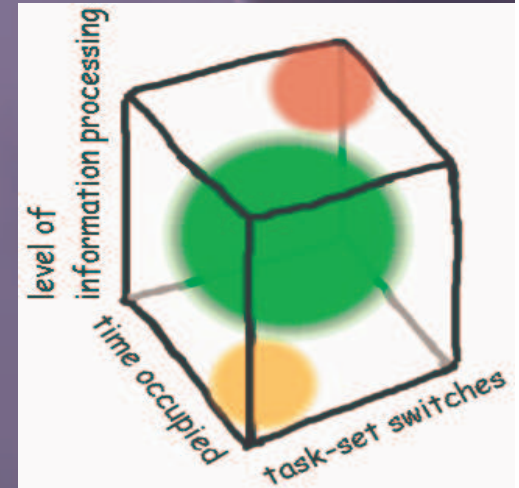


COLFUN, a general framework for task design and evaluation in high-demand environments

J.A. Rypkema, M.A. Neerincx, P.O. Passenier

TNO Human Factors



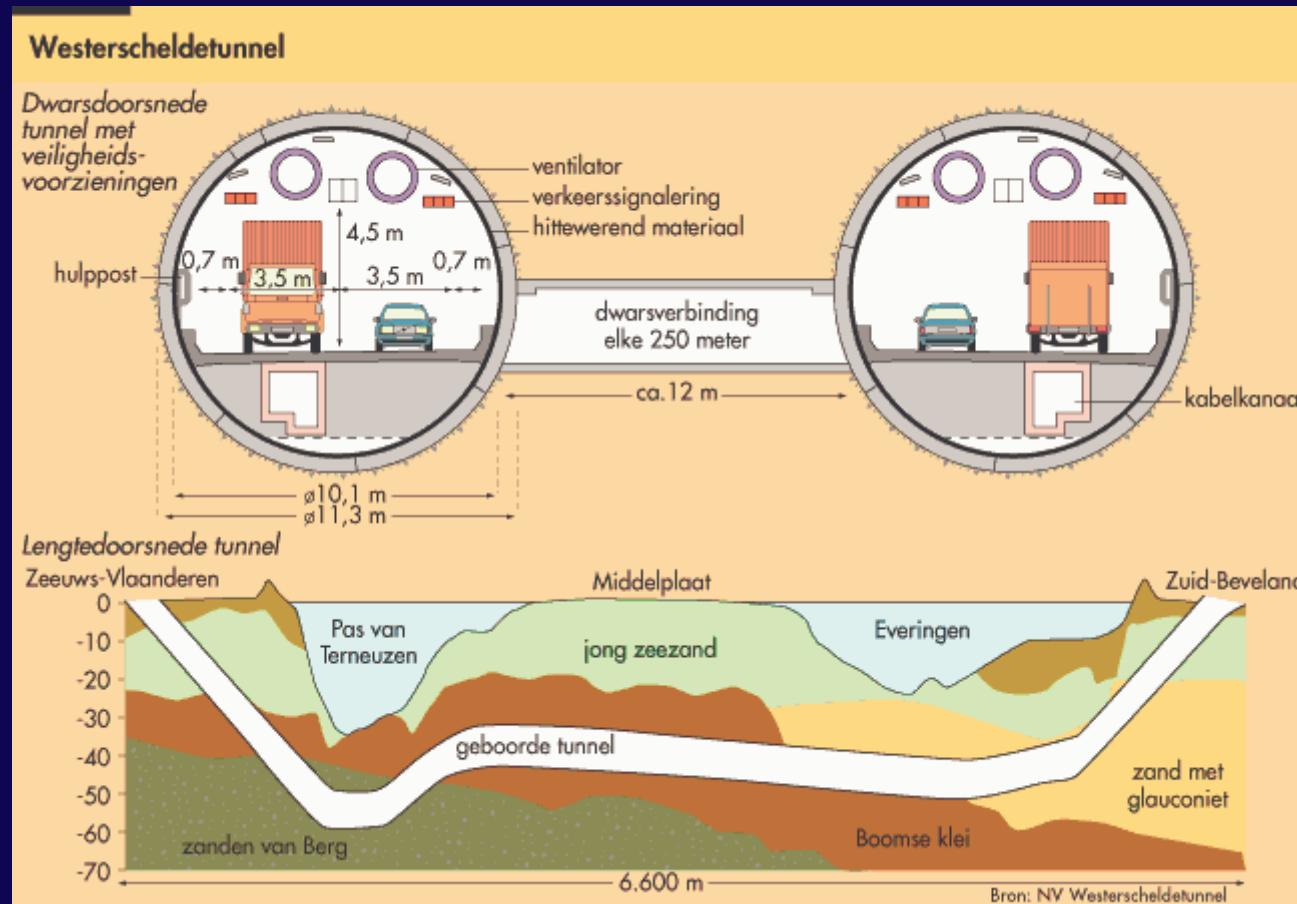
Westerschelde motor-traffic tunnel



Westerschelde motor-traffic tunnel

- 6.6 km long
- 2 tubes, each tube 2 driving lanes
- Evacuation corridors every 250 m
- Cameras every 150 m
- 20 monitor displays
- Sensors (e.g. traffic speed, vehicle height, sight)
- Controllers (e.g. traffic lights, speed reduction signs)
- One operator to guard the tunnel

Westerschelde motor-traffic tunnel



Question:

Can the tunnel be controlled safely by one tunnel operator?



Sub-questions

- What tasks does the tunnel operator have to perform?



Sub-questions

