Reaction time methods

Prof. Torsten Schubert

Behavioral data as a methodological basis in cognitive neuroscience

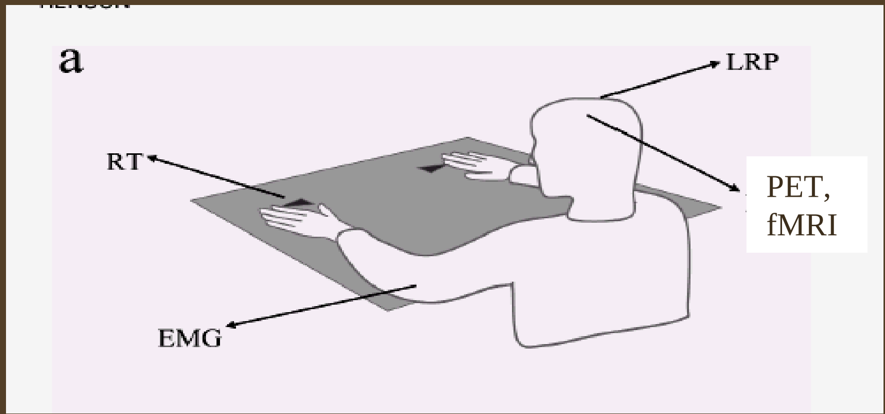
- Plan:
- 1. Introduction
- 2. Mental chronometry
  - Basic questions
  - Subtraction method
  - AFM
  - Contemporary alternative models
- 3. Mental chronometry in complex situations

1. Introduction

Behavioral data (RTs, error data):

- Not the only one measure when investigating/analysing mental events

- „one" indicator for mental events (among others)



Data and methods

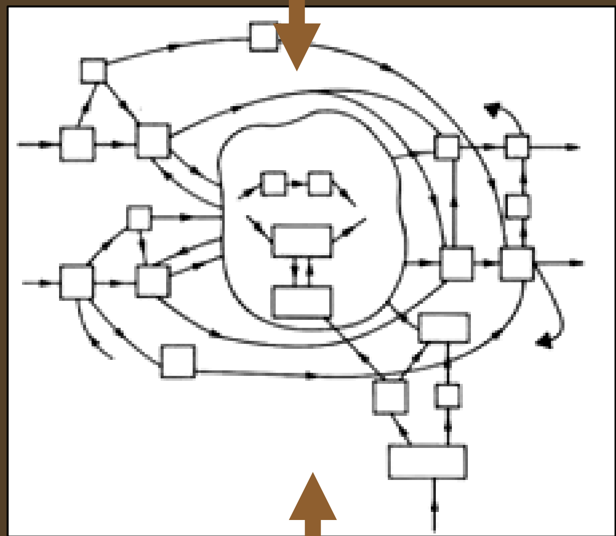
Level of analysis

Introspection

Subjektive experience

Experience,events, attitudes

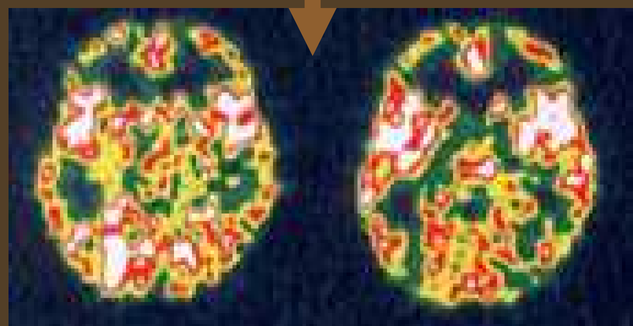
Objektive measurement and manipulation of behavior (RT, errors, threshold measures, etc.)



COMPUTATIONAL or functional

(Representations, processes, modules, architecture)

Objektive measurement of neural activity



NEURONAL

(How realize neurons the computations? What is the localisation & networks)

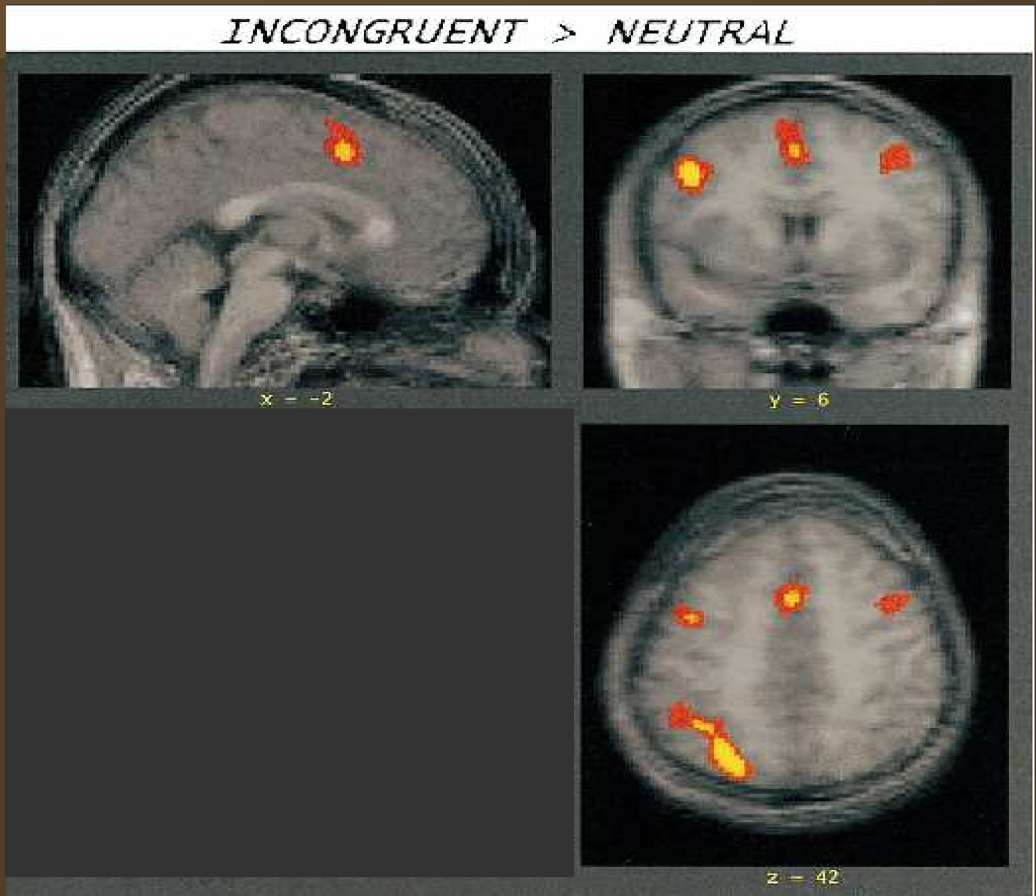
Example: Stroop

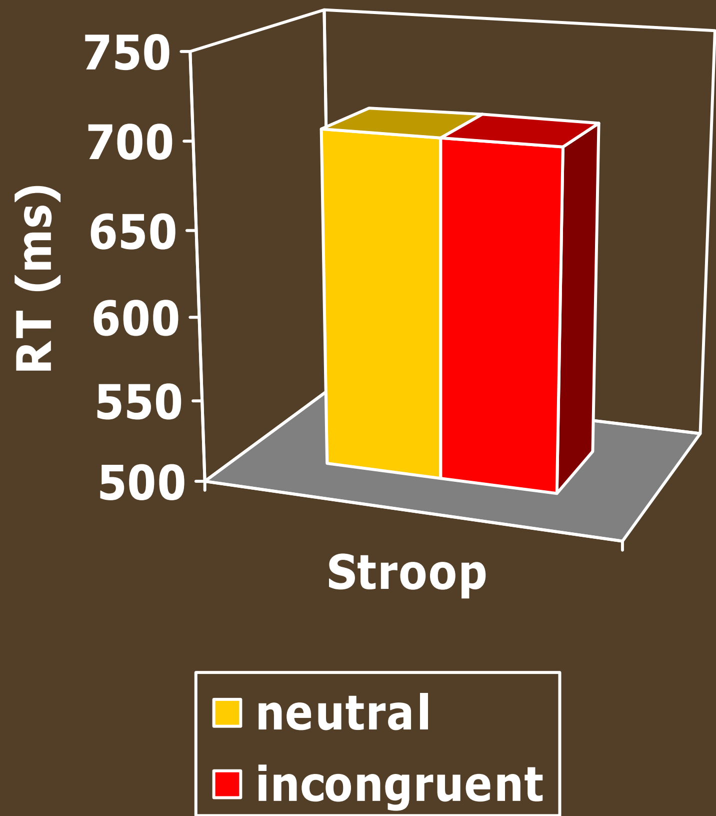
Book → „Red“ — Condition 1: neutral

GREEN → „Red“ — Condition 2: incongruent

Milham (2001)

