Task Modelling and Model Validation for Car Driving

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Task Analysis and Task Models

What is Task Analysis?

- „any process that identifies and examines the tasks that must be performed by users when they interact with systems“ (Kirwan & Ainsworth 1992)
- widely used in many domains
  - e.g. car driving (Yang, Kim & Nazareth, 2019), rail systems (Lindner et al., 2012), human-computer interaction (Ramkumar et al., 2016)
- main result of analysis: task model – abstract representation of important task structures and task constraints

Task Model Validation - Issues

Little attention towards task model validation

- “All models are wrong, but some are useful” – true, but invalid models are certainly not useful
- task models often used as background for other validations, but not validated themselves
- few systematic approaches to task model validation

Problematic because

- task models are used for norming behavior, based on claims from task model. But are these claims true?
- unclear how variance in task execution is accounted for
- unclear what the model represents. One correct way? A possible way? An intuitive way (from point of view of modeller)?

Task Model Validation - Approaches

Validity: model variables correlate with domain variables

Usefulness: variables of interest in the problem domain are addressed

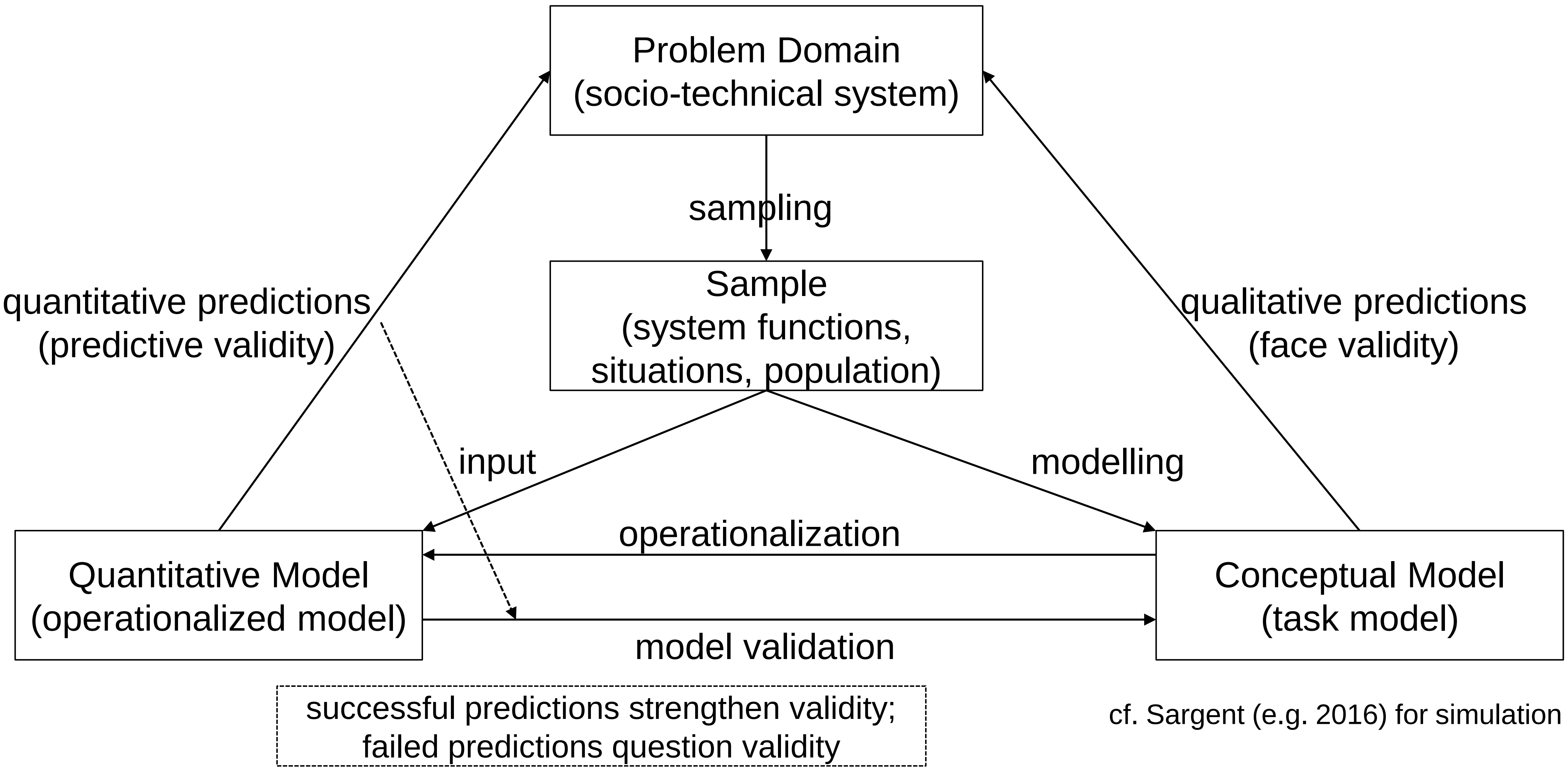
Basic approaches

1. expert judgment: “Looks good to me!”
2. constructing complete state space over all relevant domain variables (e.g. Stanton & Baber, 2005)
3. directly predict task execution time (many GOMS models)

Problems with each approach

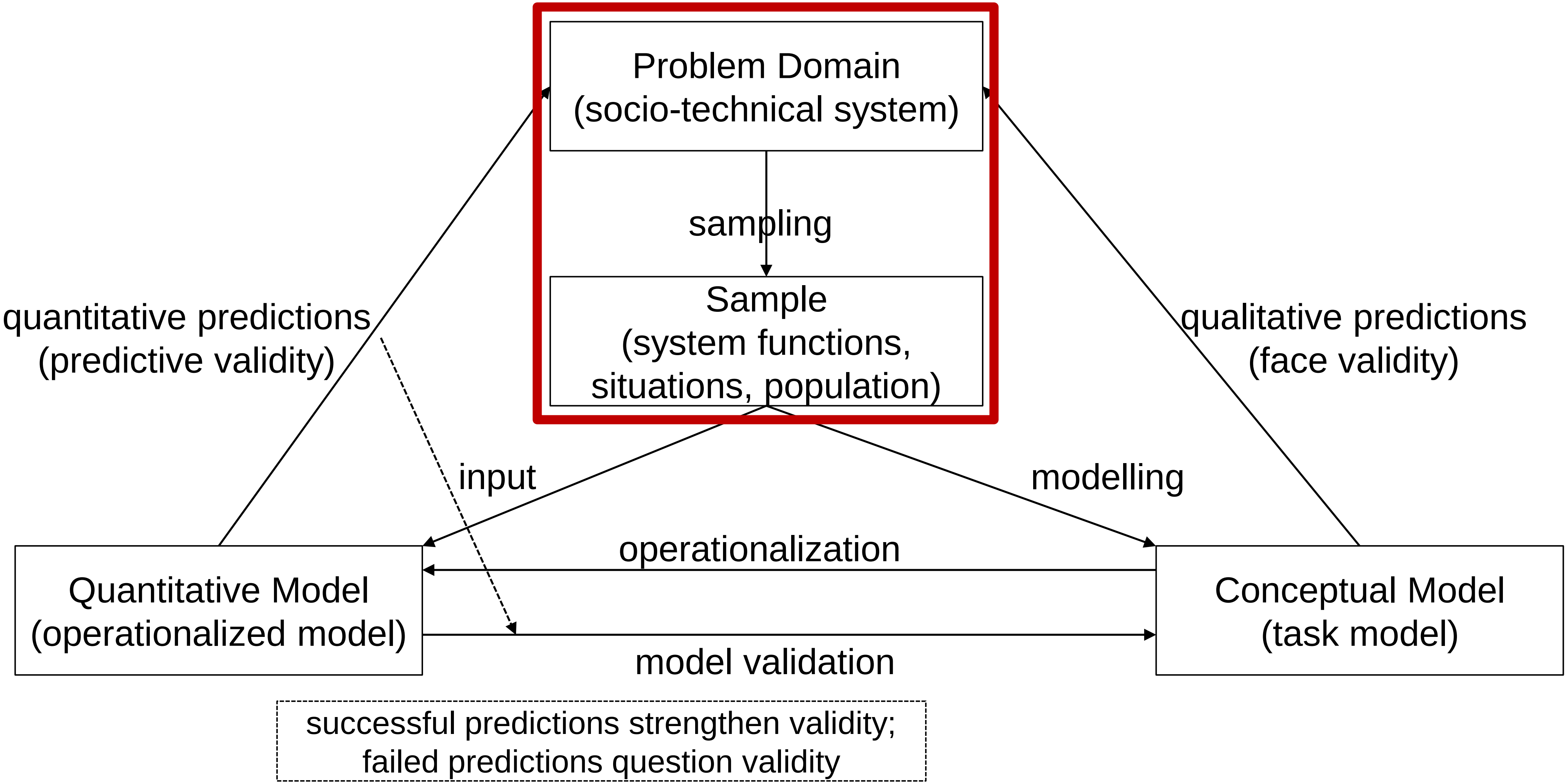
1. expert sample may be biased; unclear how to deal with disagreements between experts; may say more about usefulness than validity
2. combinatiorial explosion; many state spaces are continuous
3. model construction is very expensive; only done for short amounts of time (e.g. 10 sec); amounts to simulation model, thus simulation is needed

