SÛRETÉ DE FONCTIONNEMENT

« SAFETY IN HUMAN OPERATED SYSTEMS »

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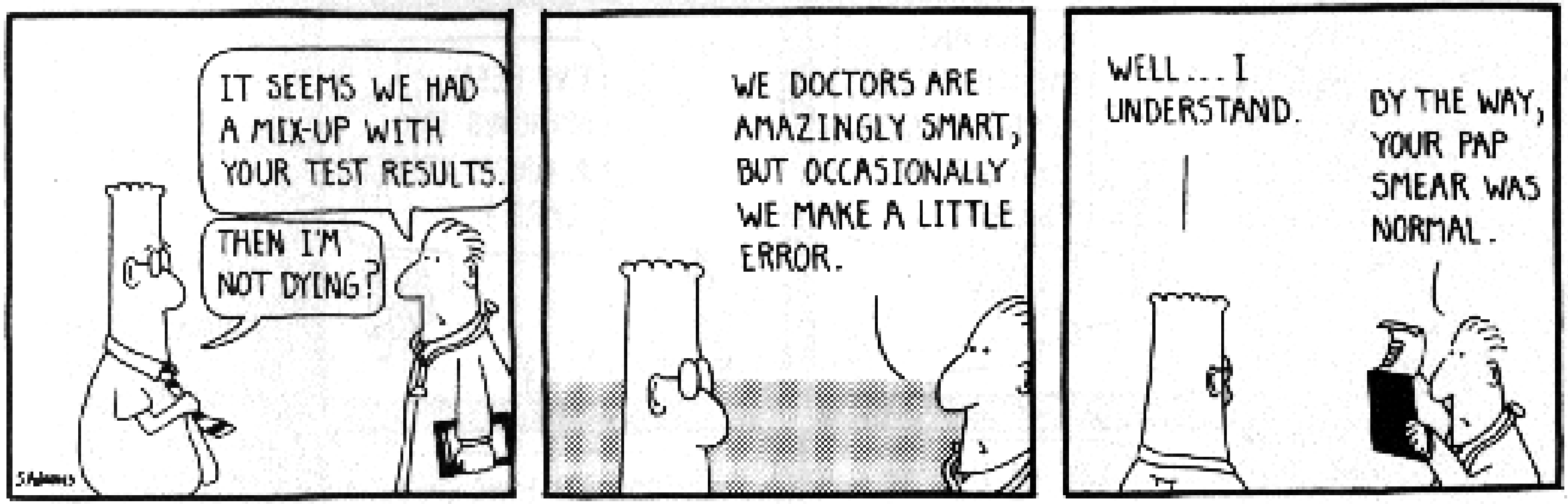
ENSTA PT

PROBLEM STATEMENTS AND DEFINITIONS

What is Human Factors ?



What is Human Factors ?

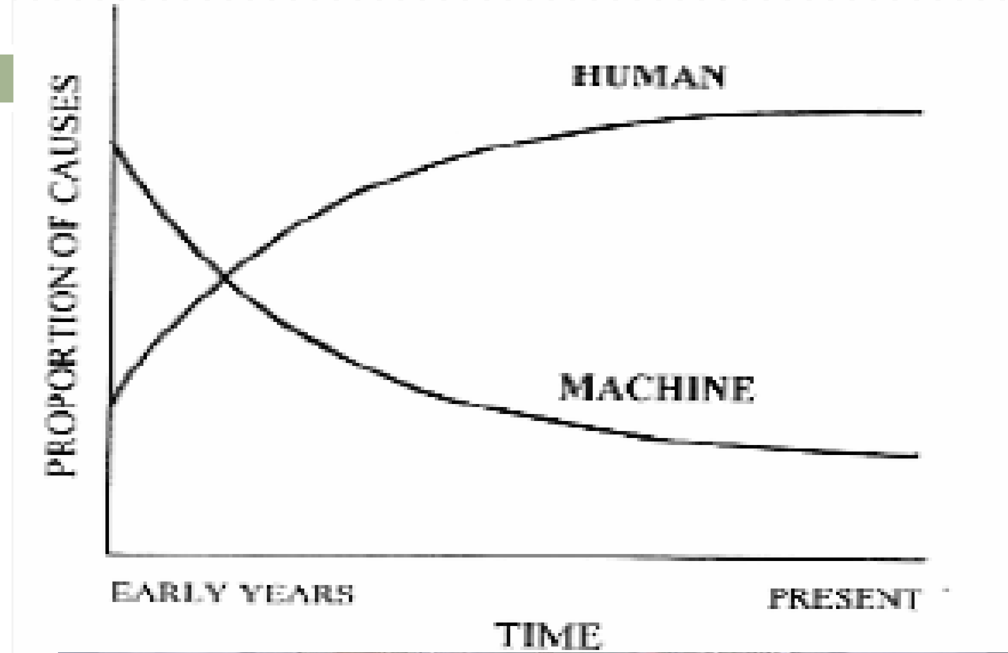
Human Factors is the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance.

What is Human Factors Engineering?

Human Factors Engineering focuses on how people interact with tasks, machines (or computers), and the environment with the consideration that humans have limitations and capabilities.

- Human Factors Engineers evaluate:
  - "Human to Human,"
  - "Human to Group,"
  - "Human to Organizational," and
  - "Human to Machine (Computers)"
- interactions to better understand them and to develop a framework for evaluation.

Why we need Human Factors?



Safety:

Performance:

- Usability
- Comfort
- Automatisation
- Ergonomy
- Complexity

Safety and Accidents Reports

- Safety: avoid accidents

- Accidents Reports:

  What happened

  Who to

  When

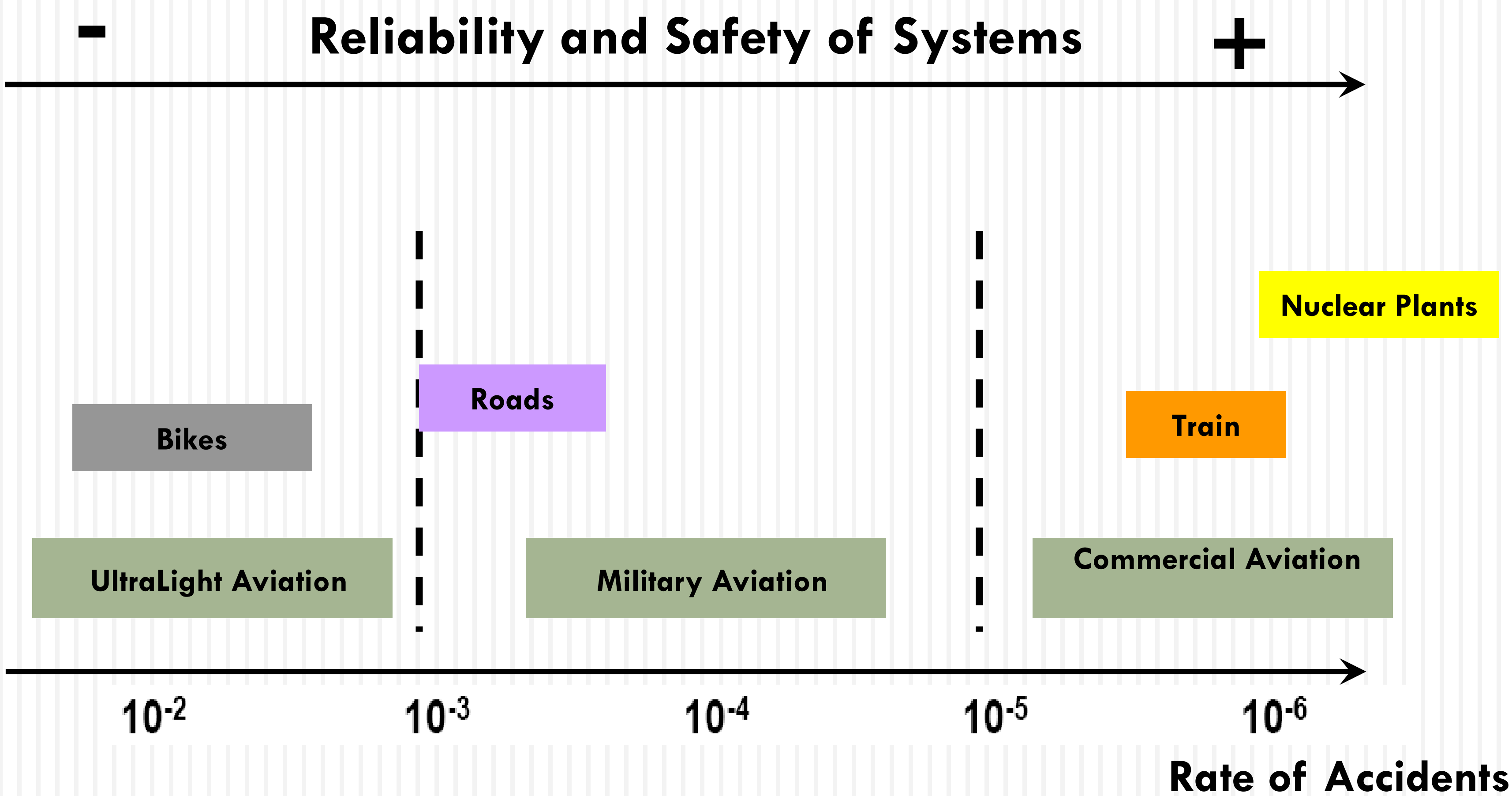
  How it happened

  But not why

Failure to consider human factors !!!!!

