Techniques for verification of expert models for dependence assessment in human reliability analysis

L. Podofillini [a], P. Baraldi [b], V.N. Dang [a], E. Zio [b], M. Librizzi [b]

[a] Paul Scherrer Institute
Villigen PSI, Switzerland

[b] Polytechnic of Milan
Milan, Italy

presented by V.N. Dang

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Techniques for verification of expert models for dependence assessment in HRA

- Background – assessing dependence in HRA practice
- Expert judgment and expert models
  - Experts, analysts
  - Assessment using a model of HRA dependence
- Two techniques for verification
  - Supporting visualization
  - Sensitivity measures
- Outlook

THERP's Dependence model

- **Is basis for many subsequent methods**
  - **Five levels** of dependence: ZERO (none), LOW, MEDIUM, HIGH, COMPLETE
  - For each dependence level, **conditional probabilities** are suggested

Zero	Low	Medium	High	Complete
< 0.01	.05 (.015 to .15)	.15 (.04 to .5)	0.5 (.25 to 1)	1 (.5 to 1)

- **Assessment of the level**:
  - Factors: closeness in time, stress, similarity of functions … +
  - Guidelines:

"Evaluate spatial and time relationships among all events.
Dependence between any two events increases as the events occur closer in time and space." [NUREG/CR-1278]

Decision trees for assessing HRA Dependence Level

e.g. EPRI HRA Calculator

Time between cues	Adequate resources	Stress	Level
Simultaneous	No	High	CD
		Low	
	Yes	High	CD
		Low	HD
0-15 min	Yes	High	CD
		Low	HD
15-30 min	Yes	High	HD
		Low	MD
30-60 min	Yes	High	MD
		Low	LD
> 60 min	Yes	High	LD
		Low	ZD

- These trees reduce the variability of the expert judgment:
- Analyst: gives input judgments → output comes from the DT
- Criteria for assessing input factors can be more explicit.
- Same input judgments → same dependence level

SPAR-H decision tree for dependence

Factors are more closely related to those in THERP.

Dependency Condition Table

Condition Number	Crew (same or different)	Time (close in time or not close in time)	Location (same or different)	Cues (additional or no additional)	Dependency
1	s	c	s	na	complete
2				a	complete
3			d	na	high
4				a	high
5		nc	s	na	high
6				a	moderate
7			d	na	moderate
8				a	low
9	d	c	s	na	moderate
10				a	moderate
11			d	na	moderate
12				a	moderate
13		nc	s	na	low
14				a	low
15			d	na	low
16				a	low
17					zero

Expert Judgment and …

- In THERP, the analyst has to be an expert
  - must know what to consider for each input (dependence) factor
  - must combine the judgments for the input factors
- Decision trees
  - the tree combines the judged inputs to yield the assessed dependence level
  - criteria for assessing (judging) some input factors can be made explicit
- Nevertheless,
  - each decision tree represents the views of different experts
  - in using a given decision tree, each analyst develops an "own" model of dependence
    - develops criteria for assessing all input factors
    - these criteria may be inferred from a set of dependence assessments, if adequately documented

… Expert models

Overall objective: develop a model of HRA dependence to replace each analyst's "own" model

- This HRA dependence model is an "expert model"
- It is (or should be) a model based on the experts' understanding of what leads to (or reduces) dependence

An expert model as an HRA dependence method

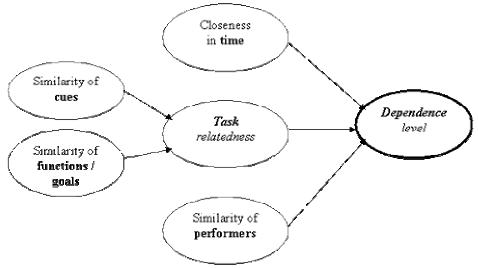
- Usually, expert judgments are elicited to obtain the desired value (the input to the PSA)
- There are structured methods (e.g. seismic, etc) but they are difficult (impractical) to apply within each HRA