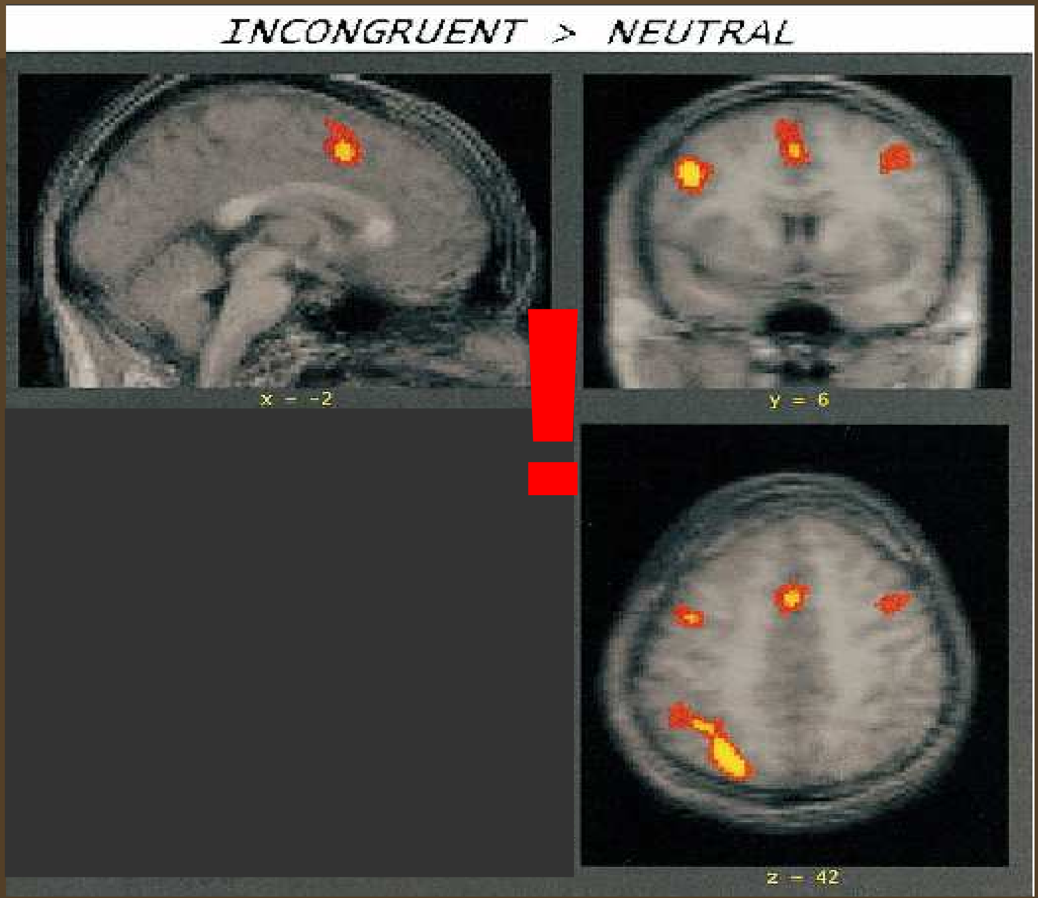
Mental events ⇔ measurable events in the brain

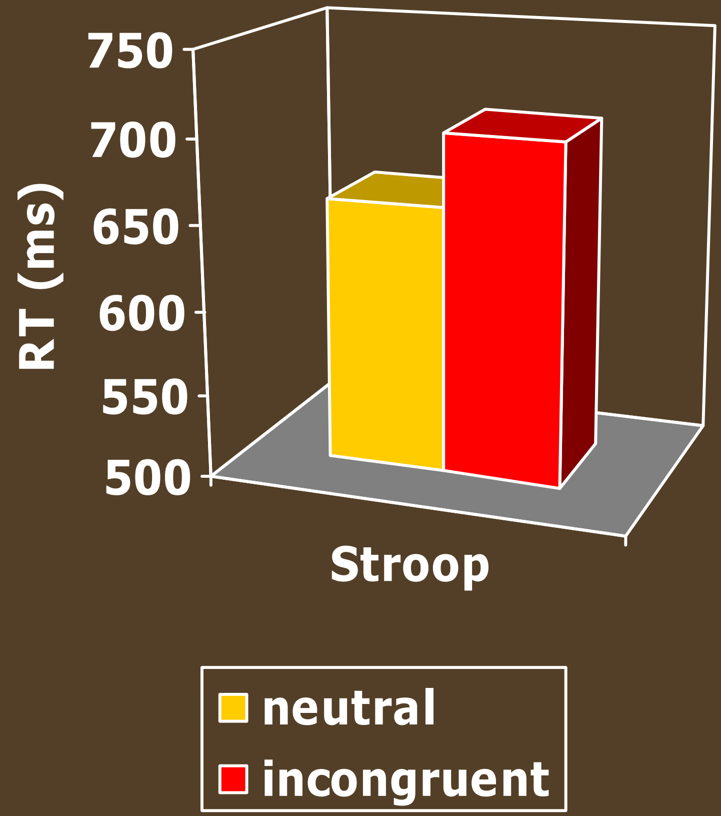




Milham (2001)

Mental events ⇔ measurable events in the brain





Milham (2001)

2. Mental Chronometry

For the interpretation of data we need a theory – about what indicate reaction times and error data:

MENTAL CHRONOMETRY

Goal of mental chronometry is to identify and to uncover mental processes, which can not be overtly observed. The way for this is the manipulation of the tasks and/or of variables determining the behavior of participants in the tasks.

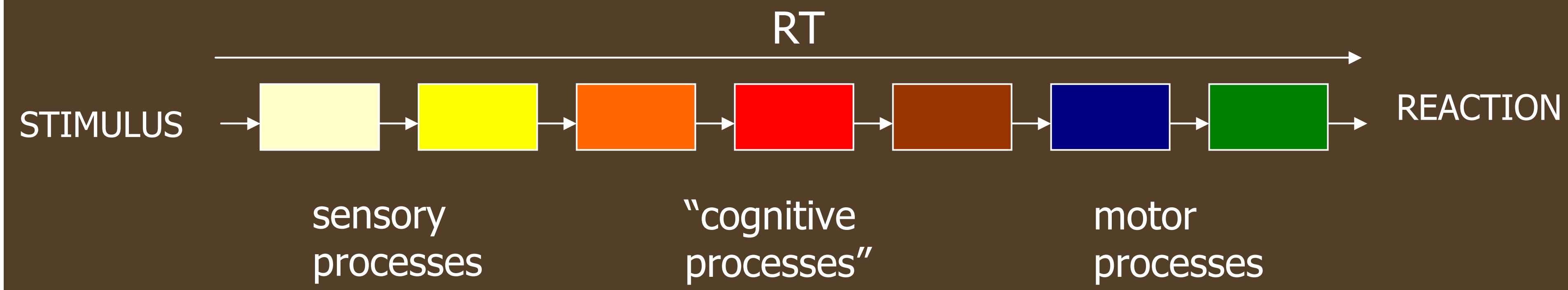
P	RS	MR

Measurement of (manual, verbal, eye movement)

- ➢ reaction times
- ➢Error rates
- ➢ speed-accuracy trade-offs

Questions of mental chronometry

- Which components of mental processes are located between stimulus and reaction and can be distinguished on the basis of separable processing times?

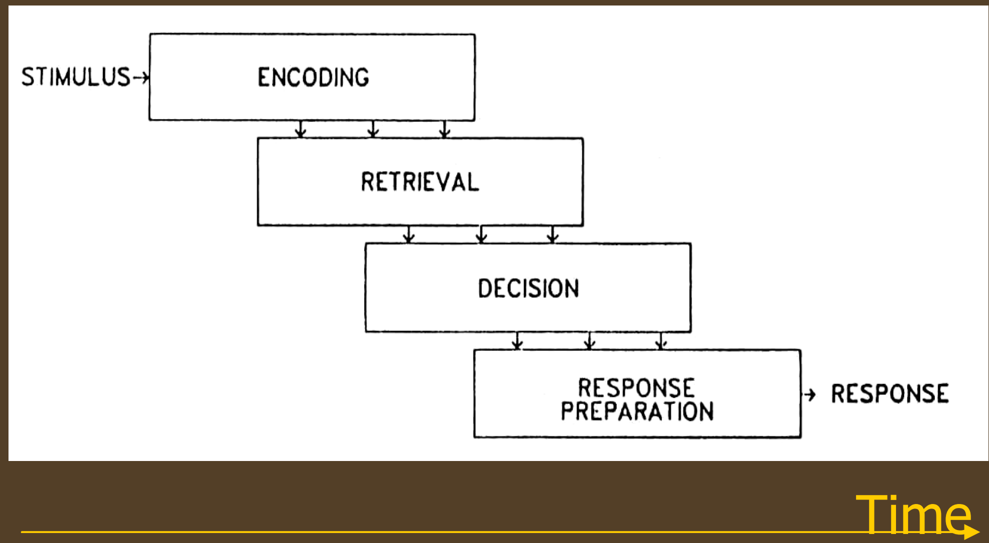


- How many subcomponents?