- What tasks does the tunnel operator have to perform?
- How complex are these tasks?



Sub-questions

- **What tasks does the tunnel operator have to perform?**
 - Task analysis
- **How complex are these tasks?**



Sub-questions

- **What tasks does the tunnel operator have to perform?**
 - Task analysis
- **How complex are these tasks?**
 - Cognitive load analysis



Task analysis

Four generic process control functions:



Task analysis

Four generic process control functions:

- Situation Awareness (SA)



Task analysis

Four generic process control functions:

- **Situation Awareness (SA)**
- **Disturbance Assessment (DA)**



Task analysis

Four generic process control functions:

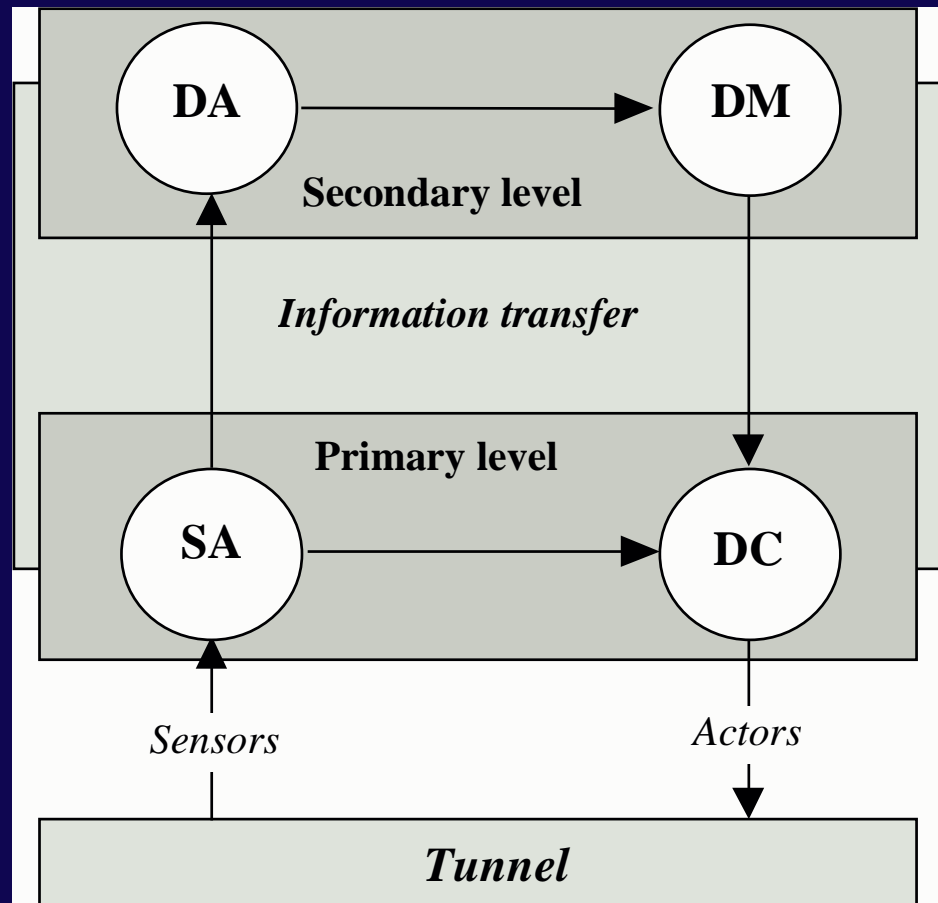
- **Situation Awareness (SA)**
- **Disturbance Assessment (DA)**
- **Decision Making (DM)**

