

The Human aspects of managing complex systems

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Goal of Command and Control (C2)

- Replace the human with technology
- In many settings this has been achieved
- In higher level tasks (e.g. CEOs involved)
 - Humans may insist on control
 - Especially when groups e.g. boards are involved

Information and Control

- Information and Control are central notions in complex systems. (The rational decision model usually assumes that the required information is available and control only becomes important when a series of decisions is required to manage a complex dynamic system.)

Communications Technology provides more, & for the rational Decision Maker:

More is Better

- Information-the more reliable and detailed the better
 - Control-the more control over persons and resources, the better
 - Communication-the more the better
 - Resources-the more the better
- rational decision makers will allocate resources optimally (cognitive economics)

A worm in the apple: although technology changes, people do not

- working memory is limited and fixed
 - results in biases e.g. discount rates
 - requires heuristics e.g. simplifying rules
- long term memory unlimited capacity
- People must:
 - construct models to simplify the world
(required by limited working memory)
 - regulate cognition, emotion & behaviour

New Communication Technologies enable the Control of Complex Systems

- Allows ever more rational decisions
 - All decision makers can be fully informed
- Virtually instant communication available
 - Control can be centralised and comprehensive
- Allows e.g. “network-centric” warfare
- Allows e.g. the lifting of the “fog of war”

People are Would-Be Rational

- Our reach exceeds our grasp
- Therefore we need to regulate ourselves
 - In cognition e.g. not overload working memory
 - In emotion e.g. avoid ‘emotional discharge’ coping/management strategies
 - Interactive behaviour towards others
- There are many regulatory systems e.g. the legal system, biology, the scientific method

Managing a dynamic environment

- Thus a decision maker's focus of concern is on the ongoing level of control over the external environment.
- Engages in a constant process of self-monitoring and self-regulation

An experimental approach: Network Fire Chief

- A micro- (scaled) world simulation
 - Focuses on psychological fidelity
- Suitable for experimental manipulations
- Allows team studies
- Not limited to fire scenarios