assessed dependence level

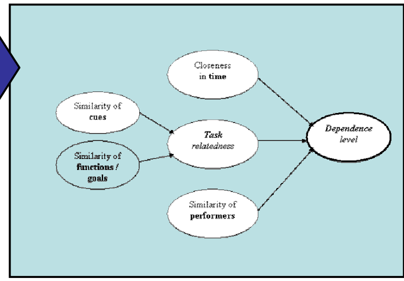
assessed dependence level

An expert model as an HRA dependence method

1. elicit judgments to build a model of how to assess the desired value



2. analysts use the expert model to assess each case



assessed dependence level

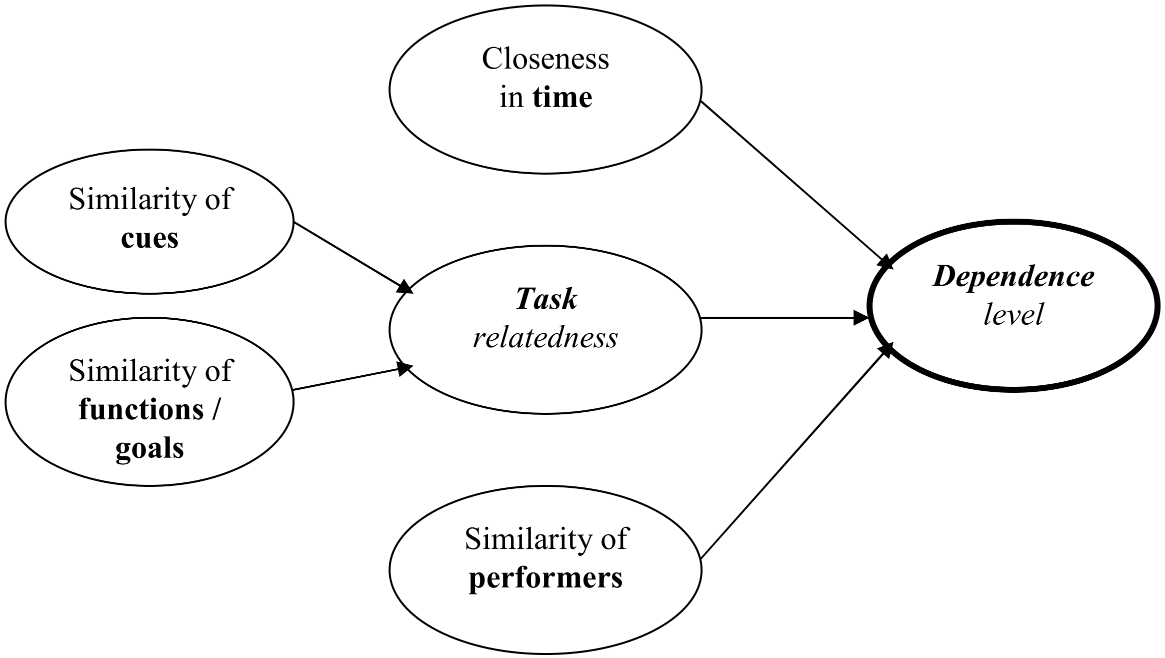
Eliciting expert knowledge to build the model

- What are the key factors to include?
  - Closeness in time, similarity of performers …
- Define "values" or ratings for the key factors and criteria
  - yes/no, low/medium/high, 1-5, 1-7, 0-10
  - criteria for the values (anchored ratings)
- How do the factors (the different levels of the factors) combine to produce a dependence level?