Task Model Validation – A Template



cf. Sargent (e.g. 2016) for simulation models

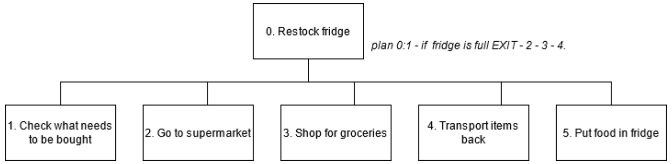
Task Model Validation – A Template



Domain Variables for Car Driving – TASC (Task, Actions, Situation, Cognition)

action =
function(**t**ask, **c**ognition, **s**ituation)

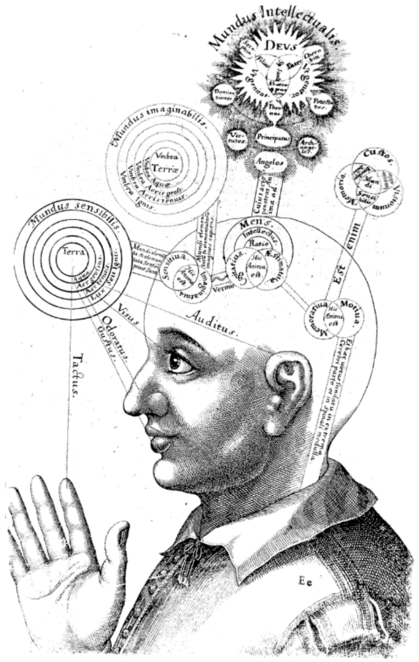
cf. Gray (2000)