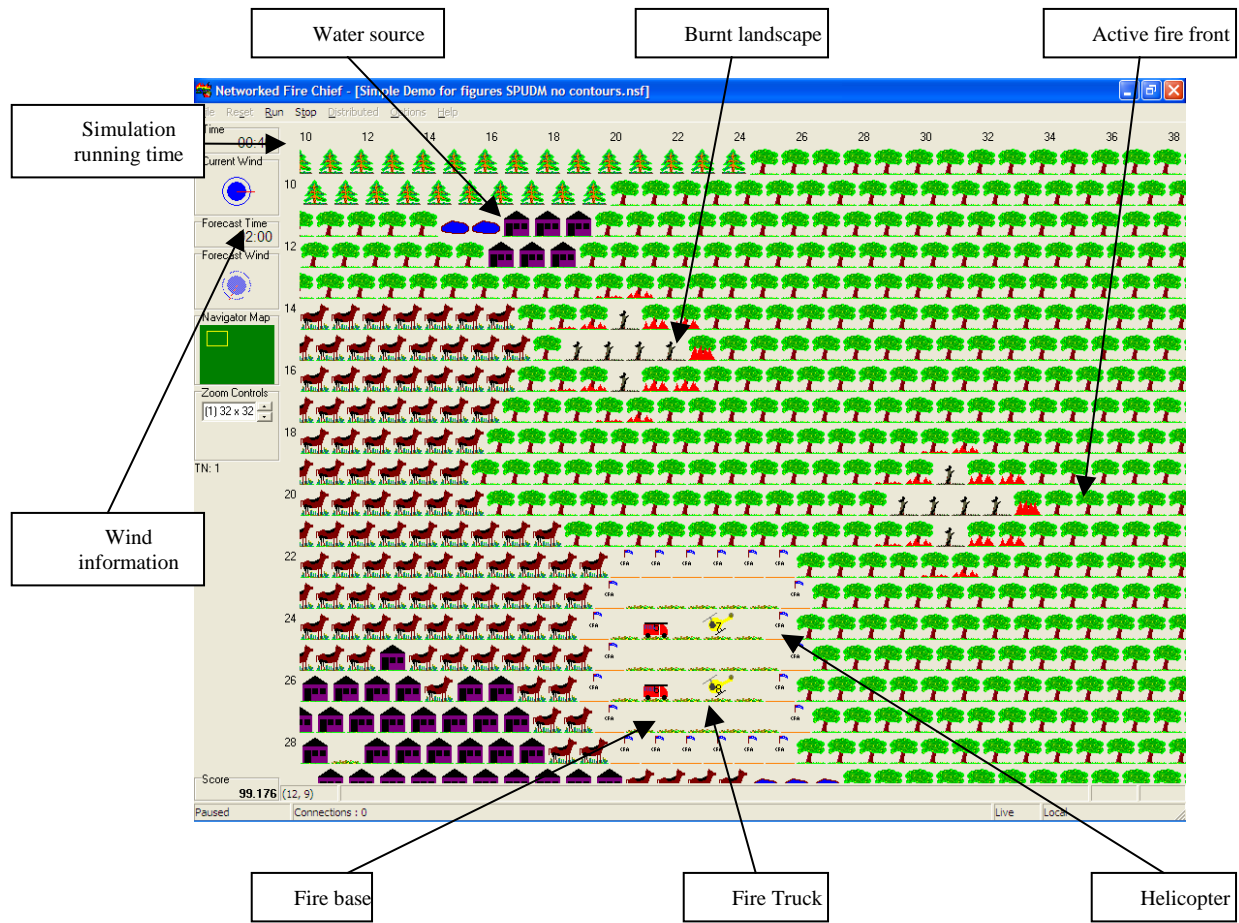


Figure 1. An Illustrative *Networked Fire Chief* Scenario (Zoomed In)

Challenges to Metacognition

- Decision makers need to learn many templates (like chess players), to maximize the use of recognitional decision processes, and minimize the demand on working memory
- It is difficult to trade off costs and benefits while not overloading working memory; decision support technology may help.
- Decision makers must match the level (specificity) of control activities to the level of the task.

The Lone Decision Maker

- Performance worse when planning information is present (exacerbated under time pressure)
 - planning information may induce a planning oriented strategy
 - planning occurs at the expense of implementing control actions (a failure of metacognition)

Operating characteristics of individuals

- Commanders may lack basic competencies e.g. in information processing speed, or field independence (the ability to extract information from the environment).
- People would rather gather planning information and plan than act: action is irrevocable. Planning may therefore occur at the expense of implementation.

What is fixed, what is mutable?

- N, E, DMQ more fixed
- Management/coping skills more mutable
 - Emotion based coping more fixed
 - Problem oriented coping more mutable

Multiple decision makers

- We have run a number of experiments involving ICs (incident controllers, in charge of fighting a fire), and SCs (sector controllers), in charge of a fighting a sector of the fire, and responsible to the IC (Incident Controller).

Experimental Manipulations: Information & Control

- The IC could either access information directly from the screen, or indirectly from the SCs
- The IC could either issue commands (exercise control) directly to the appliances, or indirectly through the SCs,
 - ICs with a high need for control were less likely to delegate command authority

Workload & Time Pressure

IC workload heavier in indirect control condition, i.e. micro-managing easier

Under high time pressure:

clarity of commands was related to good performance,

completeness of commands was related to poor performance.

Hands on is worse

- With respect to access to direct action (micro-management) ICs permitted access to direct control performed worse
- If given the opportunity for direct control, the more frequently an IC issued commands directly to the fire crews, the poorer his/her performance ($r = .60$)
- ICs provided with detailed information on the screen also performed worse

Misleading Feedback

- Commanders believe that performance is worse when they delegate information gathering and control; in fact it is better. Micro-managing is both easier and more enjoyable albeit not as effective.
- Performance may be better (or no worse) after a breakdown in communication although commanders believed it to be worse.