To demonstrate the principles and issues,
next slides show a "working model"

A working model of HRA dependence

1. Key input factors and how they relate (in general terms)



model for post-initiator, control room actions

Different types of models can be used for the “expert model”

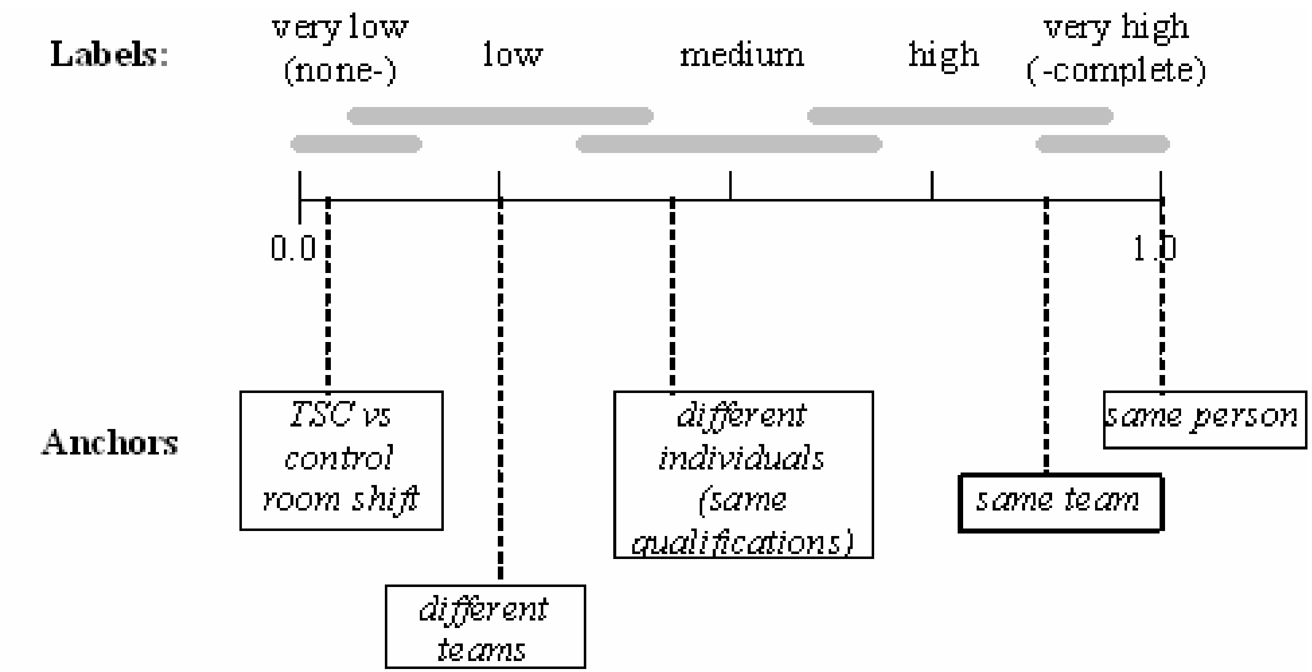
- A decision tree (if criteria are defined clearly enough for repeatability)
- Linear models or weighted sums
- Bayesian network
- Fuzzy expert system
- …

This work explores the fuzzy expert system (FES) as a representation.

Anchoring the input factor ratings

2. Ratings (levels, labels) of the input factors, with defined criteria for each.

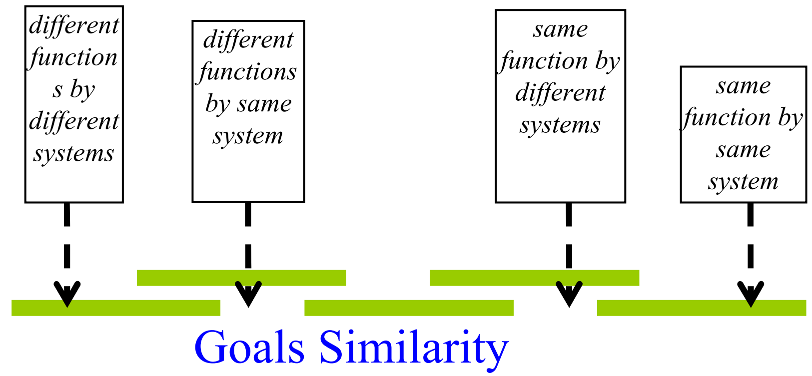
"Similarity of performers":