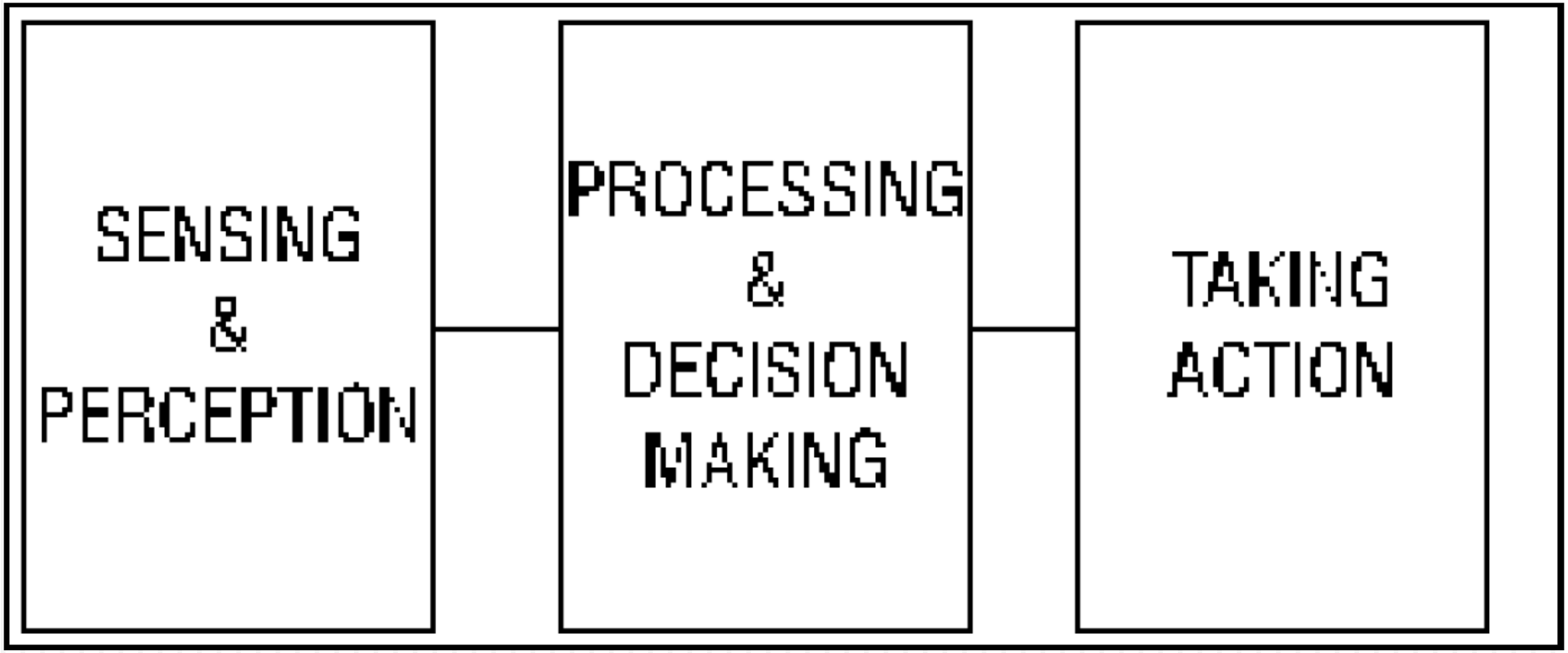
- Significance of Human Factors:
  - **Up to 90% of accidents attributable to some degree to human failures**