Decision Processes of a good Commander

- Extracts relevant information from the task situation (can tell figure from ground)
- develops a good fitting mental model of the task situation
- selects effective courses of action from repertoire
- monitors the outcomes of these actions
- keeps within the limits of working memory

A good Commander also

- Draws on previous learning to use recognitional decision processes (template matching) rather than analytically solving the problem anew
 - makes use of long term memory
 - avoids overloading working memory
- regulates allocation of cognitive resources

In Summary

- In attempting to regulate cognitive and affective demands, people attempt to choose options which minimized felt uncertainty and maximized the sense of control, and that such attempts were in the main counterproductive with respect to overall control of the decision environment

A seeming paradox

- At the same time, ICs believed that their performance was better when:
- they received all the information directly
- they had direct control over the firefighting appliances

Some Shortcomings of Decision Makers

- subjective assessment of their performance may be wrong.
- Monitoring is not natural; steps must be taken to ensure that it occurs e.g. install monitoring procedures
- Higher commander workloads correlate with poorer strategic decisions and poorer performance.
- Communications technology can foster an illusion of power and knowledge

The Commander's Intent vs Specific Orders (or Actions)

- Modern communication technologies allow a commander to specify what a subordinate should do; we contrast two conditions
- SCs getting specific instructions about actions to be undertaken
- SCs are given the broad goals (intent) of the IC (incident commander)

Findings

- Performance of Action command style inferior to Intent command style
- ICs perceived workload higher in Action condition
- SCs' perceived workload heavier in the Intent condition, but at the same time they found it easier to manage
 - SCs were free to manage as they chose
- High IC workload correlated with poorer performance
- More time was spent on strategic decisions e.g.prioritising fire fronts, in the high intent condition, and these decisions were rated as better

More findings

- High IC workload correlated with poorer performance
- More time was spent on strategic decisions e.g. prioritising fire fronts in the high intent condition, and these decisions were rated as better
- High IC workload correlated with poorer strategic decisions

Yet More findings

- ICs in Action Command style reported more engagement in tactical decisions e.g. how many appliances are needed on a particular fire front.
- ICs in Action condition perceive performance as better
- Tactical decision making is a better predictor of performance in Action conditions; strategic decision making is a better predictor of performance in high intent conditions
- Leaders with high self esteem performed better in the Intent condition

The effective commander

- In summary, the more effective commander is one in which the he or she is confident about his or her own abilities, and those of his or her subordinates, where the commander sets broad goals, where the commander minimizes workload, and where the commander focuses on strategic decisions, letting the subordinates focus on more tactical decisions.

Commanders fail because they:

- lack the necessary cognitive skills
- over-gather information at the cost of action
- receive hedonic reward (positive reinforcement) for sub-optimal courses of action
- Fail to protect working memory (due to an illusion of rational capability)
- Are influenced by misleading subjective feedback about performance