task

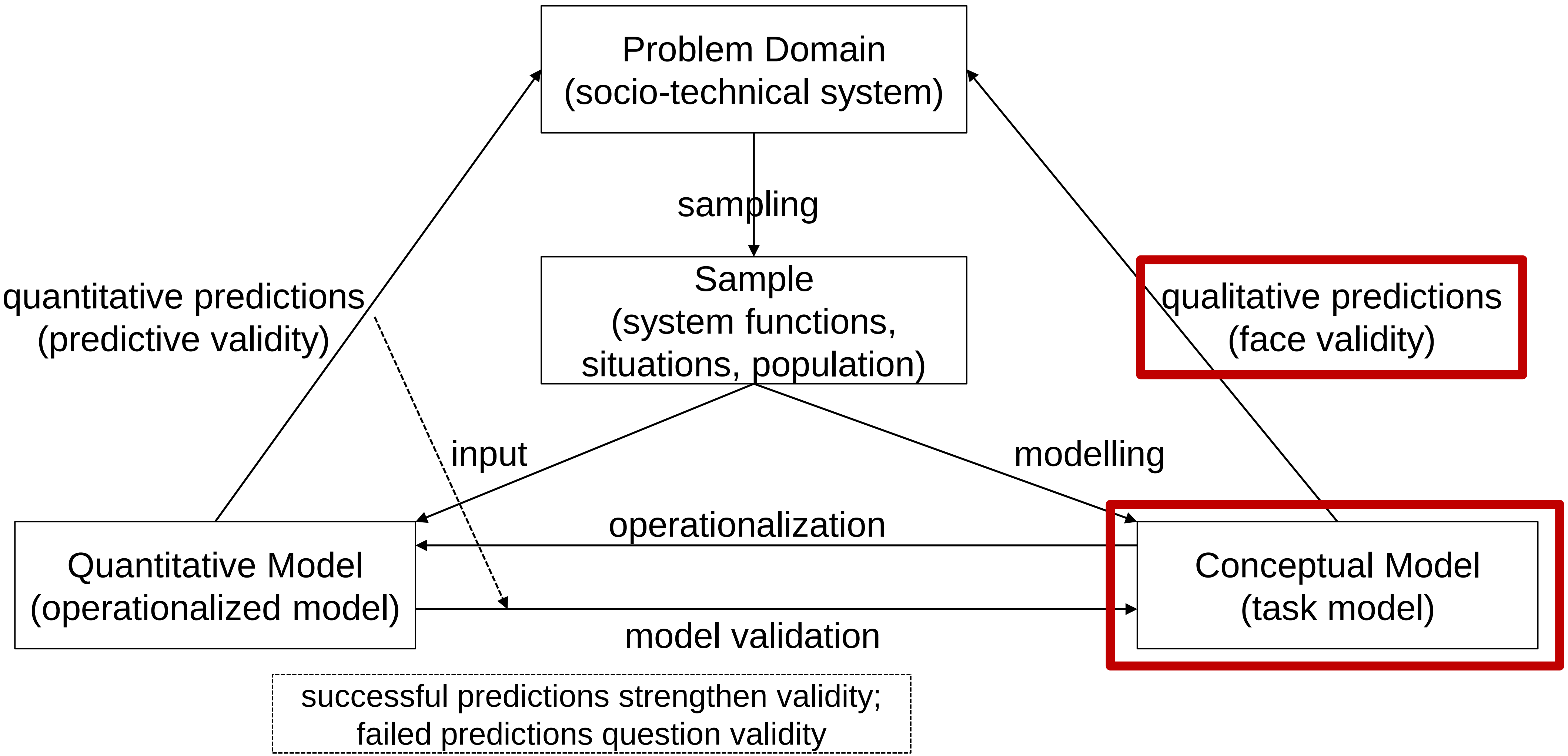
observable **a**ctions

traffic **s**ituation



embodied **c**ognition
(incl. perception, motor)

