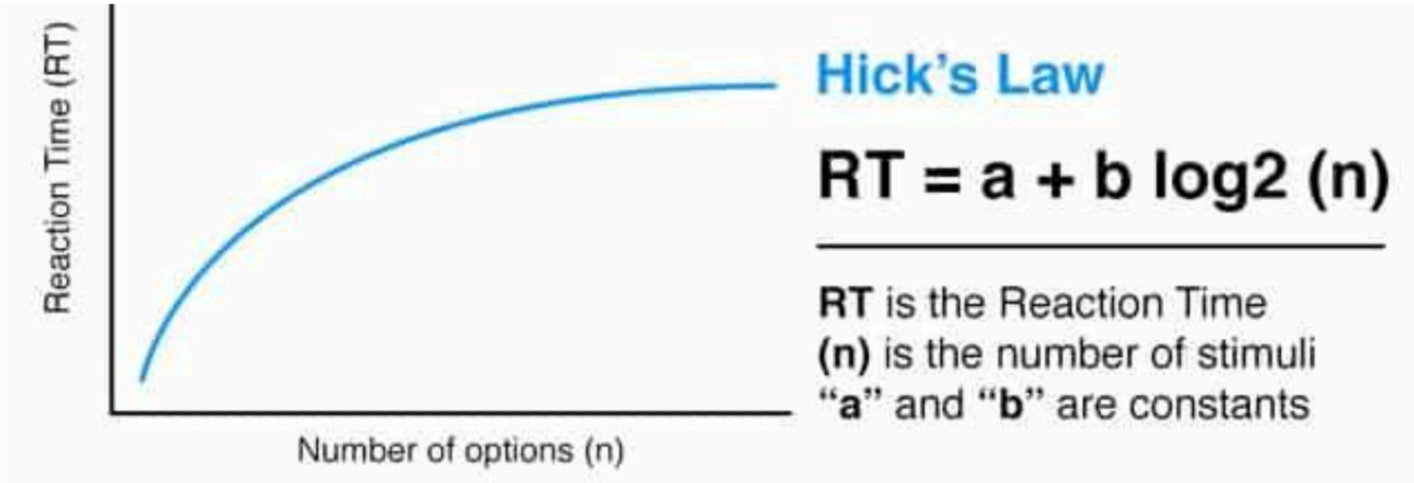
- Keeping the human informed
- Keeping the human trained
- Keeping the human in the loop
- Selecting appropriate stages and levels when automation is imperfect
- Using flexible, adaptive automation
- Managing the introduction and use of automation

Control

Response selection

Decision complexity

The complexity of the task is defined as the number of possible alternatives. Selection time depends on complexity. The more choice you have, the slower you make the decision.



$log_2 N$ is the number of bits per choice

a and *b* depend on task and individual

However, it does not always mean that few alternative is for the better. **Information transfer** is greater with a small number of complex decisions (**decision complexity advantage**). For example, keyboard vs morse code.

Response expectancy

Certain expectation about the world, so, when we design an system we have to take those in considerations as well.

Compatability

Stimulus-response (or dispay-control) compatiblity (Simon effect)