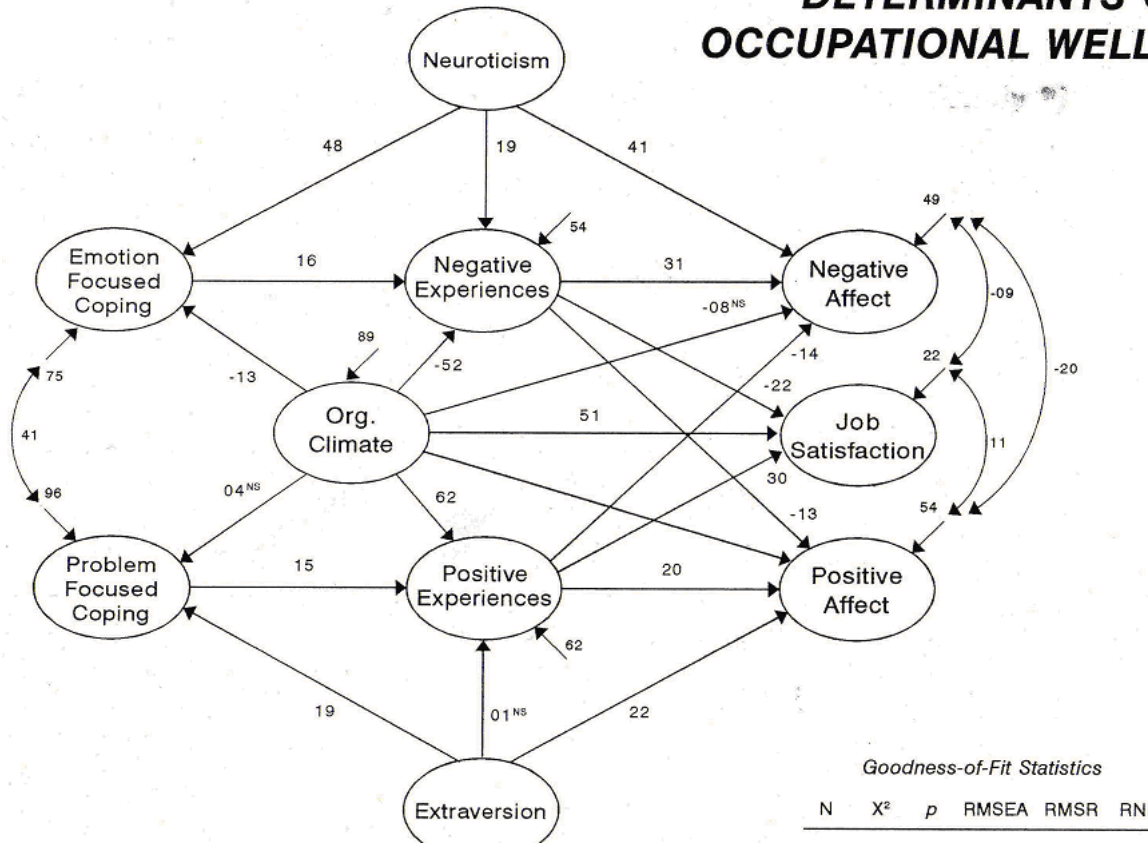
What about normal organisational situations?

- We have been looking at emergency situations, be they real or simulated
- What about managing everyday settings, in the course of which executives and managers make a series of small decisions, perhaps trivial by themselves?

Leadership & management

- Supportive leadership
- Seeking instrumental support
- Problem solving
- Planning logical analysis
- Acceptance
- Humour
- Affective regulation
- Emotional discharge