Systems Risks

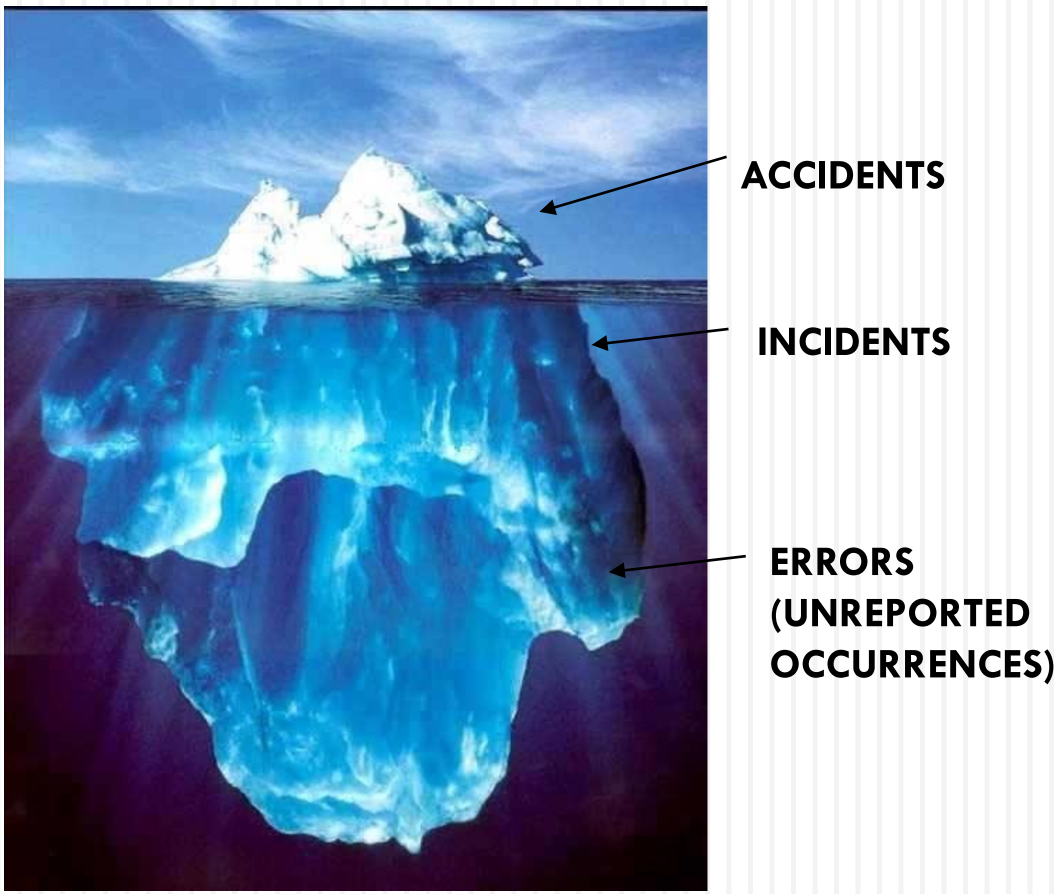


MODELS OF HUMAN ERRORS

General Human Performance Model

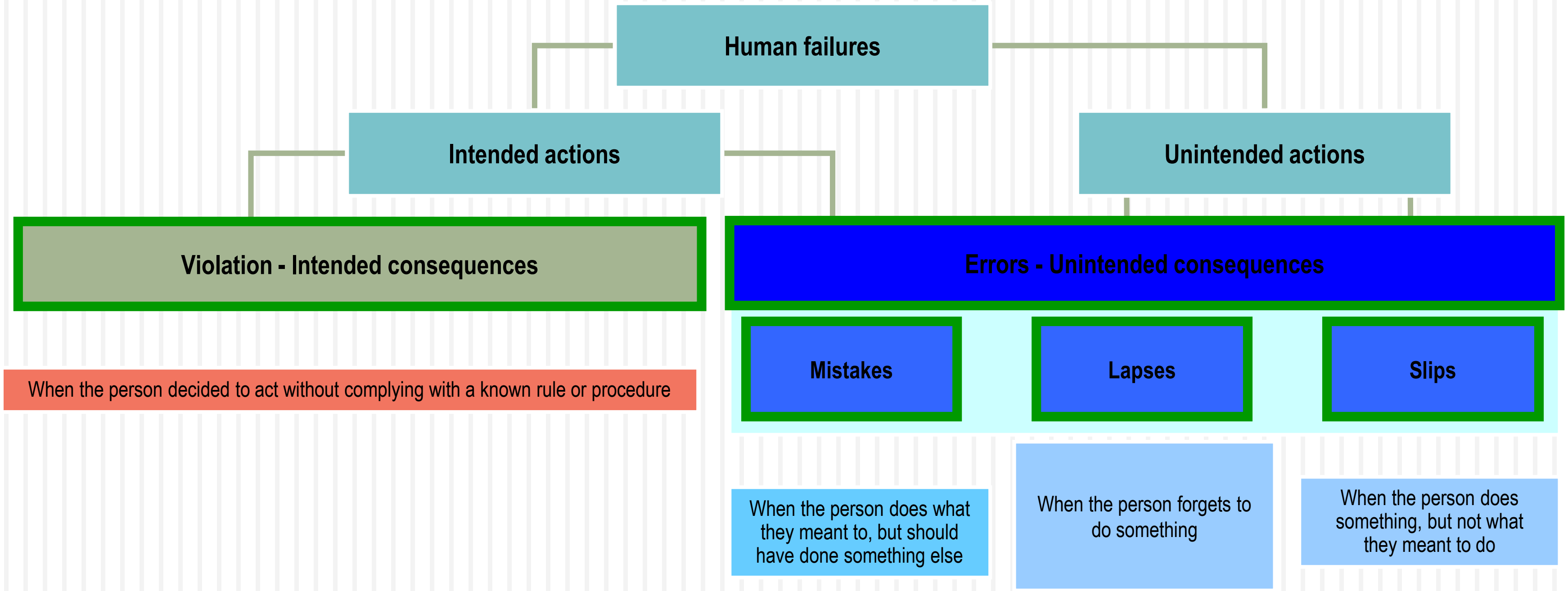


Iceberg model of accidents and errors



Heinreich HW. *Industrial Accident Prevention*. New York and London, 1941.

Human Failure Taxonomy



Error: Definition

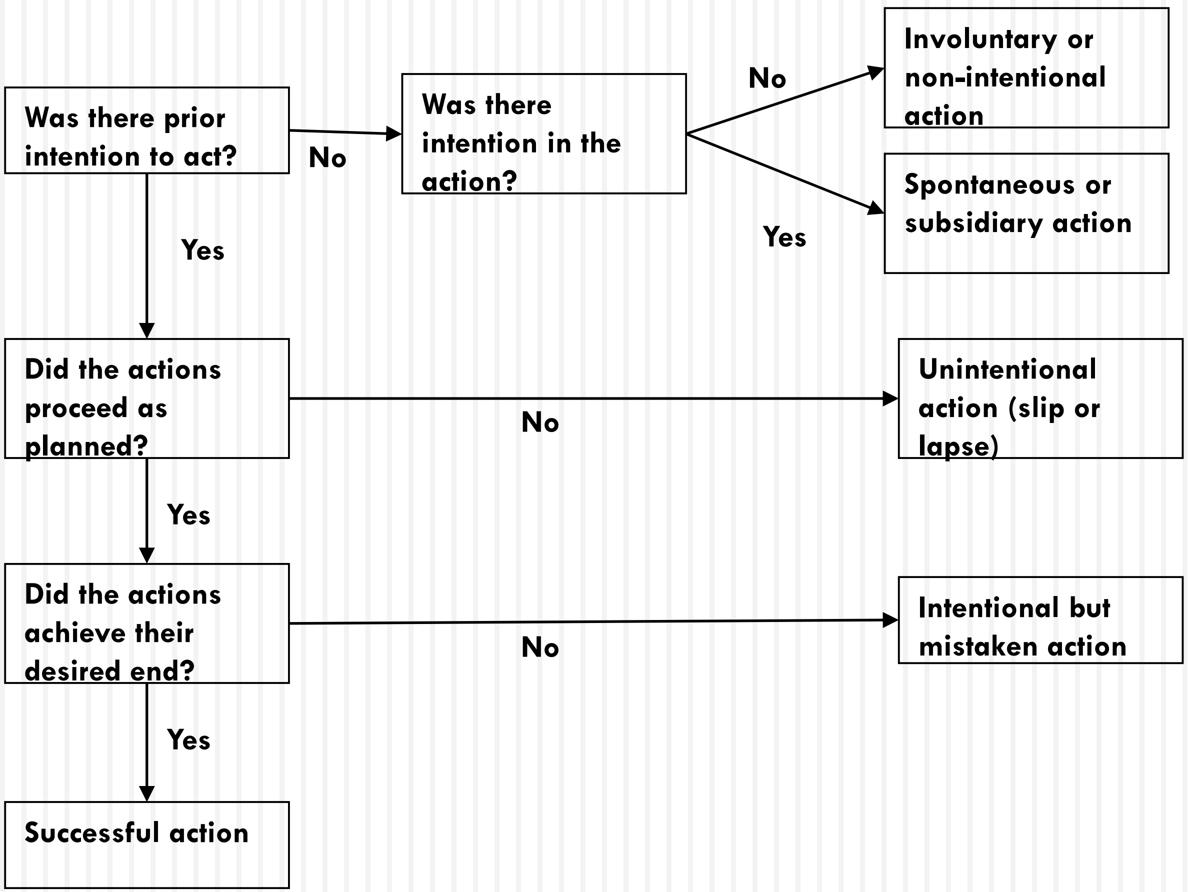
- A failure arising from
  - an action that was not completed as intended
  - a plan for action that was inadequate to begin with

- Slips & Lapses (skill-based)
  - occur at storage or execution stage (memory and attention errors)
- Mistakes (rule- and knowledge-based)
  - occur at judging or inference stage (planning errors)

(Reason, 1990)

- Ultimate outcome (detected or undetected, mitigated or leading to further errors, catastrophic or inconsequential) is not part of the definition

Slip, lapse or mistake?



What to do ?

- Identify significant behaviours
- Analyse behaviours
- Understand the errors
- Identify effective measures to prevent reoccurrence

Human Factors

- **Slip**
  - **When a person does something, but not what they meant to do**
- **Lapse**
  - **When a person forgets to do something**

- Both are unintended actions with unintended consequences

Example Slip : EK407 Flight

- Emirates Flight EK407 – flying from Melbourne to Dubai
- Pre-flight take off calculations were based on an incorrect take off weight (262 tonnes rather than 362 tonnes)
- This weight was entered into take off performance software on separate laptop
- This 100-tonne difference was the equivalent to the aircraft having an extra 20 African elephants on board, or a fully grown adult blue whale.
- It meant that the preset take-off speed would never have lifted the plane off the ground had the captain not intervened at the last second to order full thrust.

Example Slip : EK407 Flight

Example Slip : EK407 Flight

- After the accident, Captain and First Office were asked to resign by Emirates and did so
- ATSB investigation revealed:
  - Captain had flown 99 hours in last month (1 hour below maximum)
  - Had slept for 3.5 hours in 24 hour period prior to flight (shift rotas)
  - Excessively complex system for calculating take off speed (manual transfer of information from 2 automated systems)
  - No automated failsafe

Costa Concordia Boat – Italian Mediterranean Coast 2012

Costa Concordia Boat – Italian Mediterranean Coast 2012

«The followed path was not the good one »

Why do smart people do dangerous / dumb things?