Task Model Validation – A Template



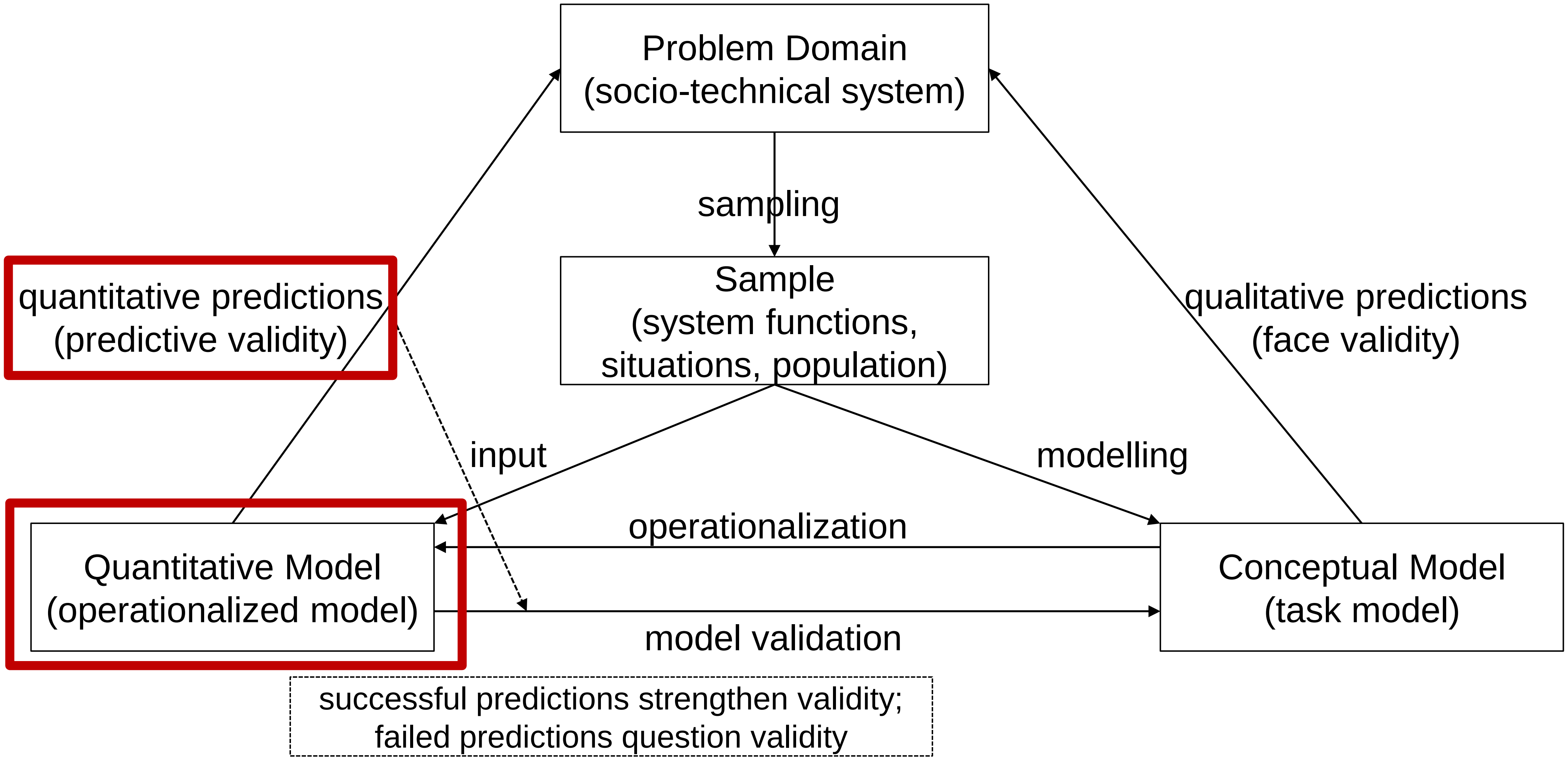
Predictive Validity for an Abstraction Hierarchy