- How long is their duration?

- How do the processing components interact with each other?
- How is the information transmission between and within the processing components?

P	RS	MR

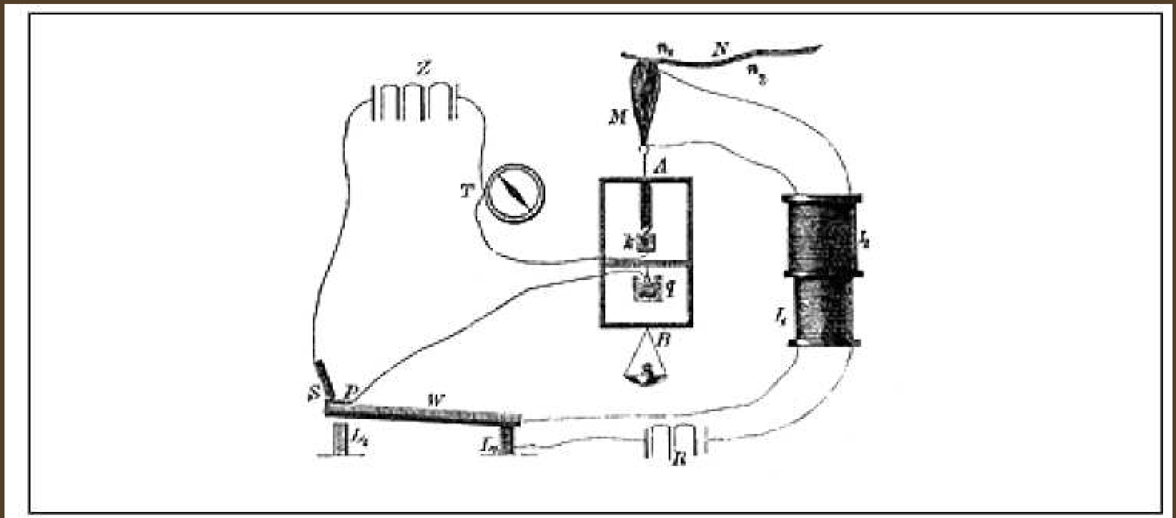


- Continuous versus discrete?
- Are processing components organized in serial or parall or partially parallel (cascade) form?

History

- before 1850 – philosophical discussion about cognition and action; measurement of mental processes appeared not possible
- 1850 Helmholtz: Introduction of the „Simple Reaction Time Procedure"- neural transmission time ~ 30m/s

  = basis of mental chronometry



History

- before 1850 – philosophical discussion about cognition and action; measurement of mental processes appeared not possible

- 1850 Helmholtz: Introduction of the „Simple Reaction Time Procedure"- neural transmission time ~ 30m/s frog) → 60 ms human

  = basis of mental chronometry
- 1850-1900 „Golden Age", 2 main issues
- reaction times (Donders, Wundt)
- error rates, Speed-Accuracy Tradeoffs (Woodworth, Hick)

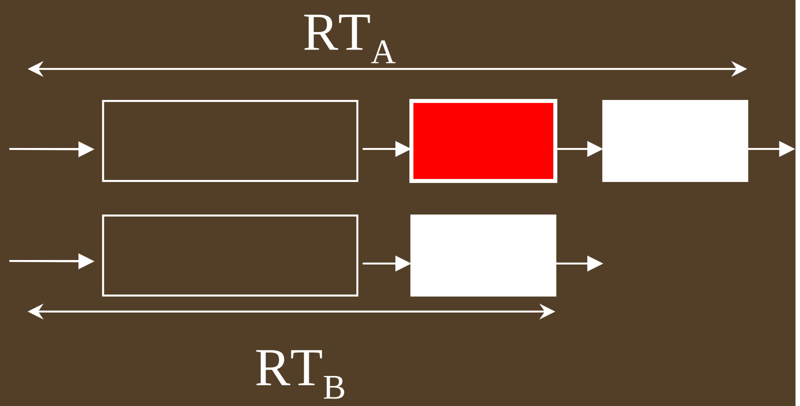
Donders' subtraction idea

- Donders (1868)

The idea occurred to me to interpose into the process of the physiological time some new components of mental action. If I investigated how much this would lengthen the physiologica time, this would, I judged, reveal the time required for the interposed term.
(Donders, 1969, p418)

– Assumption of 'pure insertion':
  - Task **A** has all the stages of Task B lacks an extra process, then
  - Extra process can be measured by:

RT_A-RT_B



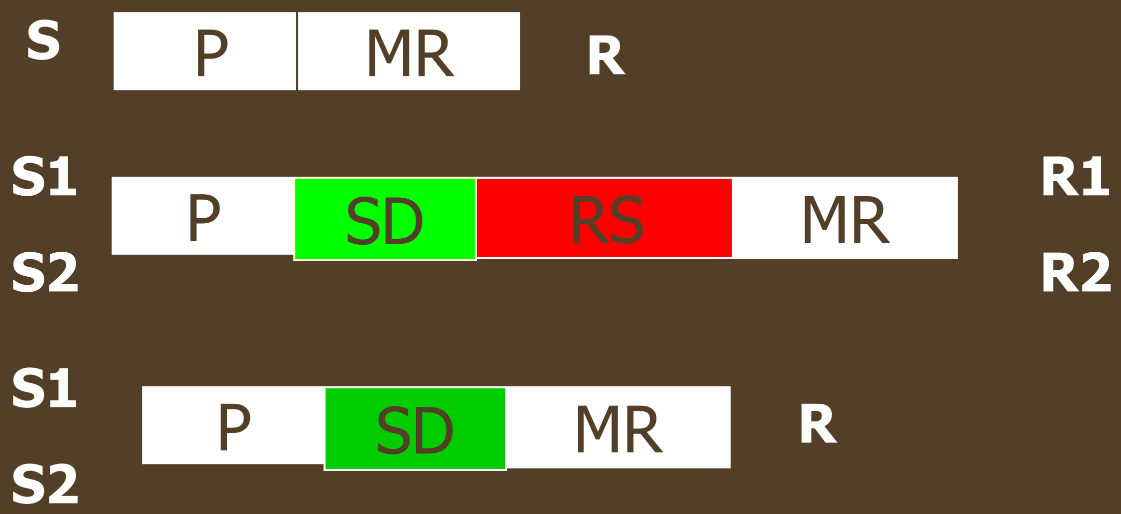
Donders (1868) method of subtraction

Comparison of different tasks

A: simple detection

B: choice reaction

C: Go/ No-GO



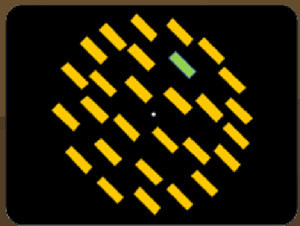
stimulus discrimination & response selection = RT(B) –RT(A)

response selection = RT (B) – RT (C)

stimulus discrimination = RT(C) – RT(A)

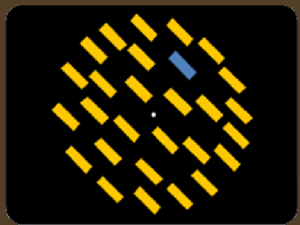
Rangelov Dragan (2010) visual search task