- Excessive Workload
  - Physical and cognitive effort involved in task performance.
- Lack of Situation Awareness
  - What's going on?
  - What's likely to happen next?
  - What will happen if I take a particular action?
- Excessive Stress, Fatigue, Uncertainty, etc.
  - Impacts perceptual-motor performance, decision-making, etc.
- Diminished Attention
  - Too much to attend to at once (overload)
  - Too little to attend to for too long (underload)
- Poor Teamwork and Communication
  - Often due to poor layout of work space and/or poor layout of command and communication structure

GENERAL MODELS FOR HUMAN MODELING IN DRIVING

Human Behavioral Adaptation

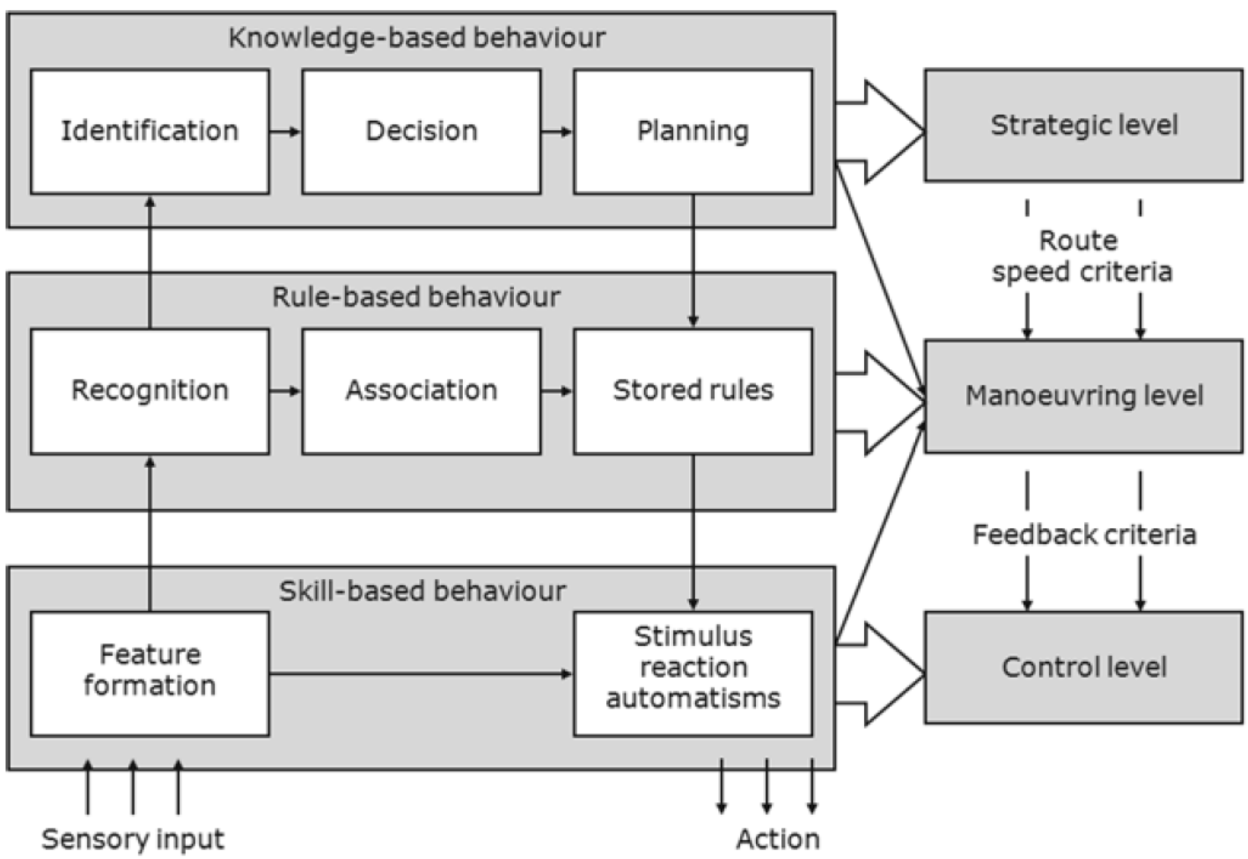
Behavioral adaptation describes the phenomenon in which people adapt their behaviour to changing situations or changing situational demand.

The OECD (1990) defined behavioral adaptation as:

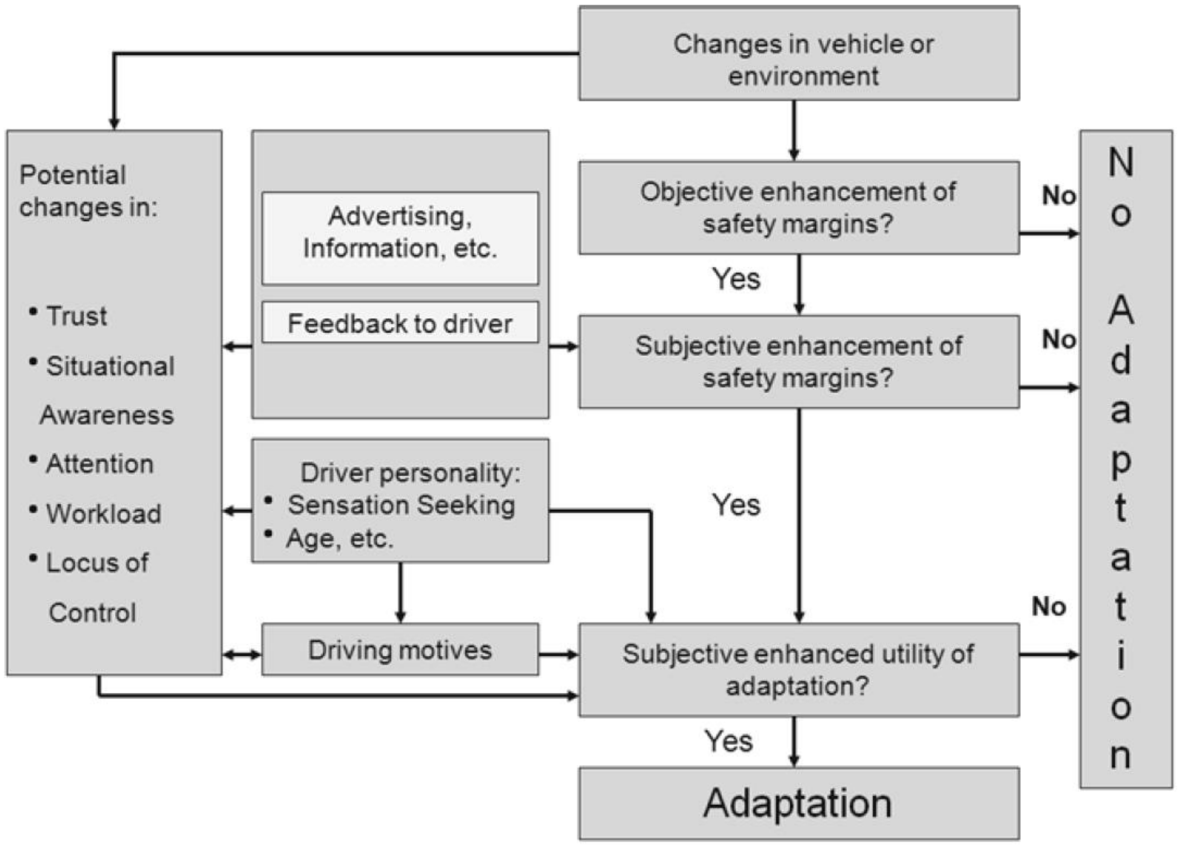
“ (…) those behaviors which may occur following the introduction of changes to the road vehicle-user system and which were not intended by the initiators of the change; behavioral adaptations occur as road users respond to changes in the road transport system, such that their personal needs are achieved as a result; they create a continuum of effects ranging from a positive increase in safety to a decrease in safety. (p. 23)

“

Driving as a Hierarchical Problem Solving Task



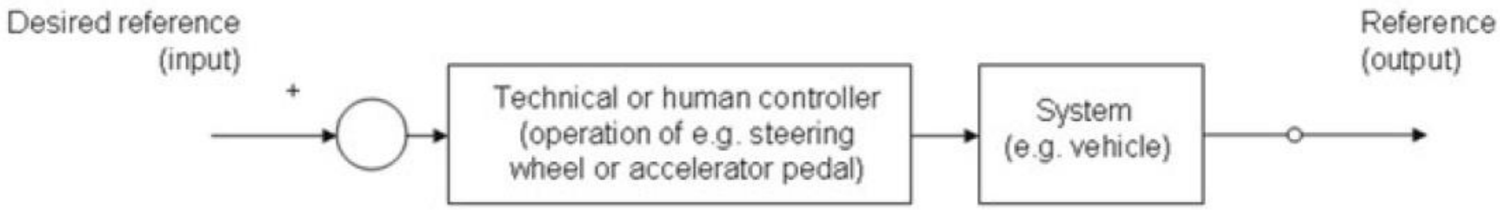
Process model of behavioral adaptation (Weller & Schlag, 2004).