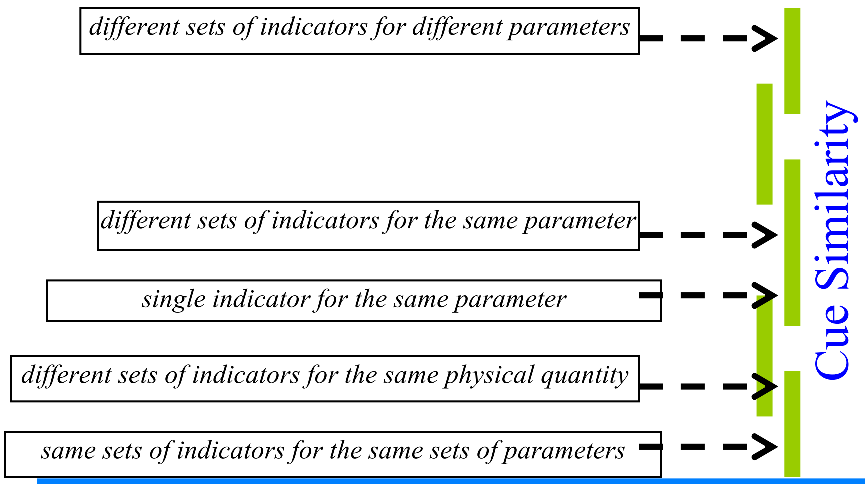


3. How do the factors combine?

Example for intermediate output "task relatedness"

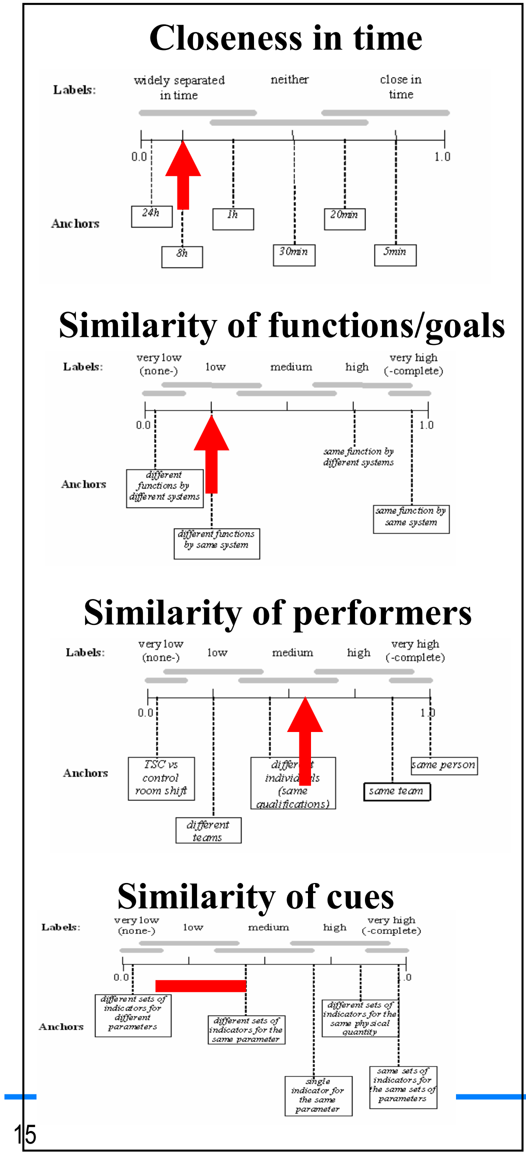
with inputs "goal similarity" (functional relatedness) and "cue similarity"