- ontology of a work domain as part of Cognitive Work Analysis (e.g. Naikar et al., 2005)
- strictly speaking not a task analysis per se, but important basis for subsequent analysis activities
- attempts to define „invariants“ (regularities, boundaries) of work domain (Rasmussen et al., 1994)

	road traffic system	...	human car driver
functional purpose	safe, efficient (time and energy) transport of people and goods		achieve personal and social goals
values and priority measures	• number of crashes / injuries / fatalities • traffic flow • compliance		• travel time minimization • risk minimization • no rule violations
generalised functions	• mobility • traffic management • regulate behavior		• navigation • maneuvering • operational control
physical functionality	• space and means for locomotion • alert, cue, direct behavior • separate traffic		• perception • cognition • motor functions
physical objects	• static (roads, signs, markings) • dynamic (people, vehicles) • laws, rules, regulations		• body with eyes, hands, feet

cf. Salmon et al. (2007, 2019)

Task Model Validation – A Template



Predictive Validity for an Abstraction Hierarchy

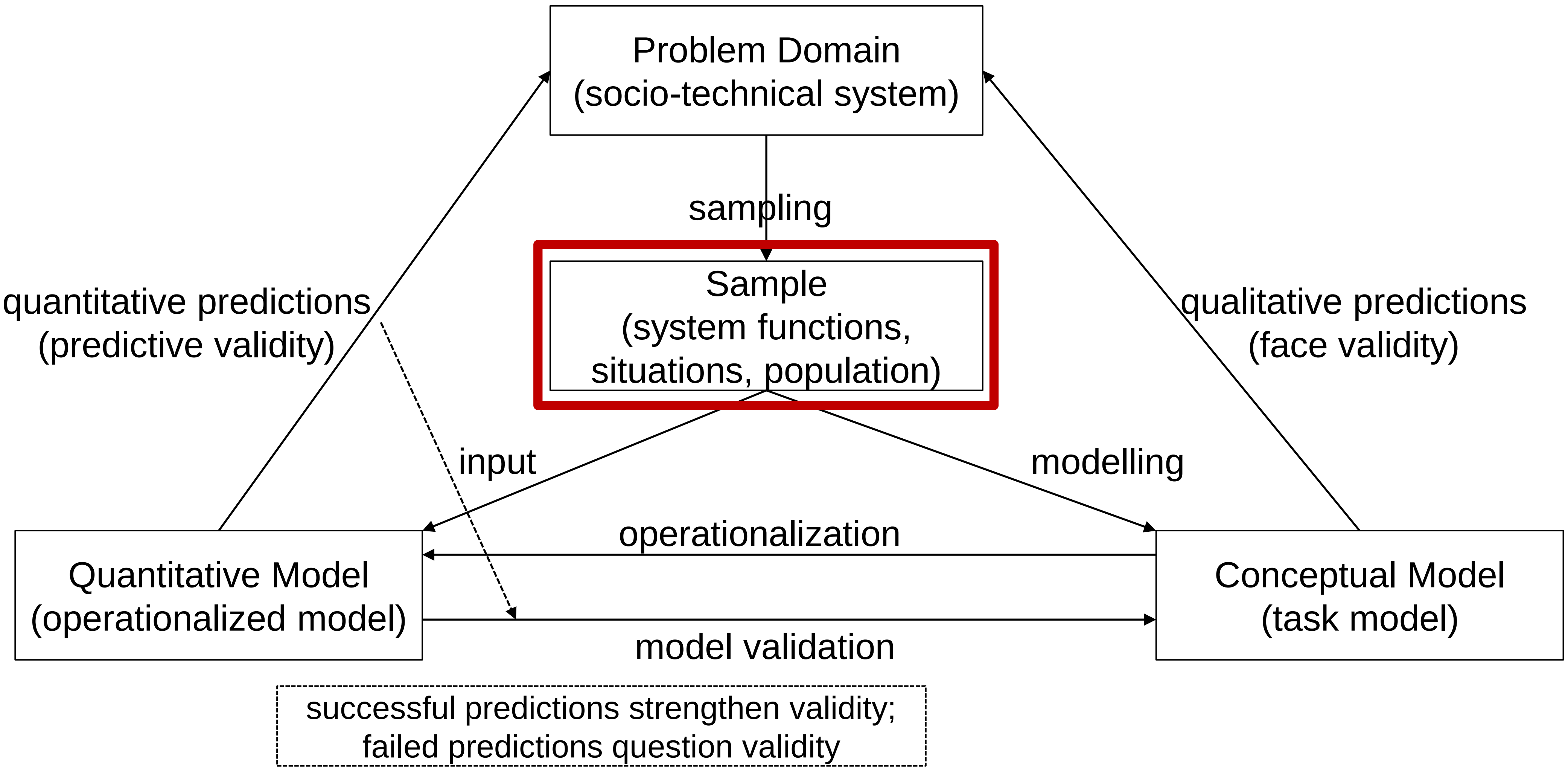
Idea behind predictive validation

1. humans are integral system elements, must implement assumed functionality
2. actions reflect domain boundaries, especially values and priority measures
3. investigate relevant domain variables–TASC
   1. Task: abstraction hierarchy defines task related boundaries
   2. Actions: inputs to the car–closely coupled with cognition
   3. Situation: dynamic position on road, relation with other traffic participants
   4. Cognition: perception, cognition, motor

Quantitative predictions based on priority measures–examples

- risk minimization: avoid small *time-to-collisions* (TTC) to car in front in own lane
  → min(TTC = relative distance / relative speed) > 3.5 sec (e.g. Minderhoud & Bovy, 2001)
- risk minimization: avoid prolonged periods of small *time headways* (relative distance / ego speed; < 2 sec)
- minimize travel time: achieve desired speed whenever possible
- no rule violations: overtake vehicles driving slower than desired speed
- no rule violations: use indicator when changing lanes
- ...