Task analysis

Four generic process control functions:

- **Situation Awareness (SA)**
- **Disturbance Assessment (DA)**
- **Decision Making (DM)**
- **Direction & Control (DC)**

Functional model



SA = Situation Awareness
DA= Disturbance Assessment
DM= Decision Making
DC = Direction & Control

Example

- **Situation awareness**
 - Alarm notifies slow speed
 - Cameras show wrecked car



Example

- **Situation awareness**
 - Alarm notifies slow speed
 - Cameras show wrecked car
- **Disturbance Assessment**
 - Accident
 - One lane blocked

Example

- **Situation awareness**
 - Alarm notifies slow speed
 - Cameras show wrecked car
- **Disturbance Assessment**
 - Accident
 - One lane blocked
- **Decision Making**
 - Close tube
 - Close obstructed lane
 - Speed reduction on other lane

Example

- **Situation awareness**
 - Alarm notifies slow speed
 - Cameras show wrecked car
- **Disturbance Assessment**
 - Accident
 - One lane blocked
- **Decision Making**
 - Close tube
 - Close obstructed lane
 - Speed reduction on other lane
- **Direction & Control**
 - Traffic lights on red
 - Activate signs

Cognitive load analysis

Three cognitive load factors:



Cognitive load analysis

Three cognitive load factors:

- **Time occupied**
 - Percentage of available time occupied with tasks



Cognitive load analysis

Three cognitive load factors:

- **Time occupied**
 - Percentage of available time occupied with tasks
- **Level of information processing**
 - Skill-based ('back bone')
 - Rule-based ('if...then')
 - Knowledge based (unfamiliar situations)