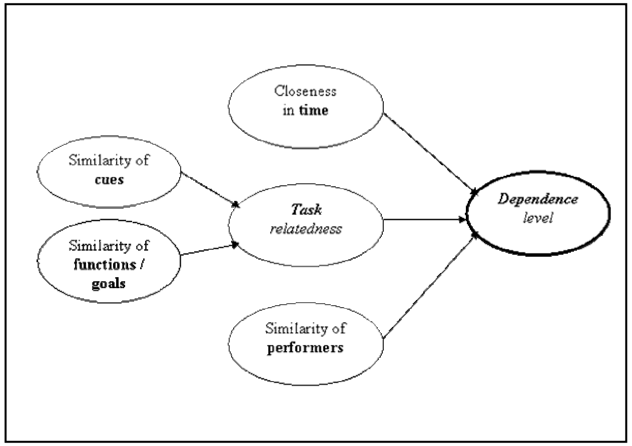


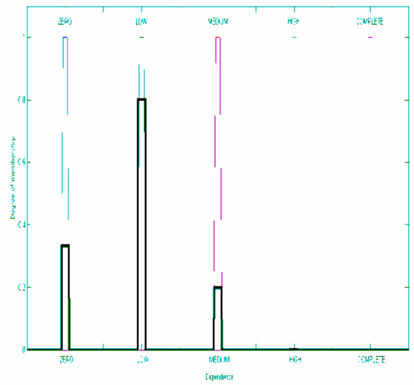


	N	L	M	H	C
N	N				M
L					
M		L			
H				H	
C	H				C

Applying the model to assess the dependence level







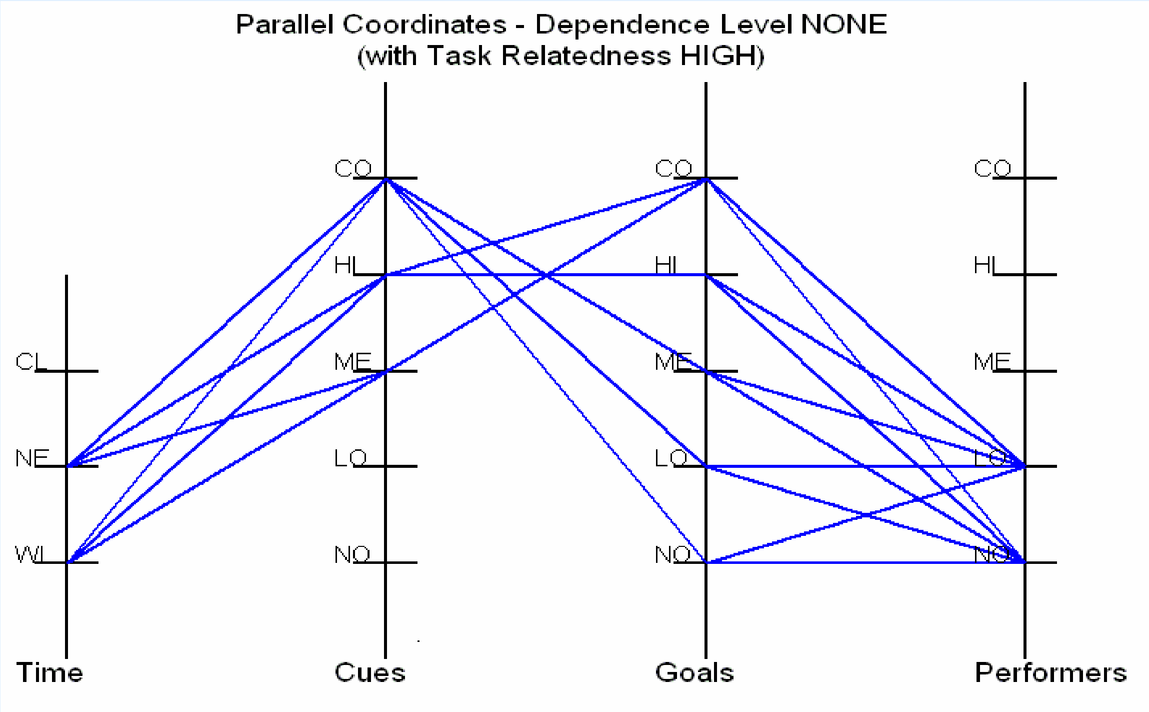
Completing the expert elicitation

- **The expert elicitation is formal and transparent.**
  - **Experts' assertions are used**
    - *"If two actions are very close in time then dependence is very high"* (Effect of one factor)
    - *If cues are identical and goals are different then task relatedness is high* (Effect of multiple factors)
    - *"Cues" are more important than "goals"* (Importance of the parameters)
  - **Evaluation of specific situations, e.g. case studies**
  - **Tendencies need to be filled in**
- **Verification of the model**
  - **Experts need to verify that the model represents their understanding**