Search detection



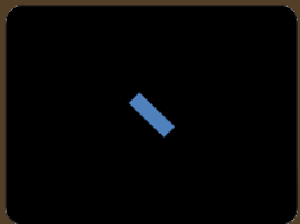
Present/absent

Search discrimination



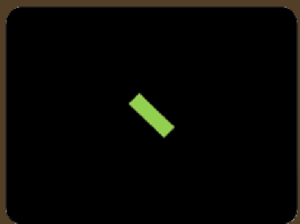
Right/left

Non-search detection



Present/absent

Non-search discrimination



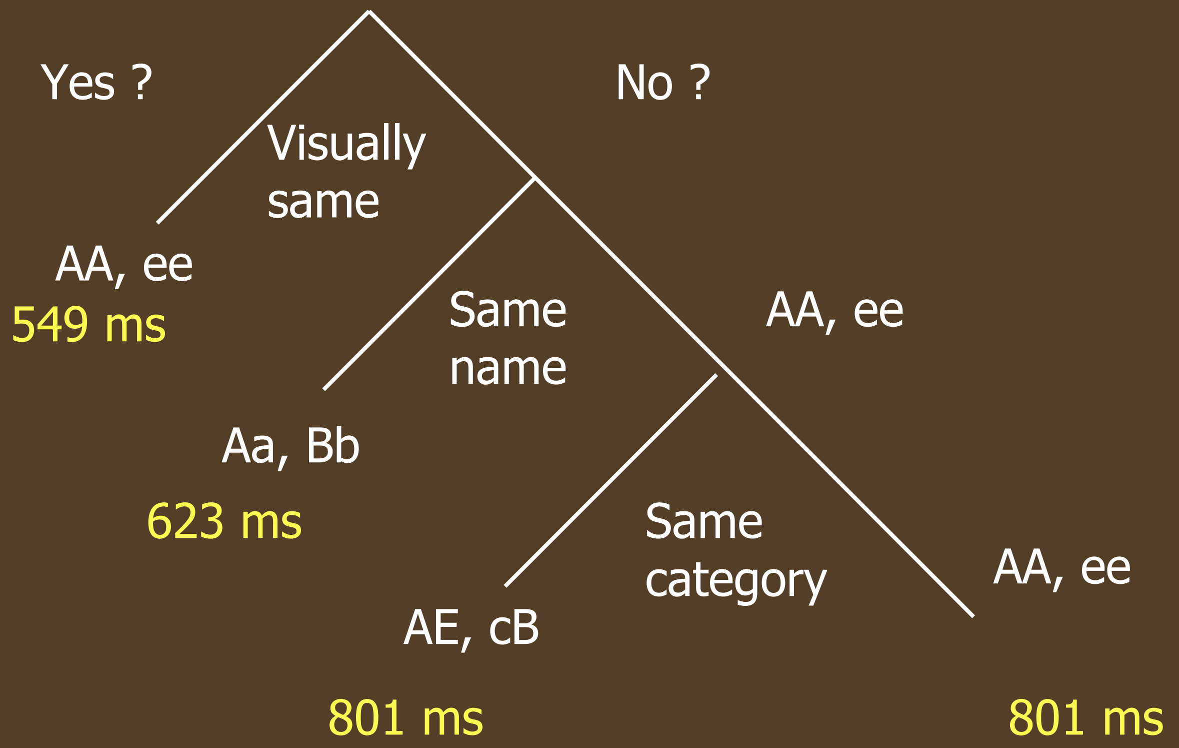
Blue/green

Same – different task Posner & Mitchell (1967)

- Task: Are two visually presented letters members of the same category (vowel/consonant) or not?
  - AA same - AK different
  - Aa same - Ak different
  - AE same - AB different

Assumption: First testing of visual identity → testing of name identity → testing of categorical identity

Same – different task Posner & Mitchell (1967)



Name comparison: 74 ms (623 – 549 ms)

Category comparison: 178 ms (801 – 623 ms)

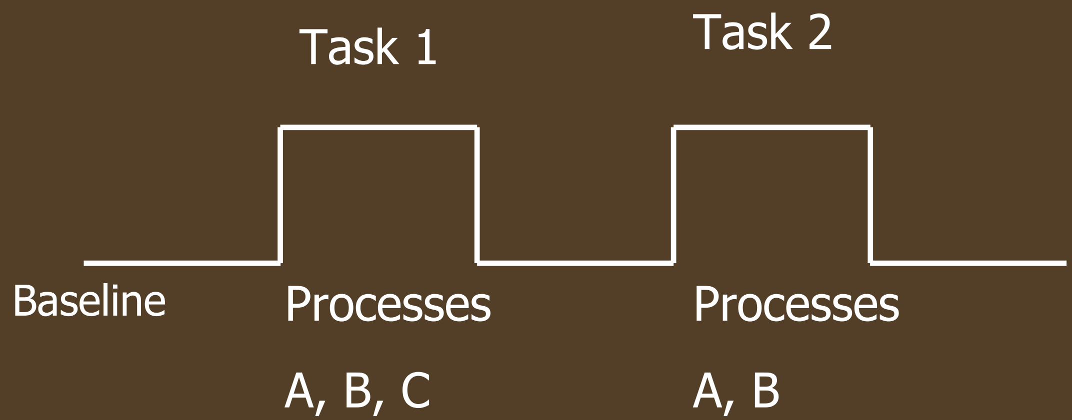
Problems with the method of subtraction

- PURE INSERTION:
- insertion/removal of processing stages does not influence other processing stages (i.e. their duration or their dynamics)
- Külpe (1893) – criticism; insertion of a new process → changes of the whole task (later "Gestalt")
- Subcomponents are successive processing stages:
  - Subcomponents do not overlap and add independently to the overal RT
- Does C task (no-go) really not involve a response selection stage (deciding whether to respond or not)? → Wundt D - reaction; simple reaction but wait for complete SD

- nevertheless excessive application; e.g. Wundt and today

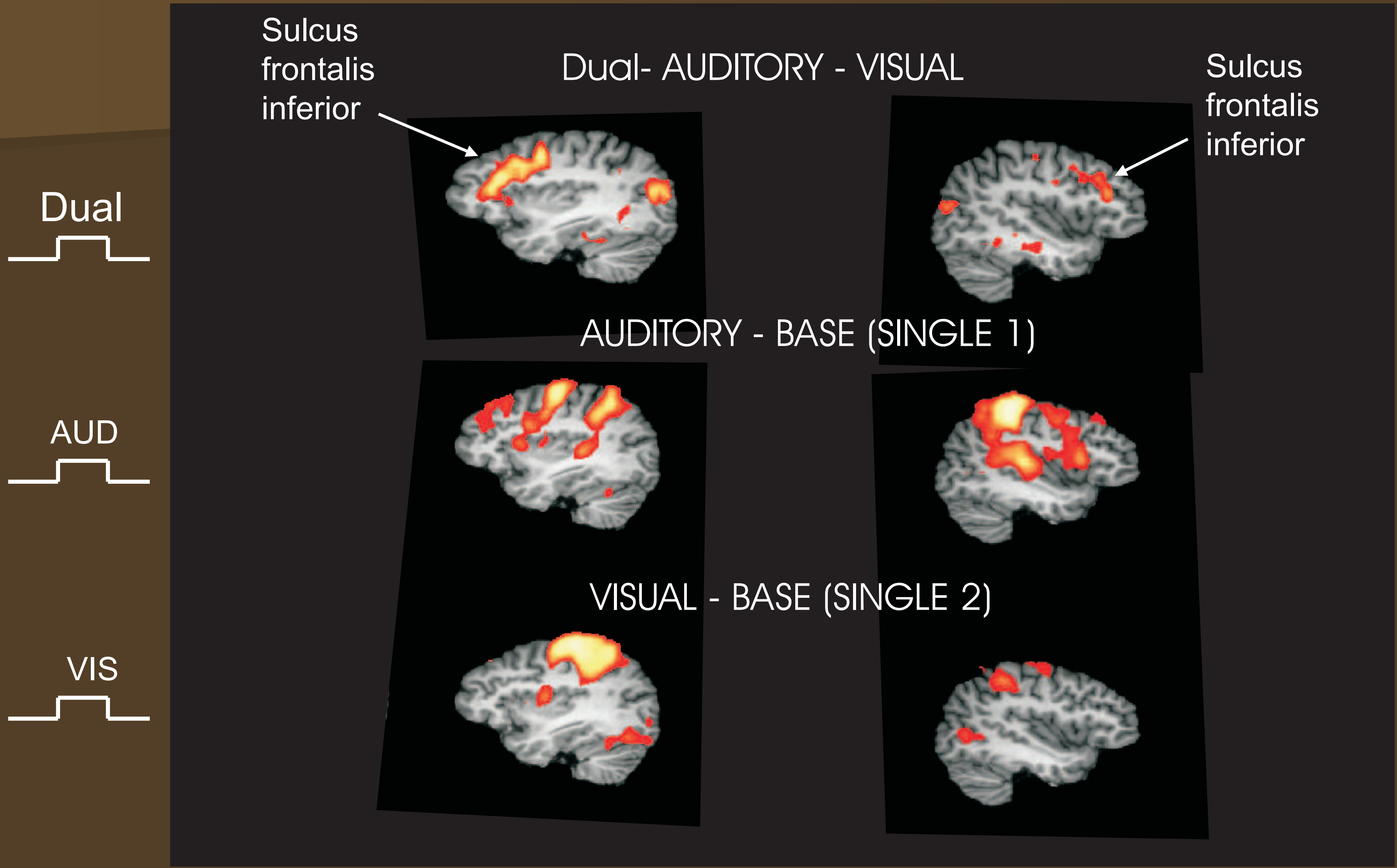
Use of subtraction method in functional imaging:

Prevailing method in fMRI (PET): cognitive subtraction to find regions associated with certain cognitive functions



fMRI activation (Task 1) – fMRI activation (Task 2) → brain area(s) related to C

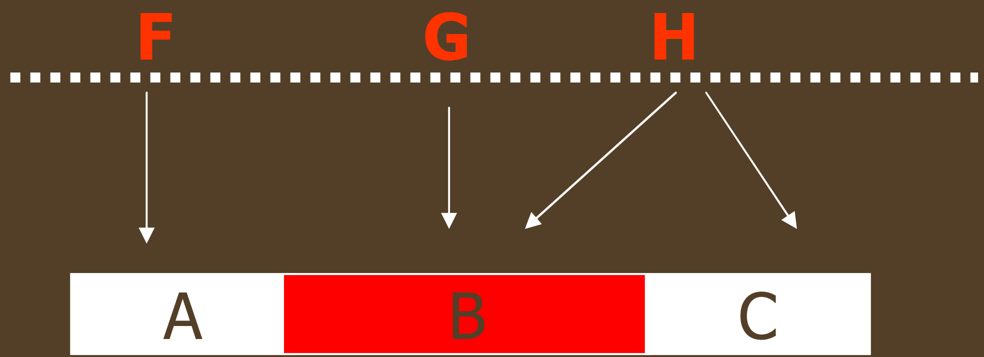
Subtraction method in Cognitive Neuroscience



Schubert & Szameitat, 2003, Cogn. Brain Res.; D‘Esposito et al., 1995; Nature

Sternberg's Additive Factor Method (1969) AFM

Which processing stages exist as independent processing stages?



Main idea:

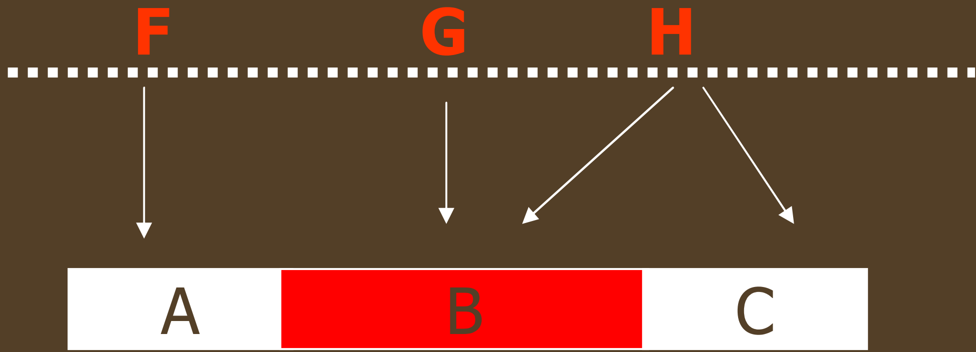
- conduct experiments

- apply several experimental manipulations, which change the duration of presumed processing stages

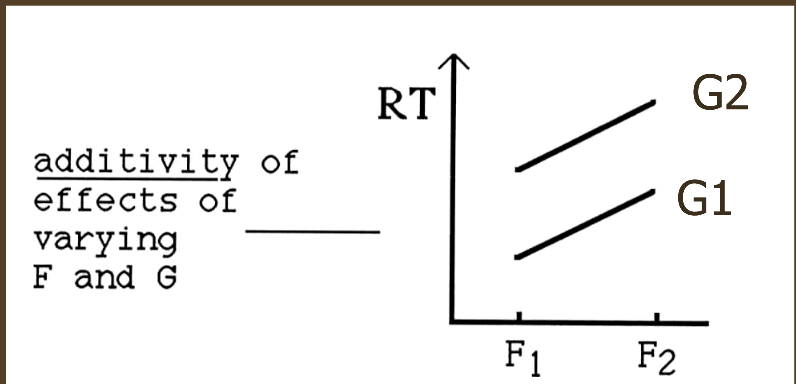
- analyse the effects of these manipulations on the overall reaction time

Sternberg's Additive Factor Method (1969) AFM

Which processing stages exist as independent processing stages?



Main idea: If two factors affect two independent stages, then their effects on the overall RTs should be additive ones.

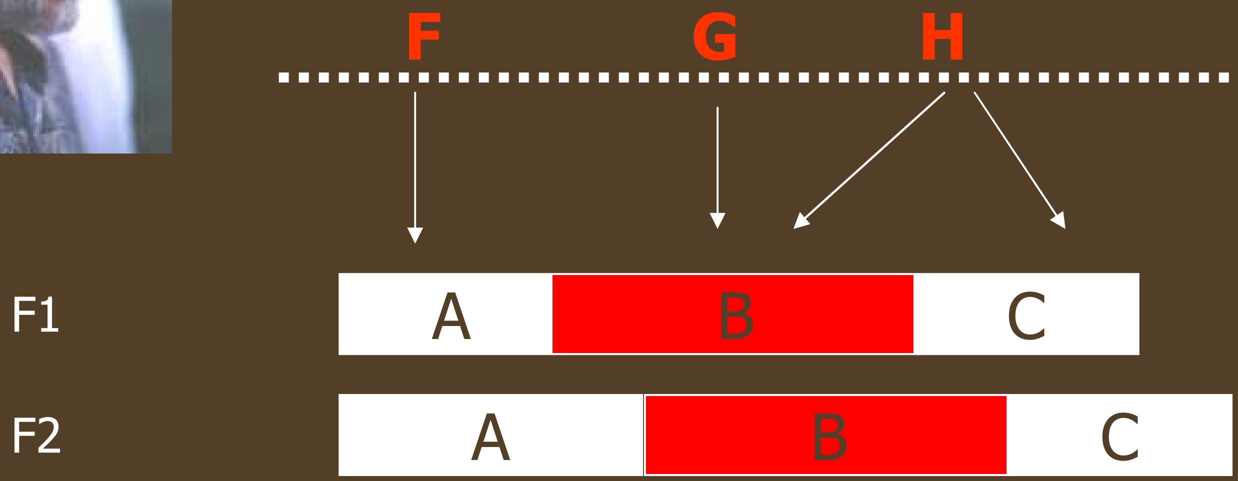


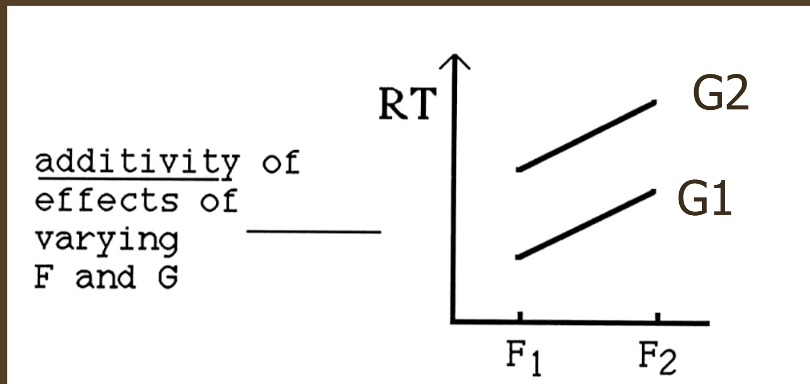
RT(F2/G2) – RT(F1/G2) =

RT(F2/G1) – RT(F1(G1)

Sternberg's Additive Factor Method (1969) AFM

Which processing stages exist? Which factors affect which stages?