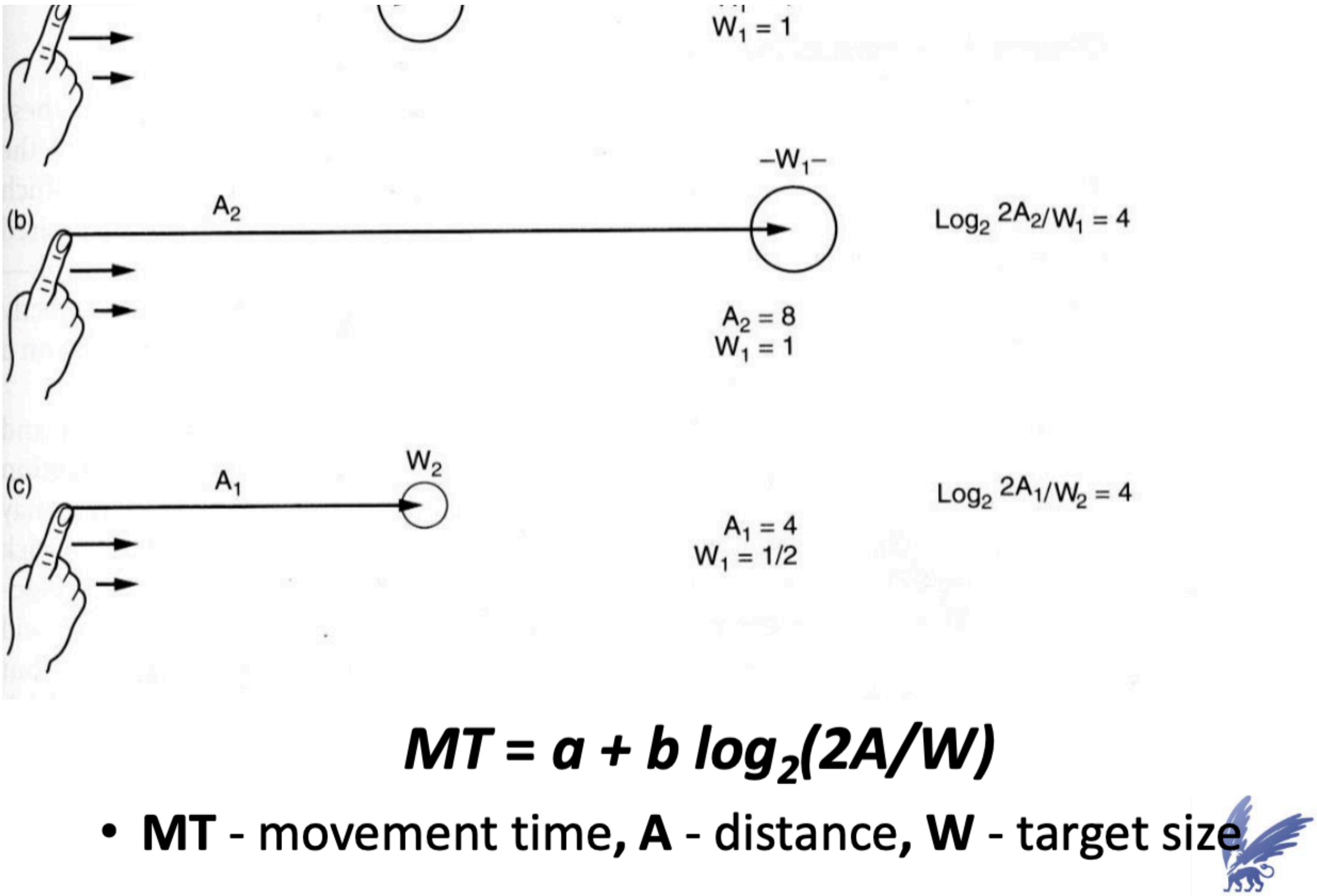
Speed-accuracy tradeoff

- When we try to do things quicker, then we become less accurate (in some cases, accuracy and speed are inversely correlated)
- However, in many cases speed and accuracy are positively correlated
- Because both correlate with task difficulty
- **Tradeoff** can occur as a result of user strategy

Positioning systems

- Controls require movement
- Hand/foot movements to reach controls
- controlling device (e.i. mouse cursor, joystick, steering wheel)

Determined by the Fitt's Law (based on the task difficulty)



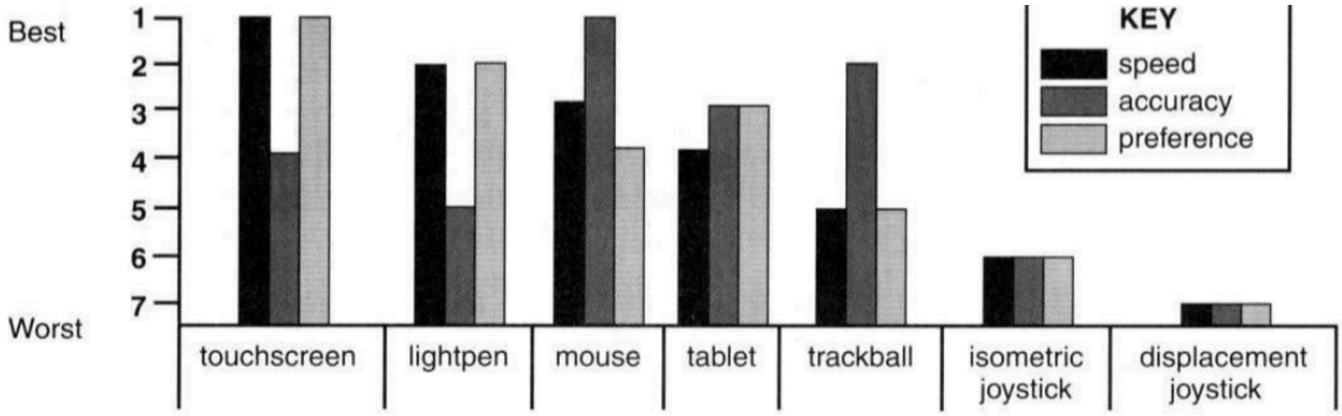
Gain = $\frac{\delta \text{output}}{\delta \text{input}}$

There are direct control of position (touch screen) and indirect control of position (mouse)

Position Control devices

The devices are task dependent:

- mouse and direct control best for pointing and dragging
- direct control and tablet best for drawing



Verbal input

- Advantages
  - Hands and eyes are free
  - Large number of response alternatives are possible
- Things that are recently improved:
  - Limited vocabulary (-> out-of-syntax errors)
  - Errors because of (small) acoustic differences
  - Effect of noise
  - Effect of accent, stress
  - Improvements in Deep RNNs

Control of continuous processes

- **Closed loop control**: control your device based ona continuos flow of feeback
  - **Negative feedback**: the human operator tries to minimize error (e(t))

There are different types of tracking

0th order

Changing the position (mouse)

1th order

Changing the speed (e.i. gas pedal, joystick)

2nd order

Changing the acceleration (e.i. controlling spacecraft)

Open-loop control

- Operator does not correct based on the error
- Advanced knowledge and experience with the system
- Experience pilot does not constantly check the instruments during landing

Remote Control