Techniques for verification

- Examining the model's "reasoning" for a set of dependence cases

- Visualization: **"Parallel coordinates" representation**



Techniques for verification
The Fuzzy Uncertainty (Index) Importance Measure

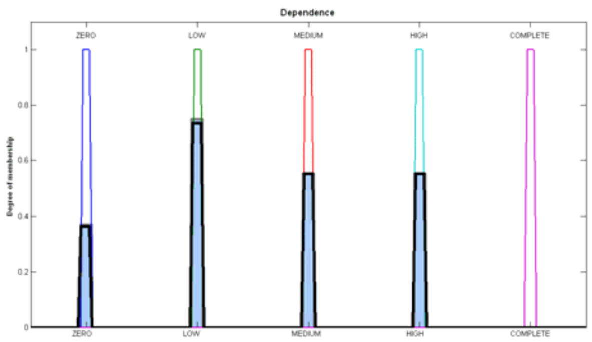
Measure of how sensitive the output is to eliminating the uncertainty in an input factor.

-shaded area: all uncertainties

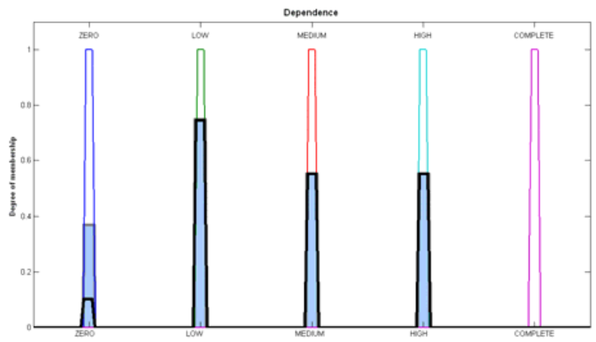
-solid line: reduction when the given factor is precise

The FUIM can be calculated numerically, considering the defuzzified output (dependence level impact on HEP).

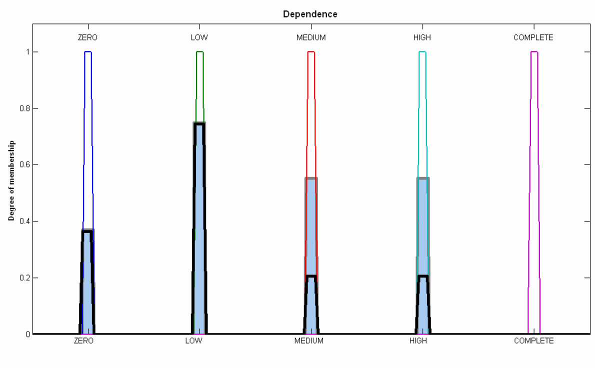
Similarity of goals/functions



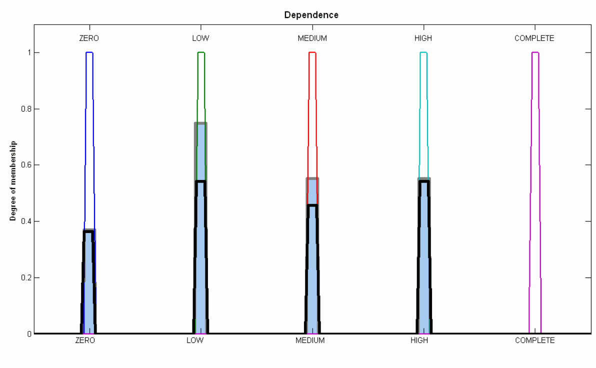
Closeness in time



Similarity of cues



Similarity of performers



Conclusions and outlook

- By capturing expert knowledge as a computable model, expert models can support analysts in evaluating HRA dependence levels.
- The relationships within the expert model are explicit and can be examined and reviewed.
- Verification techniques are needed to allow the experts to understand what the model is doing, i.e. to support verification of the model.
- A model representing the consensus of many experts is needed.