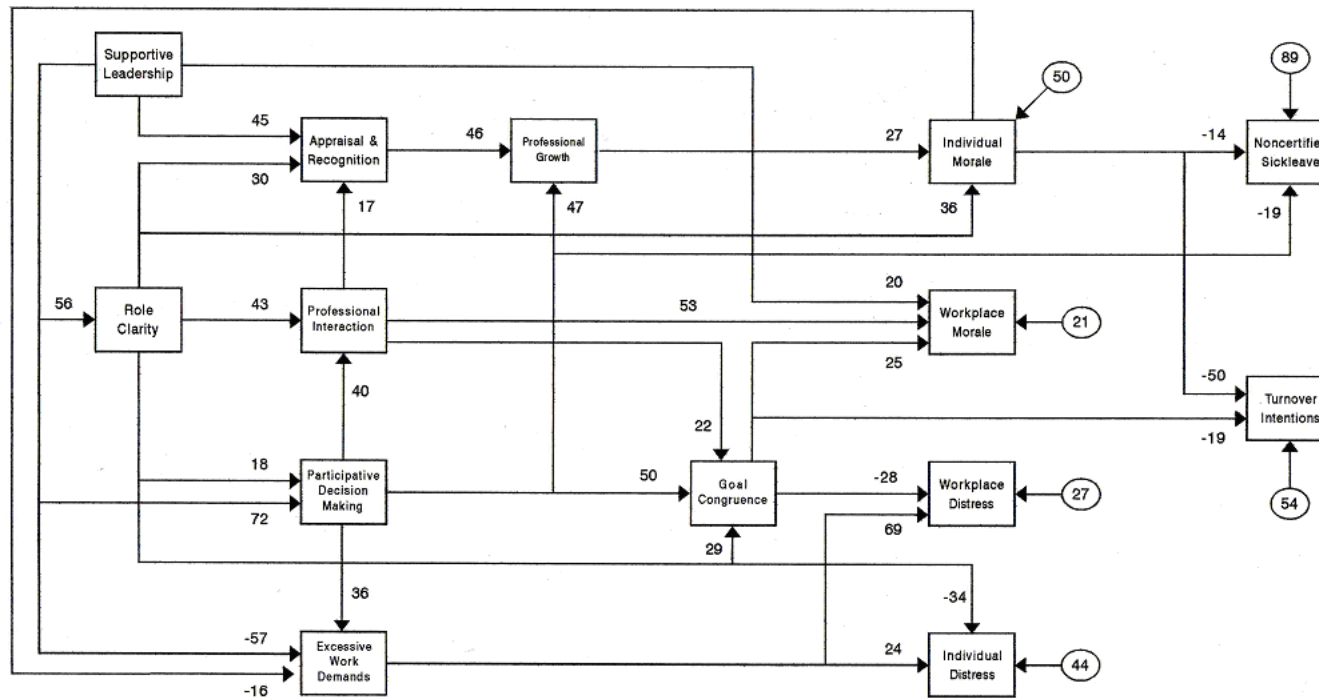
DETERMINANTS OF OCCUPATIONAL WELL-BEING



In-Depth interviews as people leave the fireline issues raised

- Overarching concepts
 - Uncertainty
 - Information flow
 - Resource allocation
 - management

DETERMINANTS OF NONCERTIFIED SICKLEAVE AND TURNOVER INTENTIONS



Specific concepts, processes, and questions

- Does a firefighter develop worst case scenarios, more optimistic ones, or factual (accords with the available intelligence) ones?
- How long does a commander persist with a model or a course of action in the face of contrary evidence, or is there no evaluation of alternatives once a decision is made
- creating and communicating a management structure
 - The task of forming IMTs in dynamic situations when there is rapid change

Specific concepts, processes, and questions

- Resource allocation
 - The allocation task may involve appliances, time, communication channels teams (effectiveness depends on metacognitive regulations)
- Mental models of fires
 - Analogies from derived from experience

Specific concepts, processes, and questions

- Affect and stress
 - fatigue
- Ego involvement
 - Will I fail?
 - Is my property at stake
- Relationships
 - Have people previously worked together
 - What is the level of trust between individuals

Specific concepts, processes, and questions

- Feedback
 - Delays in getting information
 - Relevance and accuracy of information
 - Problems in getting information/intelligence
 - Using action to generate information
 - Fog of war
 - What is the status and location of assets
 - Utilising local knowledge

Specific concepts, processes, and questions

- Obtaining strategic information
 - Are wind changes due?
 - Do people know what they need to know
 - Is the information reliable?
 - Are IMTs aware of the situation on the ground

Specific concepts, processes, and questions

- Liveware
- Delegation
- Safety
- Adequacy of briefings and handovers

More concepts processes, and questions

- Ingroups and outgroups
- Getting strategic information
- Communication hardware
- Safety and its constraints

Implications for Education & Training

- What is easy e.g. micromanagement may work only in the short term
- The control “level” should be matched to the problem
- Gathering data and formulating a course of action is not enough; the outcome of the policy must be monitored

The End