Task Model Validation – A Template



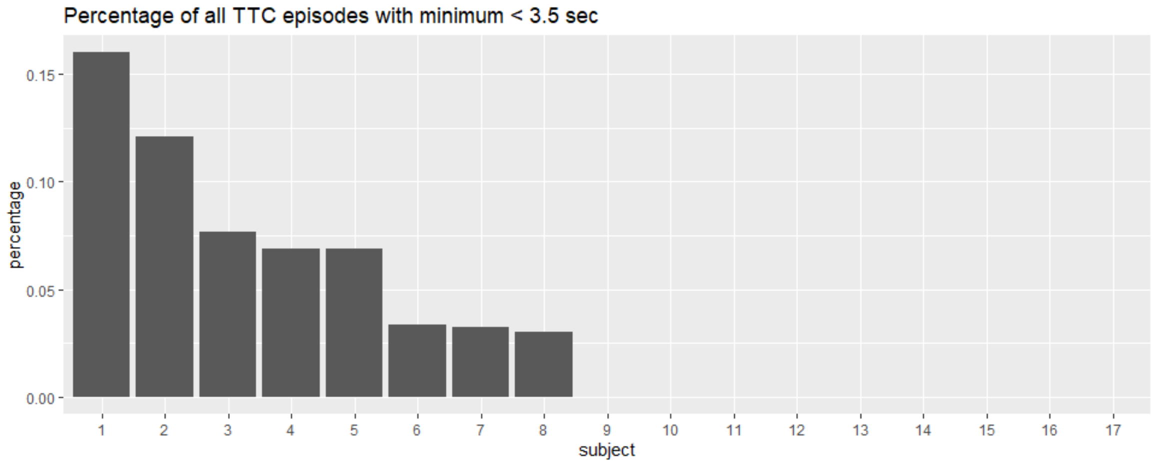
Simulator Experiment – Methods

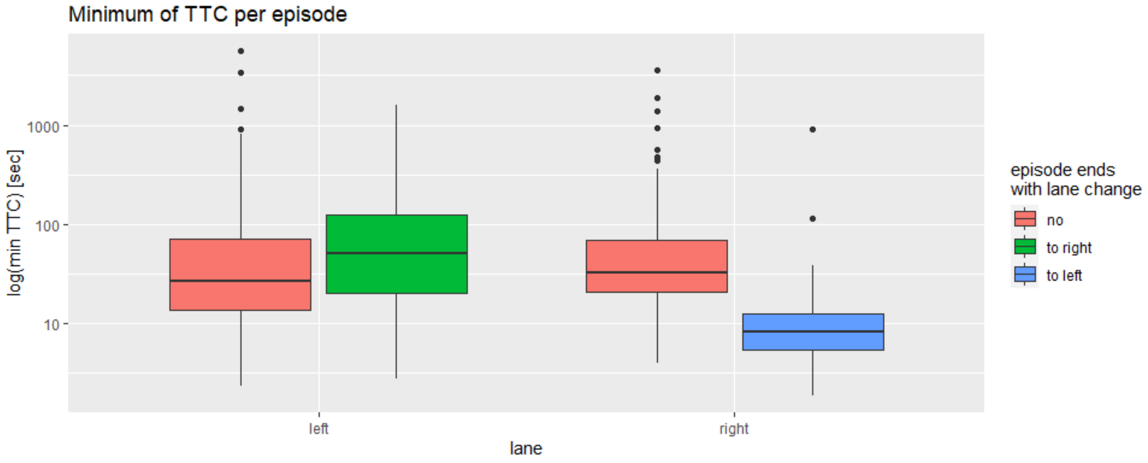
- 360° fixed base simulator with passenger car mockup
- 17 subjects drove on a two-lane motorway with medium-dense traffic (ca. 120 km/h on right lane)
- instructions
  - keep speed between 120 km/h and 150 km/h (common speeds on German motorway)
  - comply with standard traffic rules
  - otherwise drive as you wish
- simulator data, inputs into ego vehicle & gaze behavior recorded

simulator

scenario

Simulator Experiment – Findings for Situation and „$TTC_{min} < TTC_{critical}$"





- TTC episode = period of ego vehicle approaching lead vehicle
- 96 % of all episodes were not critical
- 8 of 17 subjects had at least one such episode
- worst offender: 16 % of that subject's episodes were critical

- low TTC-episodes are part of overtaking maneuvers (right to left)

lane at time of minimum TTC	ends with lane change	mean TTC (s)	SD TTC (s)
right	to left	18.0	82.5
right	no	124.3	386.0
left	to right	169.1	324.6
left	no	130.6	476.7

Discussion

Not all useful models are validated, but (almost) all validated models are useful.

- validated models enable better communication, increase trust and ease-of-use

Validation framework

- application of predictive validity possible whenever claims about empirical world are made
- usefulness: investigate variables relevant for domain (for dynamic situations TASC)

Application example

- results from simulator experiment increased trust in value „risk minimization“ but also pointed towards context dependency of metric „TTC“

Thank you for your attention!

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