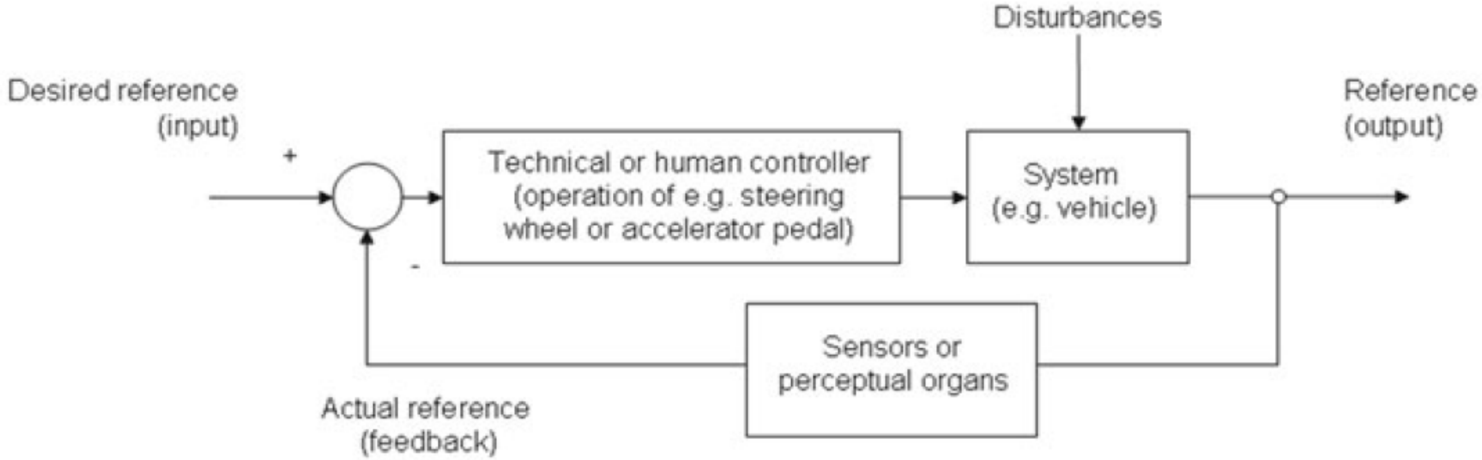
Weller, G., & Schlag, B (2004). Behavioural adaptation following the introduction of driver assistance systems, In B. Schlag (Ed.), Traffic psychology. Mobility safety driving assistance, (pp.351–370). Lengerich: Pabst Science Publ.