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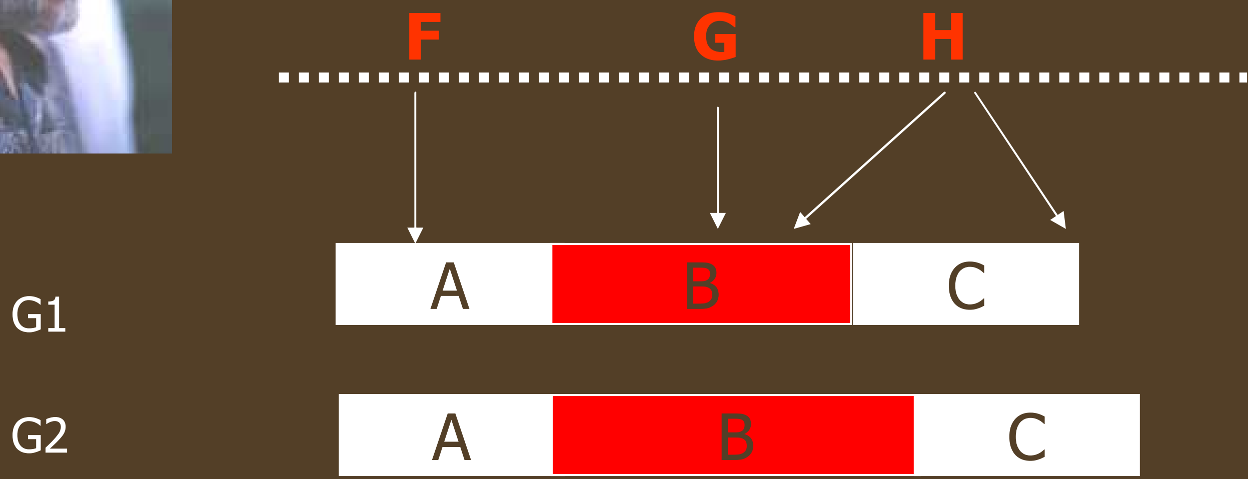
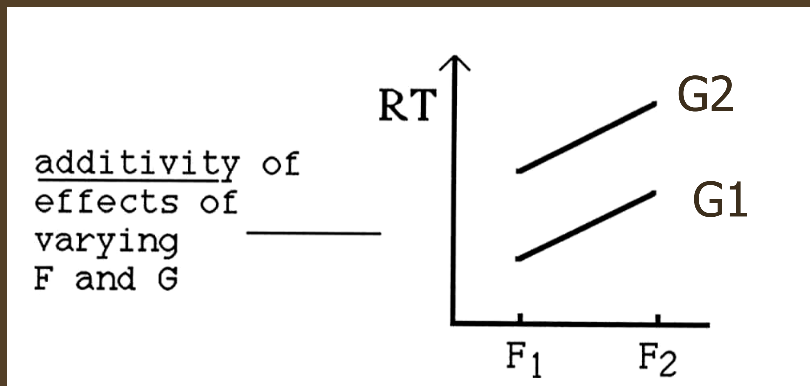
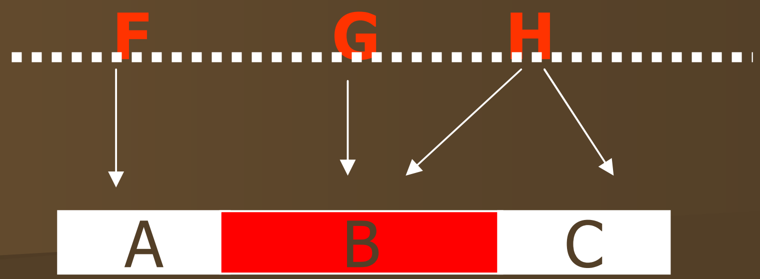
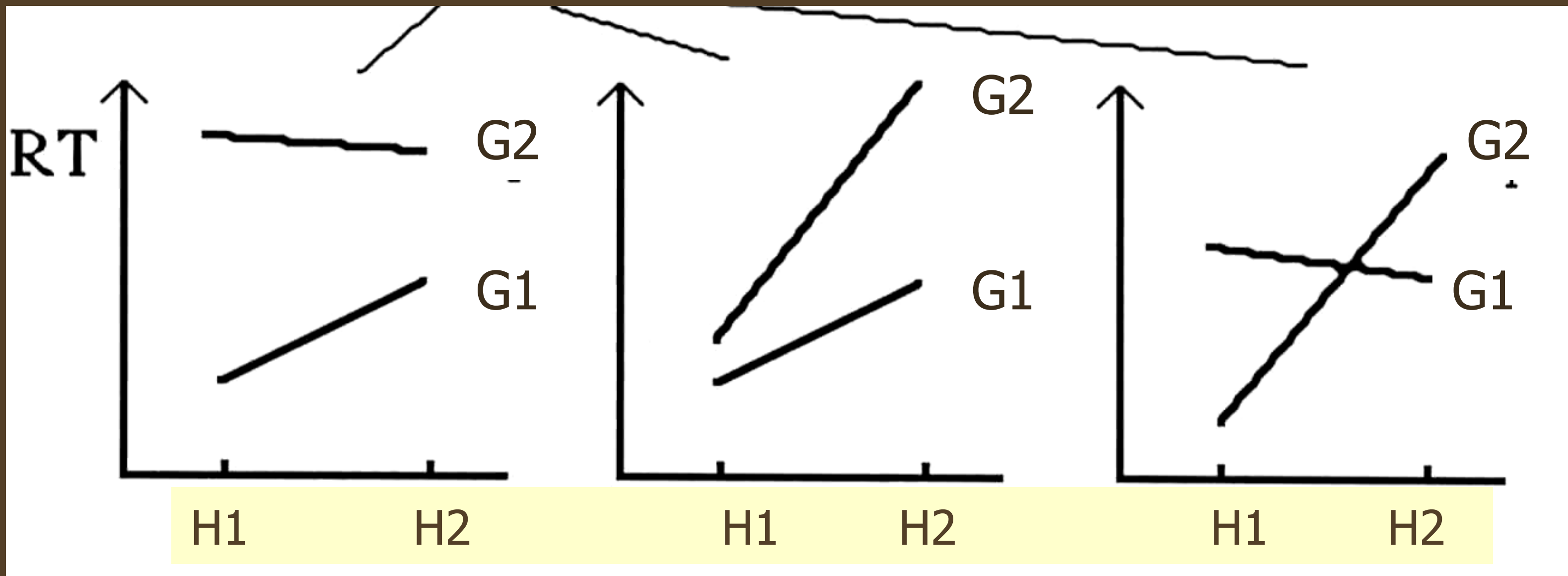
Which processing stages exist? Which factors affect which stages?







If two factors show an interaction effect on the RT, then they affect at least one common processing stage.



Results of many studies that used AFM logics (from: Sanders, 1980, A stage analysis of Reaction Processes. Acta Psychologica)

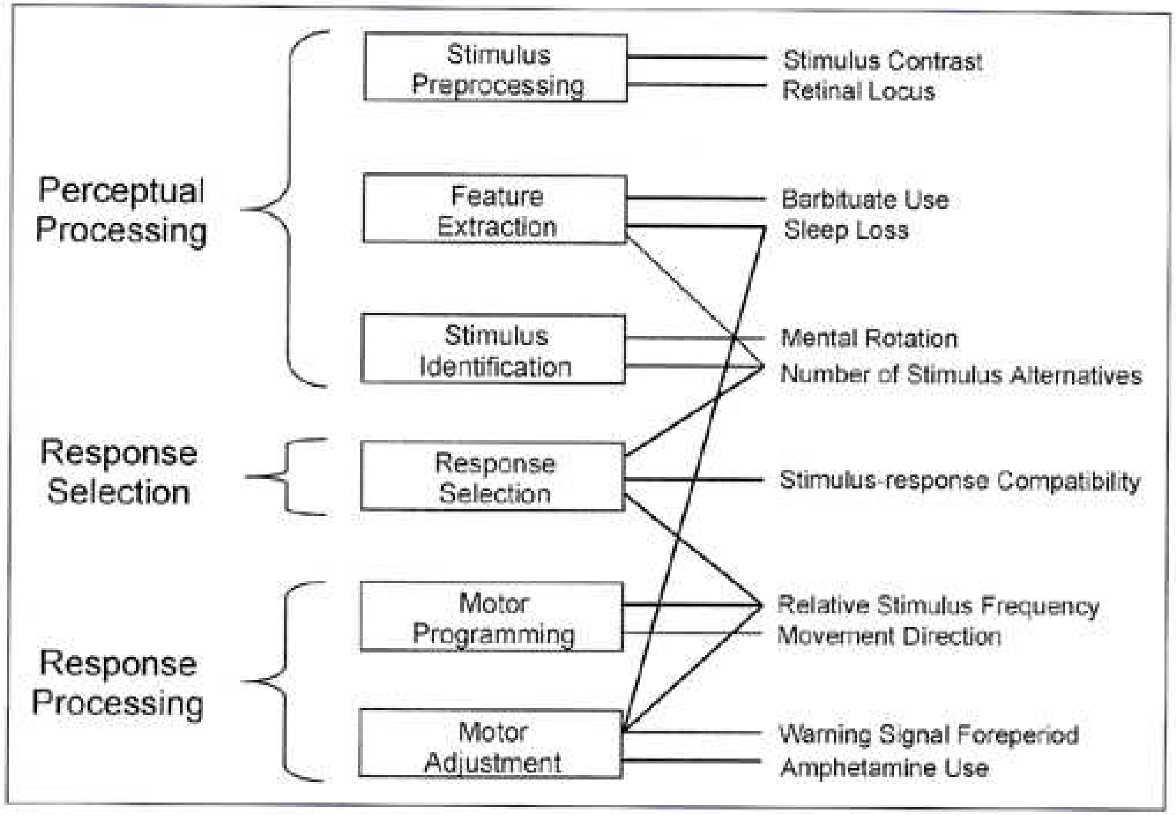


Figure 2.4 Summary of conclusions drawn from additive factors studies of human information processing.

Example:
„Sternberg"- task
– decision whether a probe item is member of a memory list or not

L R B F → F ?