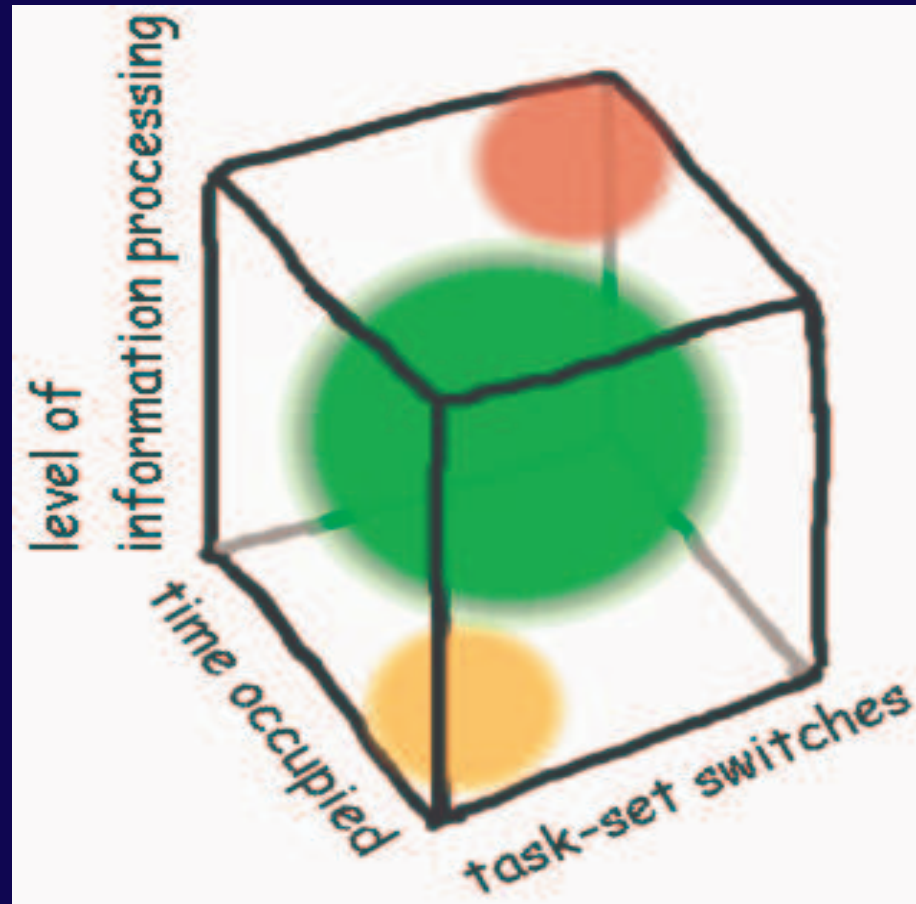
Cognitive load analysis

Three cognitive load factors:

- **Time occupied**
 - Percentage of available time occupied with tasks
- **Level of information processing**
 - Skill-based ('back bone')
 - Rule-based ('if...then')
 - Knowledge based (unfamiliar situations)
- **Task-set switching**
 - Number of switches between tasks-sets (goals, objects, knowledge, capacities)



3D cognitive load model



Scenario analysis

5 scenarios, based on:



Scenario analysis

5 scenarios, based on:

- Frequency



Scenario analysis

5 scenarios, based on:

- Frequency
- Severity



Scenario analysis

5 scenarios, based on:

- **Frequency**
- **Severity**
- **Expected mental effort**



Scenarios

- **Scenario 1**
 - Accident with bus with elderly people, fire



Scenarios

- **Scenario 1**
 - Accident with bus with elderly people, fire
- **Scenario 2**
 - Cargo falls of truck, collision, fire



Scenarios

- **Scenario 1**
 - Accident with bus with elderly people, fire
- **Scenario 2**
 - Cargo falls of truck, collision, fire
- **Scenario 3**
 - Driver heart attack, car hits barrier