Control Theory for Behavioral Adaptation

Open Loop Control System



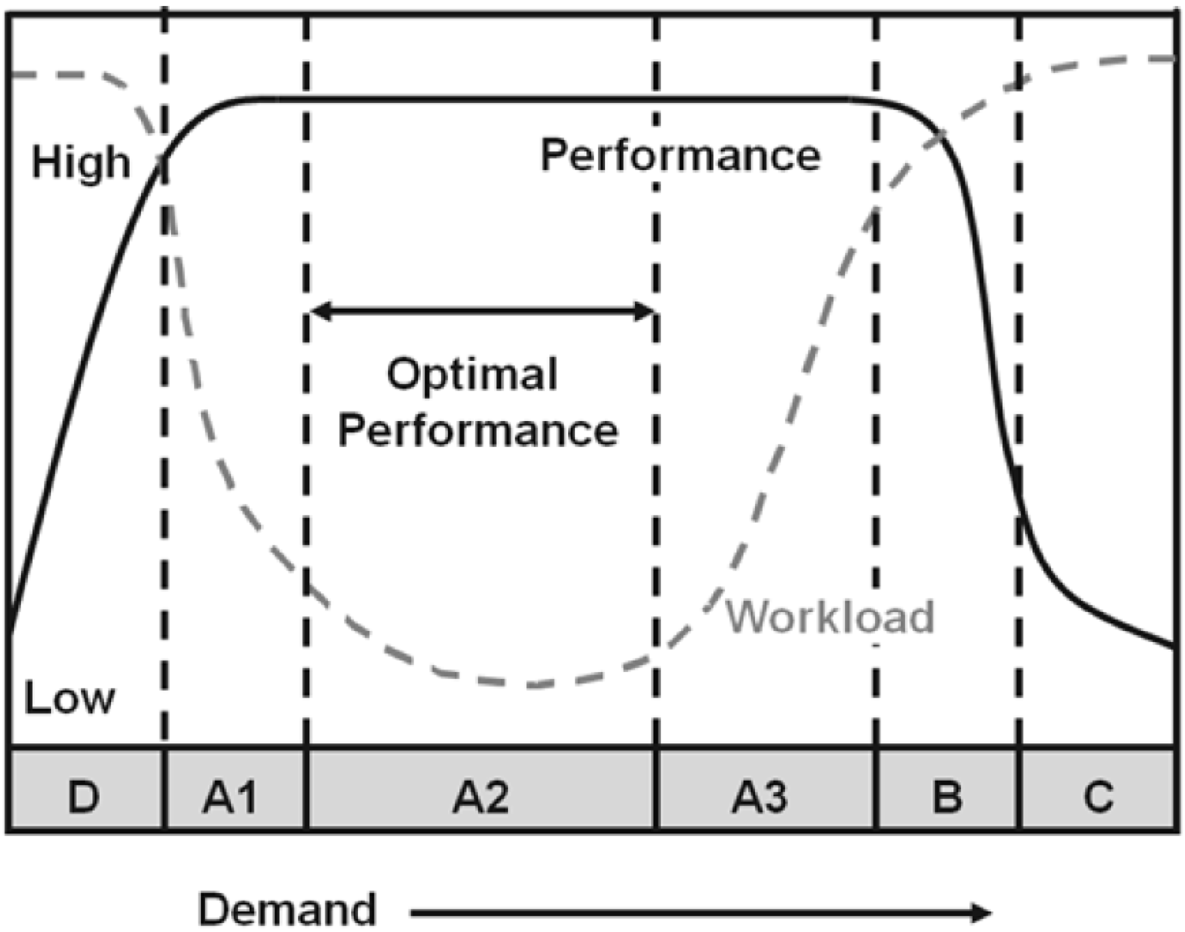
Closed Loop Control System



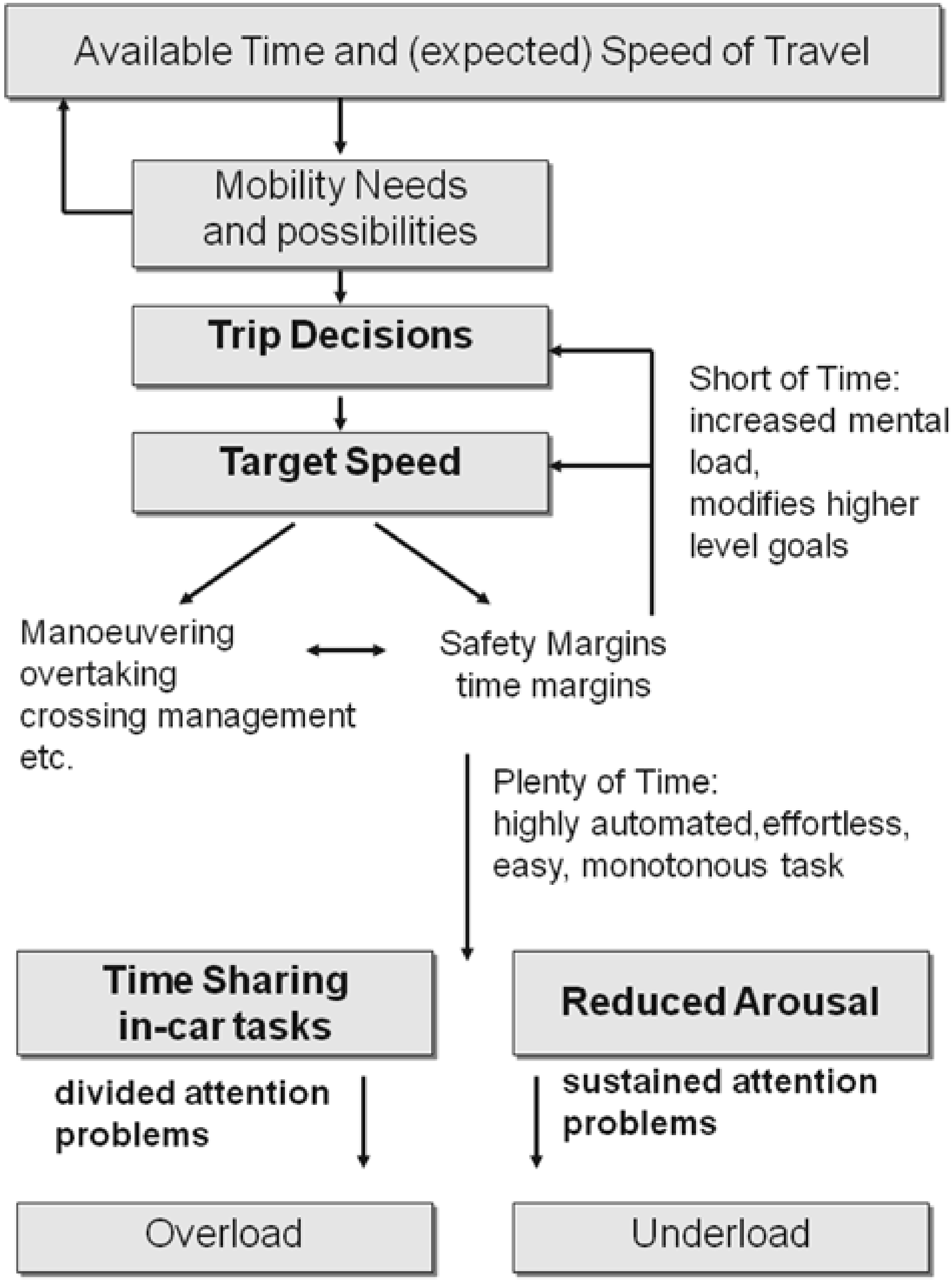
Workload Models for Drivers/Pilots

- The multitude of different infrastructure characteristics, the various features of the landscape and the diversity and number of other road users and environmental conditions mean that the characteristics of the operating task change constantly.
- These characteristics result in a certain level of physical and also mental demand or stress which impacts the driver when negotiating this road.
- Mental stress or demand is defined as ‘the total of all assessable influences impinging upon a human being from external sources and affecting it mentally (ISO100751,1991,p.1)
- Acting within a stressful environment or executing a demanding task will have an effect on the person who executes this task.
- ‘Performance’ can be defined in terms of safety and in terms of mobility, although ideally both should be achieved at the same time.

Interrelations between workload and performance on different levels of demand (de Waard 1996) – Effect for Safety



De Waard,D.(1996).The Measurement of Drivers Mental Workload.The Traffic Research Centre, VSC, University of Groningen, The Netherlands. Retrieved March 7, 2007, from http://www.home.zonnet.nl/waard2/mwl.htm



Hierarchical model of behavioral adaptation (Summala 1997)

Attention

- Driving/Piloting/Operating is an active search process through which information is selected and transformed. However, this process is complex.
- Outdoors Operators are exposed on their journeys to a multitude of stimuli that are mainly visual. They must make a choice based on these stimuli that will in turn determine their behavior. Within this concept, the operator is an information processor. However, humans are inherently creatures of restricted capacity; that is, we are able to process only a limited amount of sensory information at any given time.
- ***Driver/Pilot/Operator inattention*** represents one of the leading causes of accidents. The advent of new, complex technologies, such as satellite-based global positioning systems (GPS), cellular phones, and so forth, and the increased power of computers are in the process of revolutionizing many aspects of system operating, but, at the same time, they are exacerbating the operator attentional limitations.

Attention

- Situations and tasks can be differentiated according to how much of the following three types of attention they require (Kluwe, 2006):
  - selective attention:
    - Exogenous - having an external origin
    - Endogenous - having an internal origin
    - Automatic
    - Controlled;
  - divided attention
    - Is used when there are several relevant stimuli which need processing in parallel
  - sustained attention or vigilance.
    - Is needed for situations which require attention to be maintained for longer periods of time.

Attention

- New technology – telematics and In-Vehicle Information Systems (IVIS) – has begun to infiltrate the context of driving.
- In order to perceive, assimilate, interpret, predict, and respond to the driving environment, a driver must have his/her full range of attentional resources from which to draw.
- Multitasking results in multiple tasks competing for a driver's attentional resources.
- Multitasking while operating results in less efficient visual search, slower reaction times, and fewer and shorter eye fixations.

Attention

- Recarte & Nunes, 2000

  When cognitively complex tasks are performed while driving, the "visual inspection window" decreases between 25-40% horizontally, and 40-60% vertically.

- Just, et al., 2001

  Less cortical brain tissue is able to respond when 2 cognitively complex tasks are performed simultaneously (as compared to a single task)

  Suggests a natural/biological limit on attention?

Things to Remember

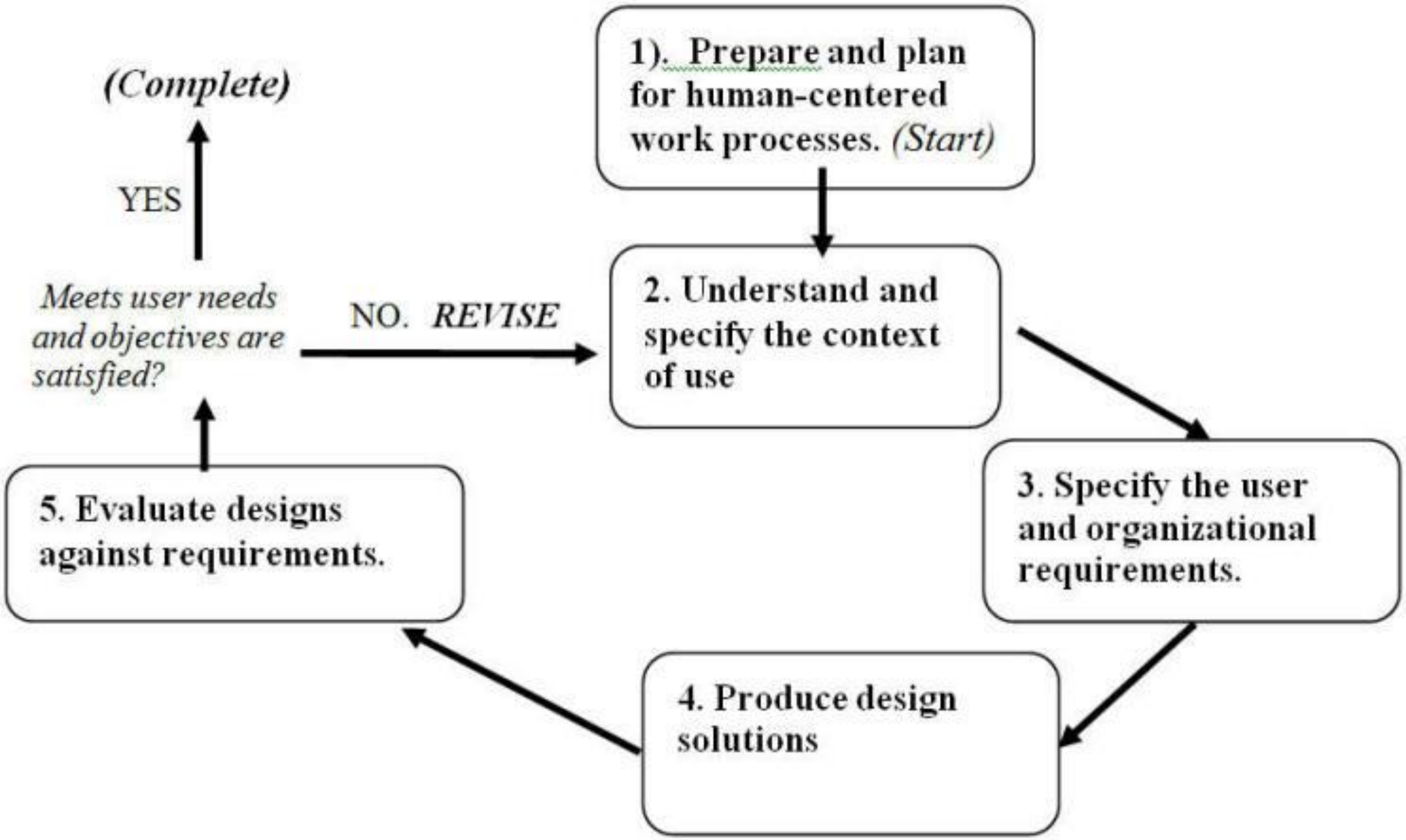
- Driving/Piloting/Operating is a complex task that requires multiple cognitive mechanisms such as attention, perception, memory, learning, decision making, motor control, and so on.