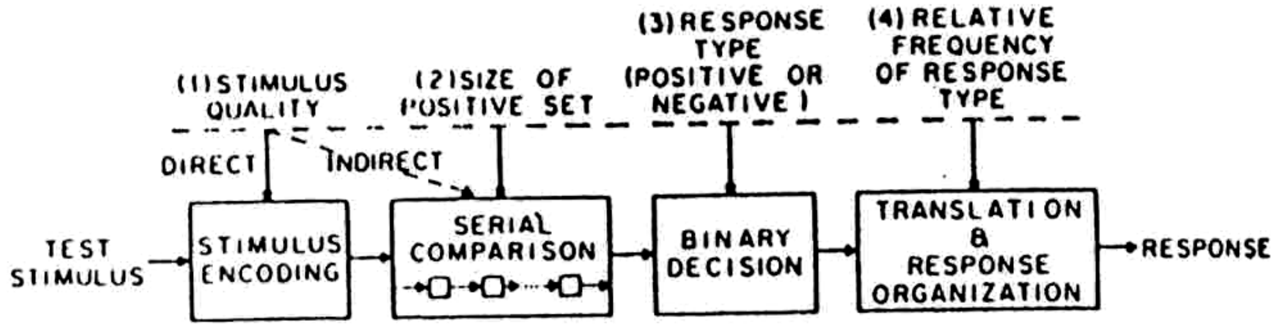


FIG. 13. Four processing stages in item-recognition. Above the broken line are shown the four factors examined. Below the line is shown the decomposition of RT inferred from additive relations between factor pairs 1&2, 1&3, 2&3, 2&4, and 3&4, the linear effect of factor 2, and other considerations. (The indirect effect of factor 1 on the comparison stage, and the resulting interaction of factors 1&2, is seen in unpracticed subjects only.)

An example of AFM in cognitive neurosciene

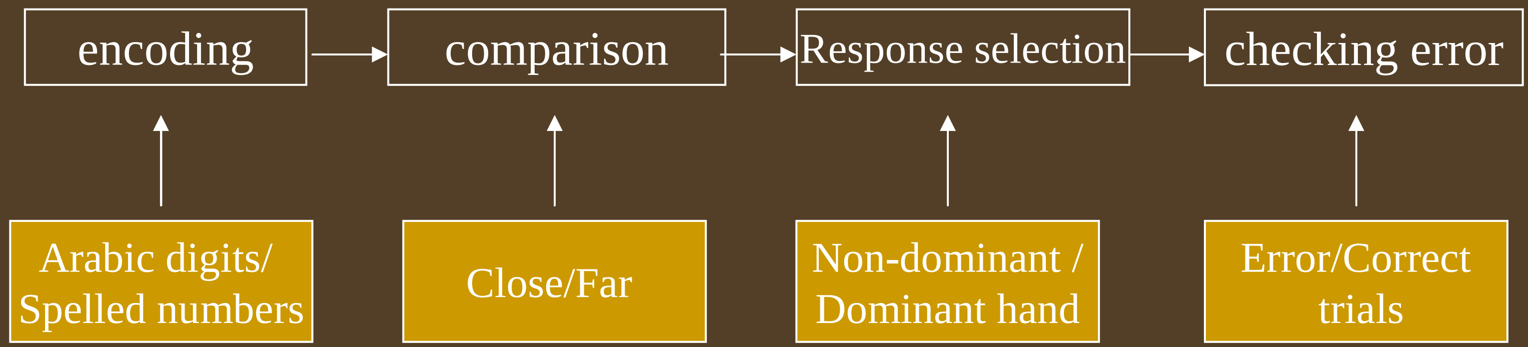
- Dehaene S (1996) The organization of brain activations in number comparison: Event-related potentials and the additive-factors method. J Cogn Neurocsci 1: 47–68.

  – investigated cognitive and neural mechanisms of number comparison: a number is presented on the display and subjects have decide number </> five.

  – Manipulations:
    - Input: Arabic digits / spelled numbers (4 / four)
    - Comparison: Near 5/ far from 5
    - Response: dominant / non-dominant hand

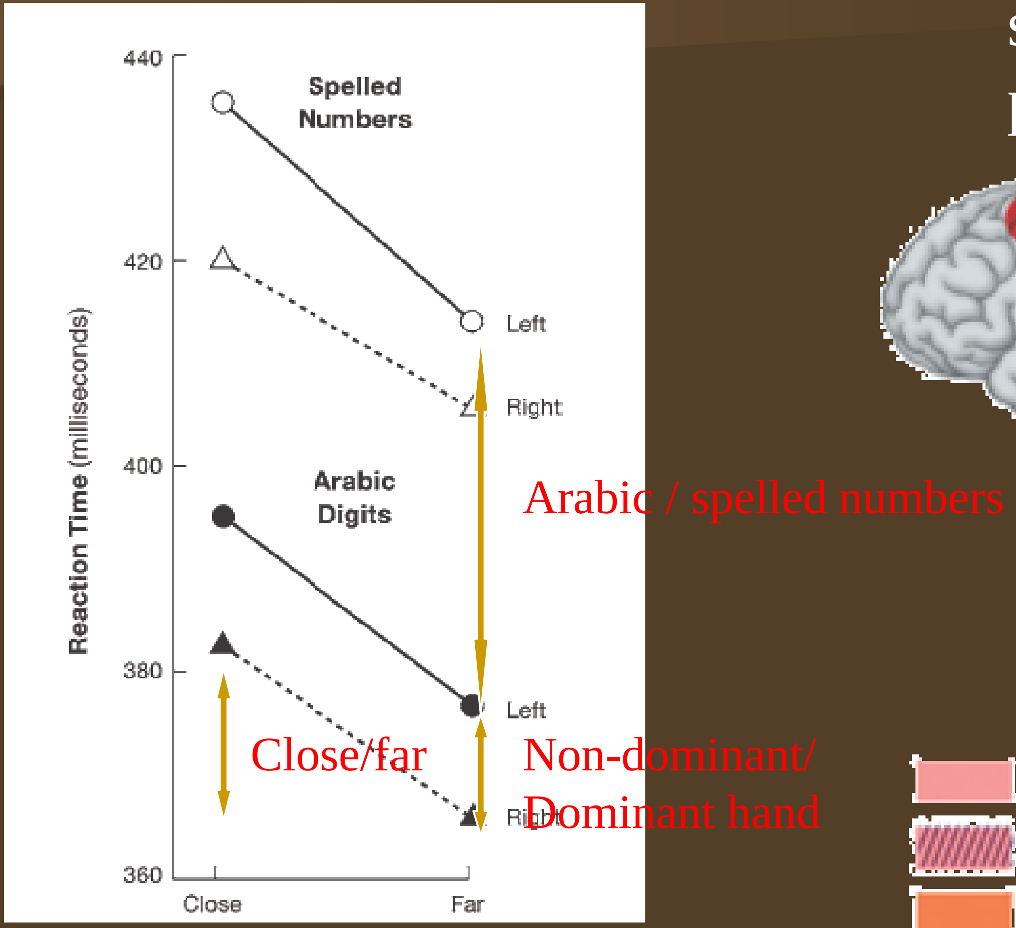
An example of AFM

– **The authors proposed four different stages**

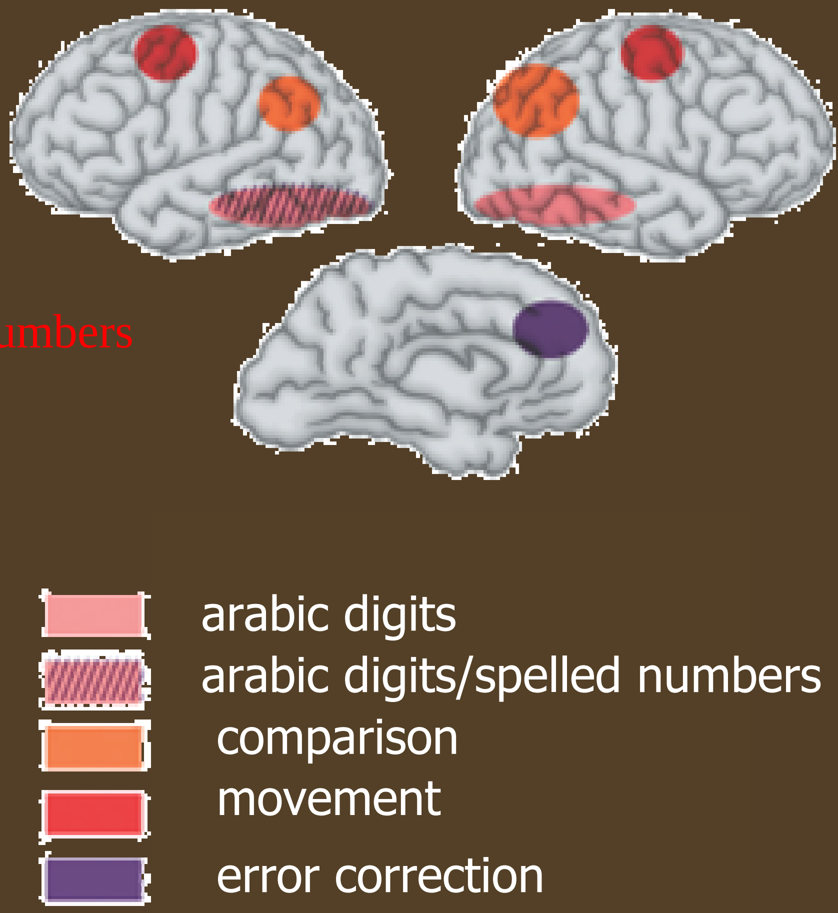


– According to additive factors theory, a variable that affects overall reaction time by varying the time to complete one stage will be additive with the effects of factors that affect other stages.