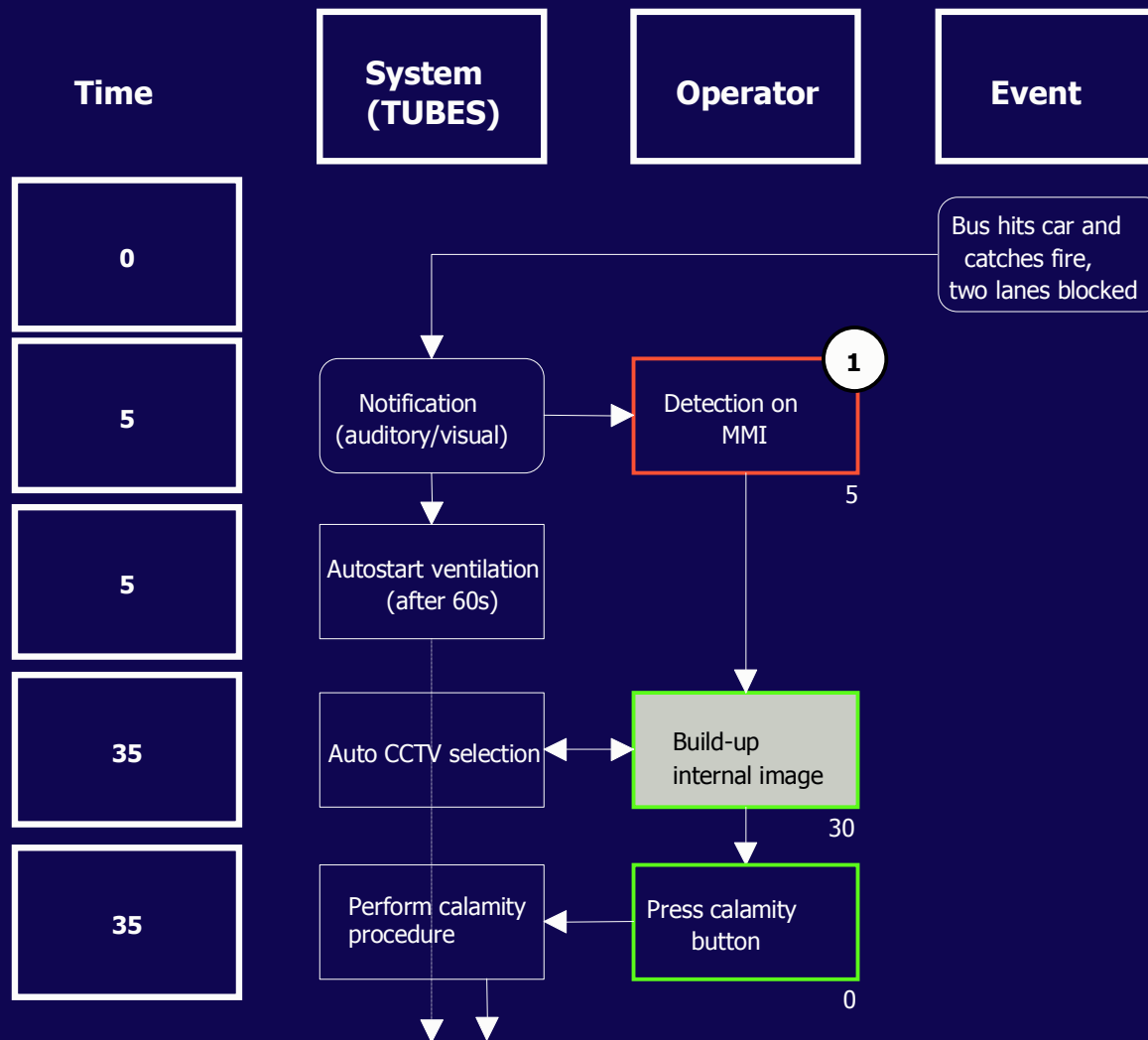
Scenarios

- **Scenario 1**
 - Accident with bus with elderly people, fire
- **Scenario 2**
 - Cargo falls of truck, collision, fire
- **Scenario 3**
 - Driver heart attack, car hits barrier
- **Scenario 4**
 - Short circuit, no camera images

Scenarios

- **Scenario 1**
 - Accident with bus with elderly people, fire
- **Scenario 2**
 - Cargo falls of truck, collision, fire
- **Scenario 3**
 - Driver heart attack, car hits barrier
- **Scenario 4**
 - Short circuit, no camera images
- **Scenario 5**
 - Car without fuel standing still in tunnel

Method scenario analysis



Results scenario analysis (1)

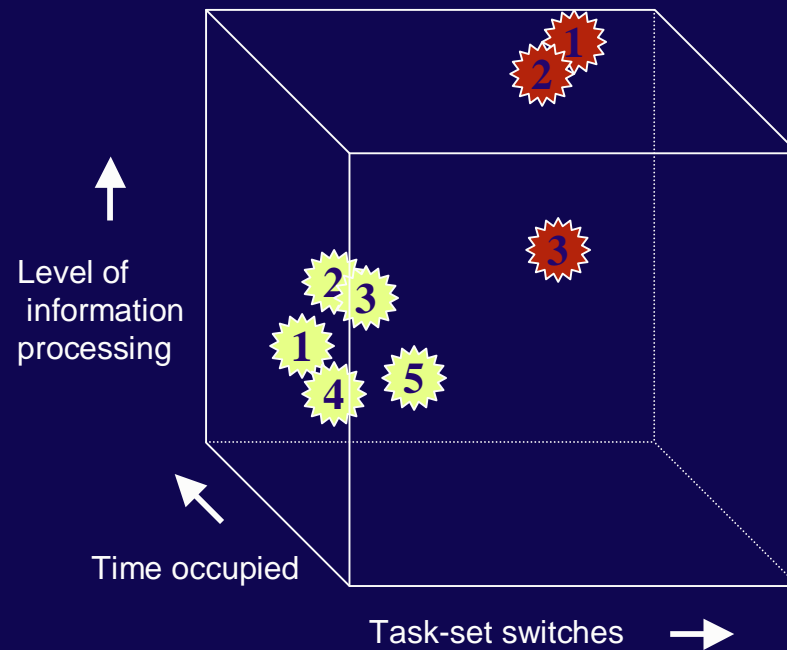
Scenario	1	2	3	4	5
Time (in sec)	44360	21310	14875	4320	1240
Time occupied (in %)	100	100	100	100	100
Complexity (in %)	21	25	19	15	7
Task-set switches (number)	28	26	23	6	8
Task-set switches (average time between switches)	1584	819	647	720	155