- Individual Differences: Traits and Demographic Variables

- Take into consideration all these human factors while analysing or designing a system

HUMAN CENTERED DESIGN PROCESSES FOR INTERACTIVE SYSTEMS

Human centered design processes for interactive systems – ISO 13407



Human centered design processes for interactive systems

Seminal Researches:

- Schneiderman, B. (1982) How to Design With the User in Mind. Datamation 28, no. 4: 125–126.
- Norman, D.A. & Draper, S.W. (1986) User Centered System Design: A new perspective on Human-Computer Interaction. Lawrence Erlbaum & Associates, Hillsdale, N.J.
- Billings, C.E. (1991). Human-Centered Aircraft Automation: A Concept and Guidelines. NASA Technical Memorandum 103885. Moffett Field, CA: NASA-Ames Research Center.

FROM COGNITIVE TO COMPUTATIONAL MODELS

Context-Aware Operating Behavior Model

- Programming the existing cognitive or motivational models into operated devices
  - natural idea of an ITS (Intelligent Transport System) approach toward predicting driver behaviour in real time.
- Unfortunately, the subjectiveness of motivational models, make such approach challenging.

- A proposed approach consists in observing the operator in his/her real operating condition with sensor technology.
- The observation is a learning process that can improve the prediction capability.
- Bayesian learning is used as a form of uncertain reasoning from observations. It simply calculates the probability of the occurrence of an event, given an observation, and makes predictions on that basis.

Context-Aware Operating Behaviour Model

The observations provide information about

1. the physiological state of the operator
2. the behavior of the operator
3. the dynamics of the system and
4. the description of the surrounding environment.

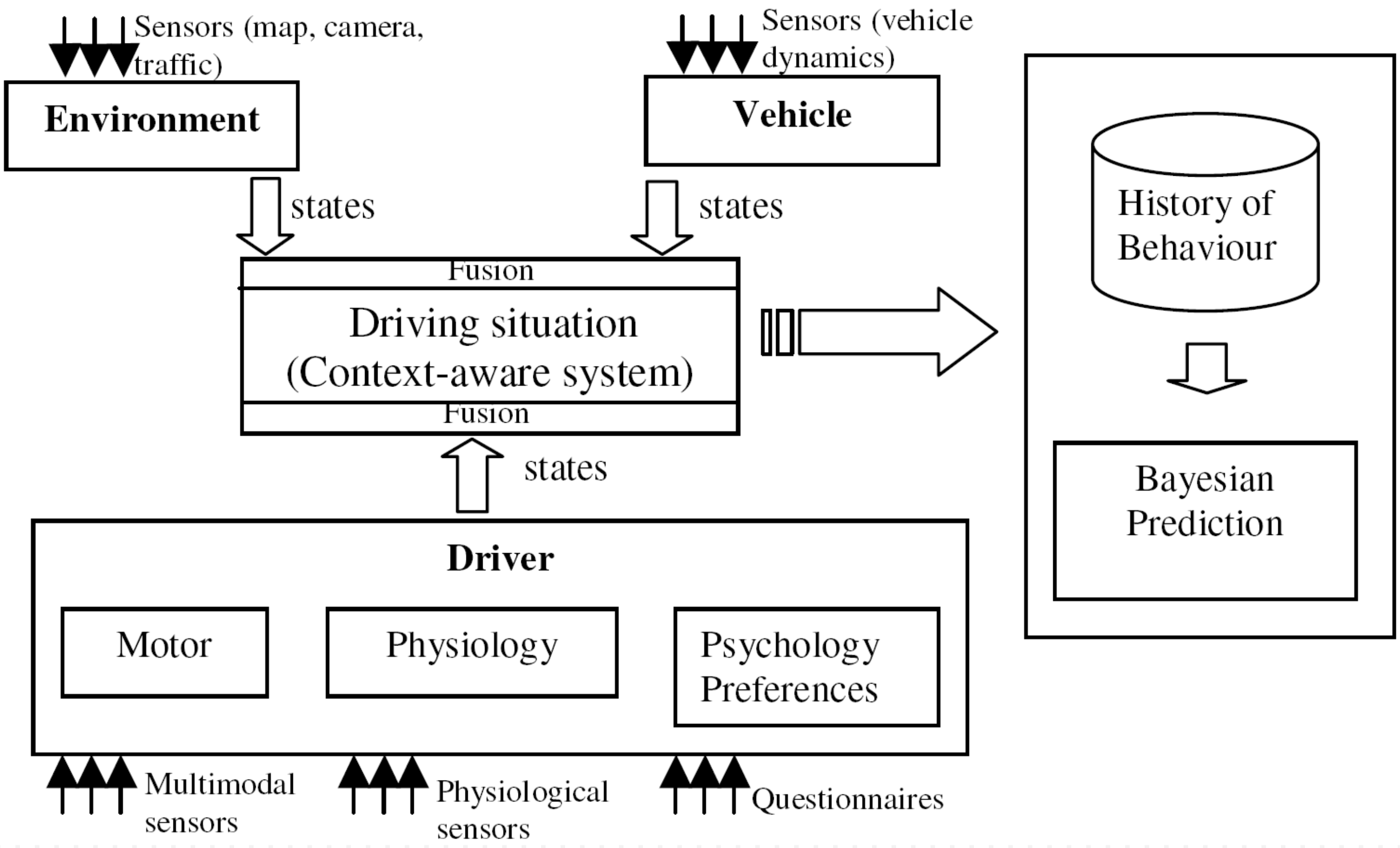
Context-Aware Driving Behavior Model

- An operator ”manages behaviors sequentially in space and time and it organizes goals, intentionally and anticipatory set, which it maintains or changes as appropriate. It plans, prepare, formulates and oversees the execution of action sequences; it monitors the strategic aspects of success or failure, the consequences (including social) of actions, it applies both foresight and insight for non-routine activities and provides a sustained and motivating level of drive.” (Bardshaw , 1995)
- It is impossible to design a computational program which could predict future operator behavior by taking into account all the complex factors shown above.
- These factors are not necessarily measurable and are afflicted with uncertainty.

The physiological state of the operator: Fatigue and Monotony

- Three different types of fatigue are discriminated: sensory (degradation of sensory perception), muscular and cognitive fatigue
- Monotony is a complex and multidimensional phenomenon which affects drivers' physical, cognitive and affective sensations
- Monotony is often associated with three dimensions:
  - The nature of a monotonous task. Such a task is often repetitive, predictable and requires low activation of sensory perception. Straight, uneventful and long road infrastructure are well-known factors that contribute to the increase of driver monotony.
  - The physiological or biochemical state of monotony. This dimension can be detected by sensors such as **EEG**, **skin conductance …**
  - The psychological dimension of monotony, a subjective symptom of feeling boredom or lack of interest

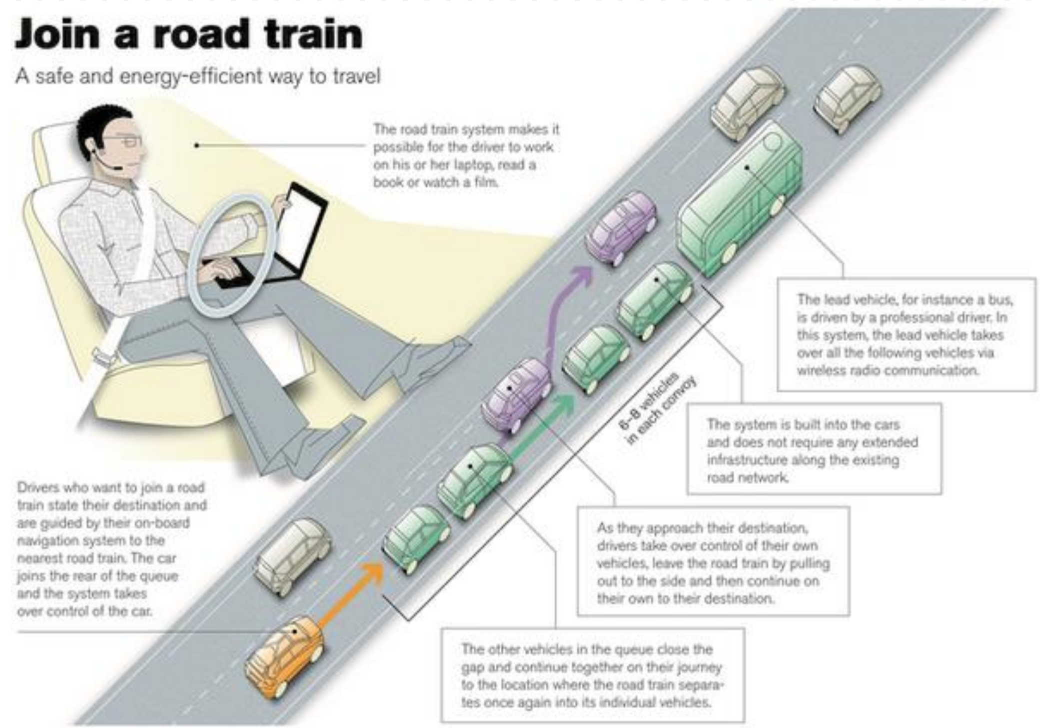
Context-Aware Driving Behaviour Model



EXAMPLES OF NEW OPERATIONAL SYSTEMS

The Safe Road Trains for the Environment (SARTRE) project

- The Safe Road Trains for the Environment (SARTRE) project in Europe aims to develop a wireless system that will allow cars on a public highway or motorway to join in a platoon, or semi-autonomous "road train" of vehicles with a professional driver in a single vehicle (such as a bus or truck) at the front driving for all vehicles in the platoon.



2. PATH project – UC Berkeley

- The human factor -- such as the lag in reaction to unforeseen events -- is the primary cause of road accidents.
- Researchers are now experimenting with WiFi technology to make **cars talk** to each other and to transmitters along the road, and to **alert drivers** of dangers such as an approaching vehicle at an intersection.
- The smart-car technology includes screens on cars' dashboards that for example flash red arrows when it's not safe to turn, while and warning arrows also appear on signs alongside the road.

CHALLENGES TO ADDRESS IN INTEGRATED VEHICLE-BASED SAFETY SYSTEMS (IVBSS)

Many research issues to look at:

1. Multiple threats and Prioritization of warnings
2. Ways to avoid a crash
3. Behavioral adaptation
4. Non-useful warnings (includes false warnings)
5. Effective DVI design

Many research issues to look at:

Multiple Threats

- A major issue with multiple warnings is not only alerting the driver to the presence of multiple threats, but communicating the hazard type and appropriate response.

Many research issues to look at:

Multiple Threats

- How can **multiple threats that occur at near-simultaneous points** in time be communicated to the driver?
  - Is multi-modal presentation **more or less effective** than using one modality?
  - **Can drivers discriminate** between alerts and effectively respond to each threat?
- Can an Integrated Vehicle-Based Safety Systems (IVBSS) system be effective without **prioritization**?

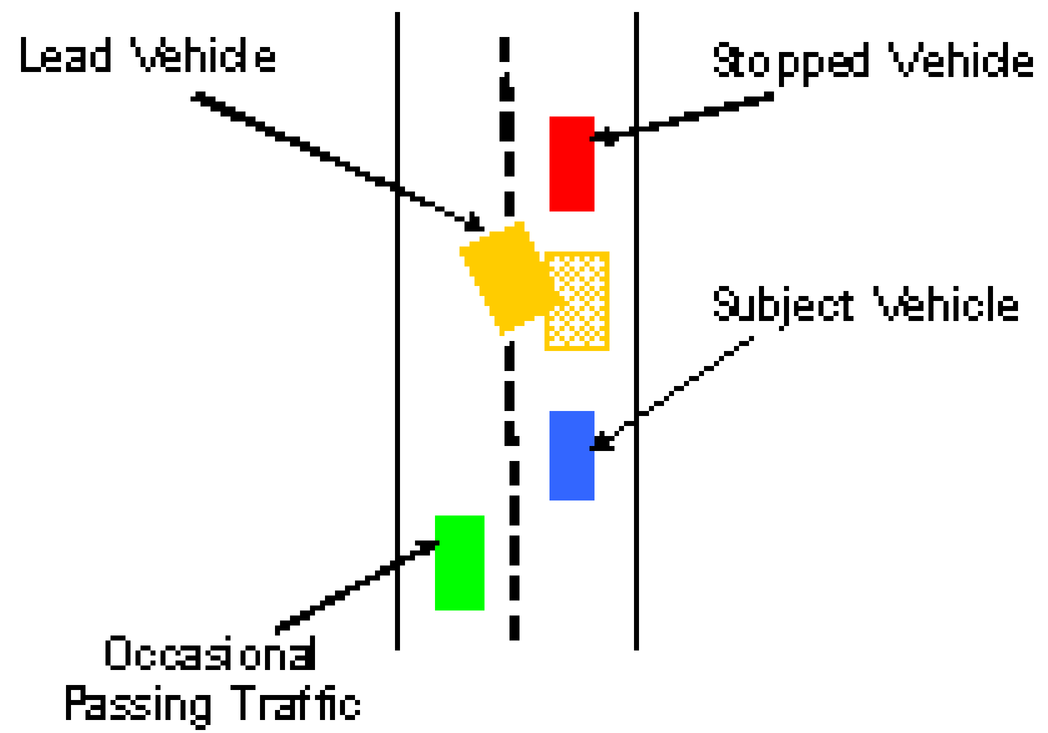
Many research issues to look at:

Avoiding a crash

- Can a driver successfully be directed **how to avoid a crash**?
  - How many **scenarios** need to be developed to understand what is possible?
- **Are auditory instructions** (such as "swerve left") **appropriate** or are there better ways to elicit quicker or appropriate responses from drivers?
  - For example, a haptic cue or a pedal push may result in quicker response times or less confusion as to how to respond

Many research issues to look at:

Avoiding a crash



Many research issues to look at:

Behavioral Adaptation

- How should the system be designed to **minimize adverse behavioral adaptation** by drivers?
  - What is needed to prevent riskier driving behavior due to the **perception of increased safety** provided by an (effective) crash avoidance system?

Many research issues to look at:

Non useful warnings

- **Non useful warnings** include:
  - False alarms
  - Nuisance warnings
- **Examples**:
  - A Forward Crash Warning (FCW) system detects an object ahead of the vehicle on a curve, out of the intended travel path, but in the radar's field of view
  - A driver is already responding to an object detected by a Collision Warning (CW) system

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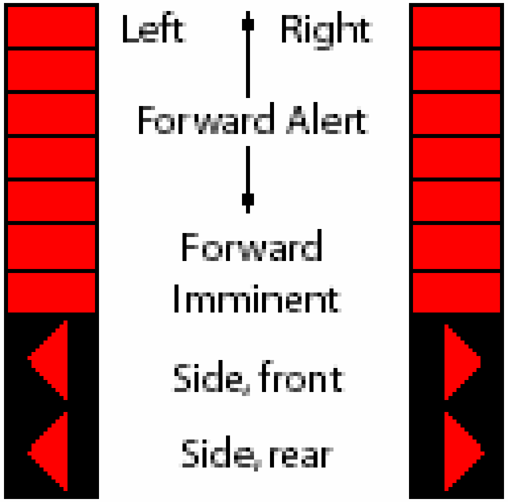
Many research issues to look at:

DVI Design

- Sensors and technology may be able to detect a crash threat, but the **Driver Vehicle Interface (DVI) must be effective or the IVBSS system will not be successful.**



Many research issues to look at:

DVI Design

- How will **individual differences** and intervening variables such as age be accommodated? What are the DVI implications?
- Should a DVI adapt to the **state of the driver**? (distracted, impaired, alert)
- Are there DVI parameters that should be **standardized**?

Conclusions on IVBSS

- **The key to driver acceptance and successful deployment** of IVBSS technology will be an effective DVI

- There are **significant human factors research issues that need to be and will be addressed** in the IVBSS program

- Creating an effective DVI may be a **larger challenge** than the integration of system hardware and software

CONCLUSIONS

Conclusions

“ We have come to understand many of the factors that contribute to human error… With good human factors design and testing techniques, the effects of man sources of human error can be controlled “

(Michael E. Maddox - member of the Human Factors and Ergonomics Society)