Scenario	1	2	3
Time (in sec)	0 - 675	0 - 1105	0 - 920
Time occupied (in %)	100	100	100
Complexity (in %)	52	54	23
Task-set switches (number)	13	12	10
Task-set switches (average time between switches)	52	92	92

Critical period



Results scenario analysis (2)



Conclusions

Cognitive load too high at the start of incidents, because:

- **Too many tasks in short time (especially with evacuation)**
- **Tasks too complex because lack of (clear) procedures**
- **Sometimes number of task-set switches too high as a result of intertwined task-sets**

And:

- **Sudden change from monotonous vigilance task to highly demanding crisis situation**
- **Responsibility until emergency services arrive**



Recommendations

- **Develop / improve procedures related to the categorisation of incidents.**
- **Develop evacuation procedures. Pay attention to communication and guidance.**
- **Improve procedures for communication with third parties. Restrict communication tasks during crisis situations.**
- **Cluster the operator tasks in sets.**
- **Provide a second person for assistance during crisis situations.**
- **Rearrange the calamity buttons**

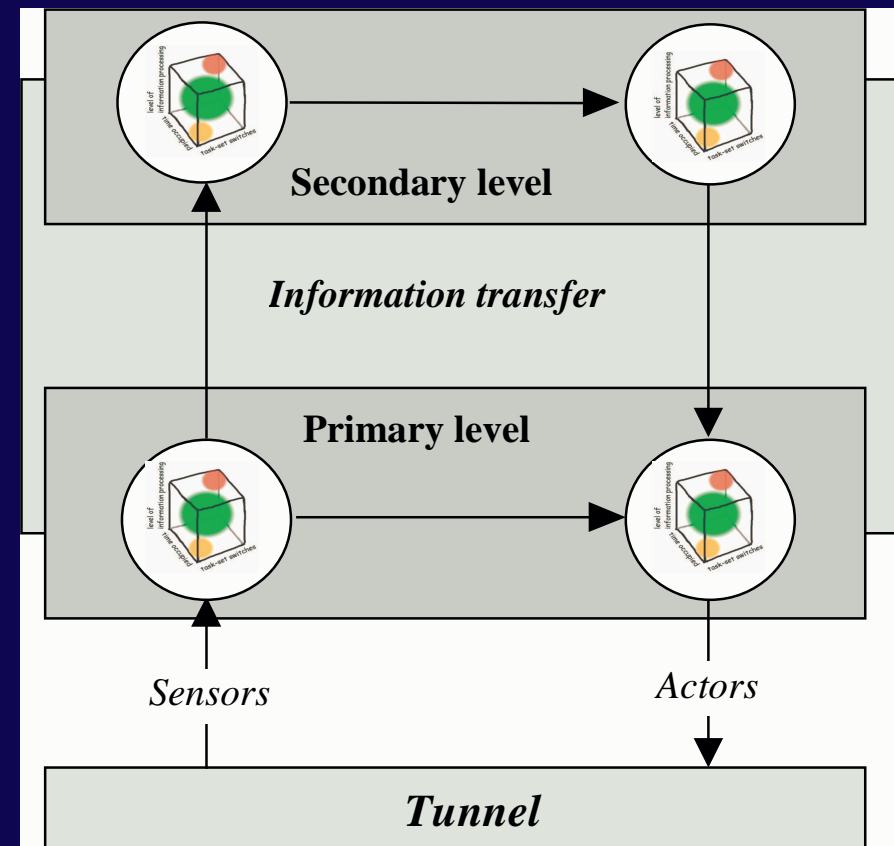
Recommendations training

- Train “on the job” for normal situations
- Use a simulator to train for critical situations
- Repeat training frequently (3-6 monthly)
- Organize interdisciplinary training with emergency services



Cognitive load functional framework (COLFUN) supports ...

- Envisioning high demand situations in process control
 - Task analysis
 - Cognitive load analysis
- Task design
 - Procedures
 - Manning
 - Organisation
 - Training
 - Support systems



Questions?