An example of AFM



EEG and fMRI studies showed these four factors processed in different regions



Advantages:

- No problem with „pure insertion" – manipulation of the duration of a processing stages

- comparison between one and the same type of tasks → criticism of Külpe does not hold

- Problems:

- Basic assumption: factors can affect certain processing stages (while leave other stages unaffected)

- stages should not temporally overlap („seriality" assumption)

- output of a stage is a discrete information „quantum", all-or-non-principle

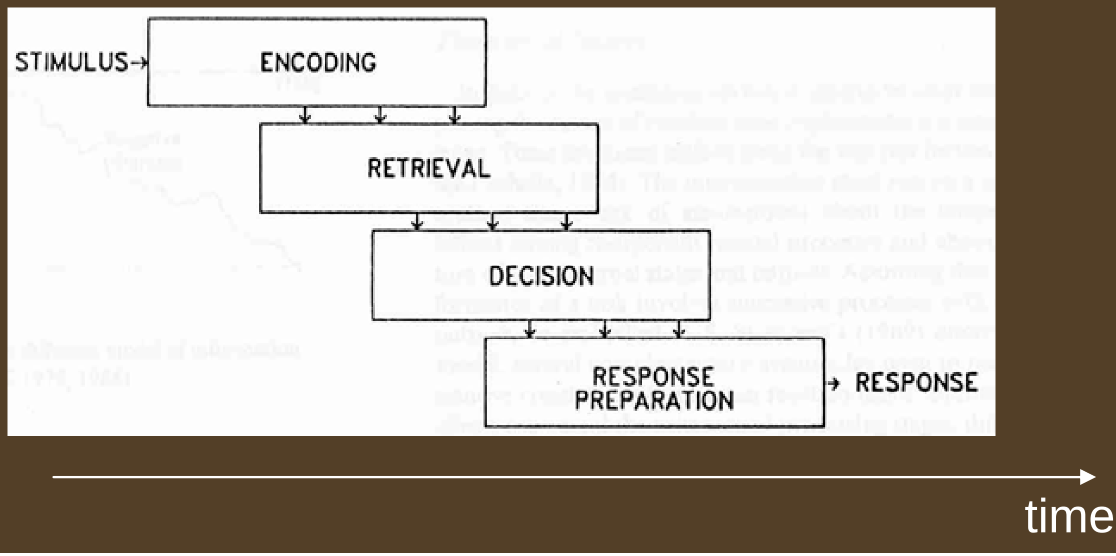
- interpretation of non-additive (interaction) effects?

- problems with the reversed inference:
  - additive effects of two factors does not necessarily mean that two separate stages
    - If p then q; If q then p?

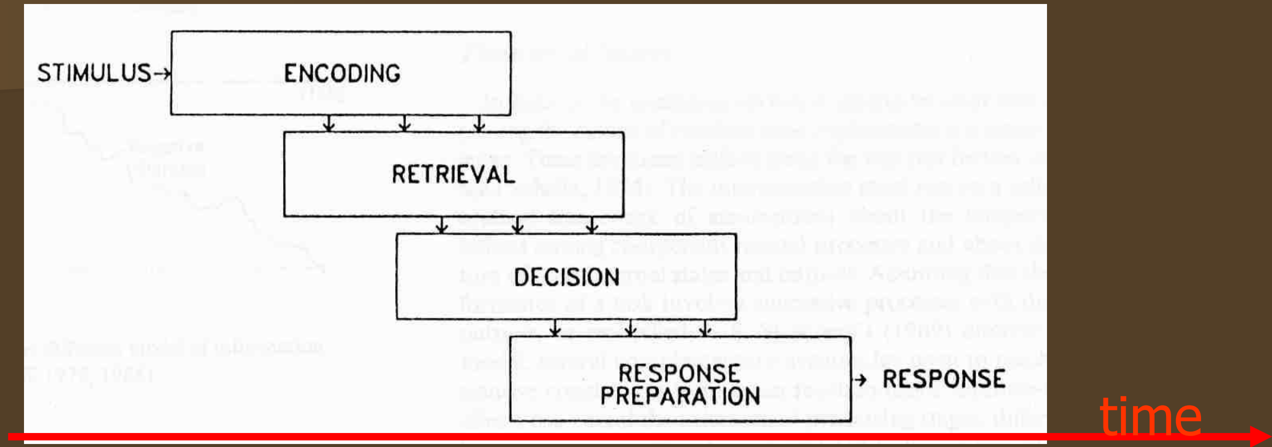
Nevertheless: AFM is one of the most succesfull analytical tools in modern reaction time psychology.

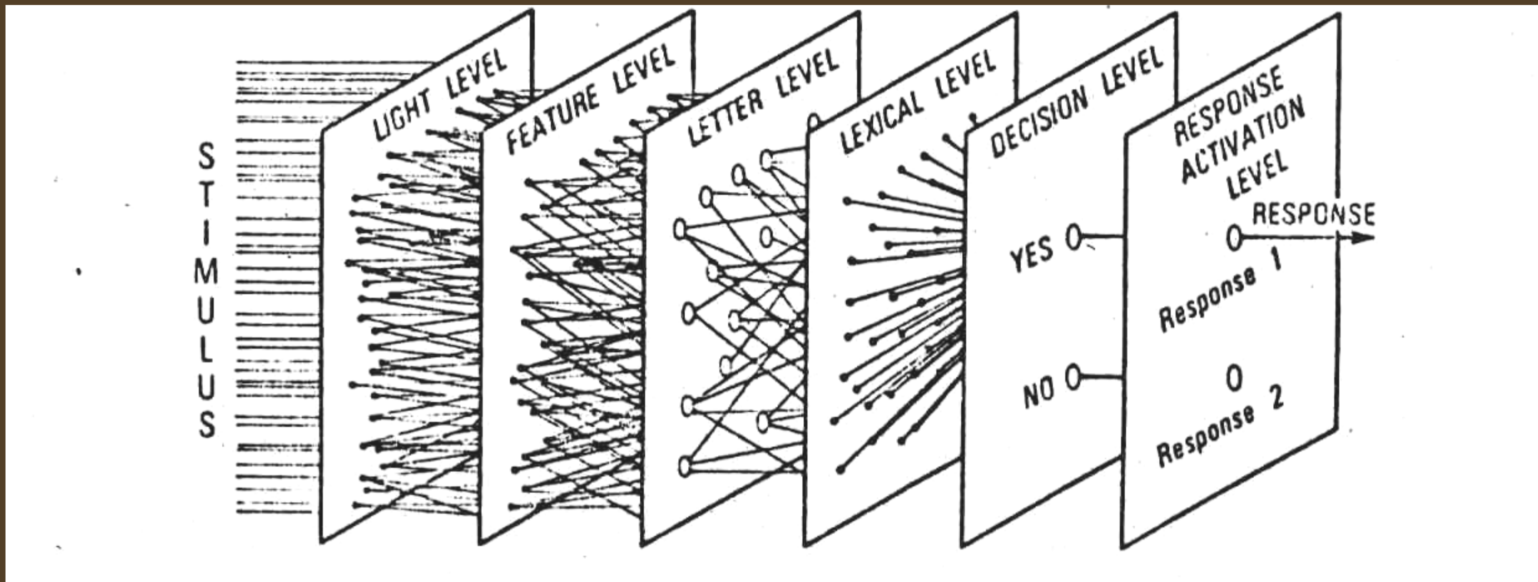
Alternative theoretical models: Cascaded processes model

- McClelland (1979)
  - –A series of processes cascading activation from an input level to an output level. Allows a given processing level to start with information transmission to the next stage before it has finished processing.



McClelland's (1979) simulation of cascaded processes in a connectionistic model of a lexical decision task

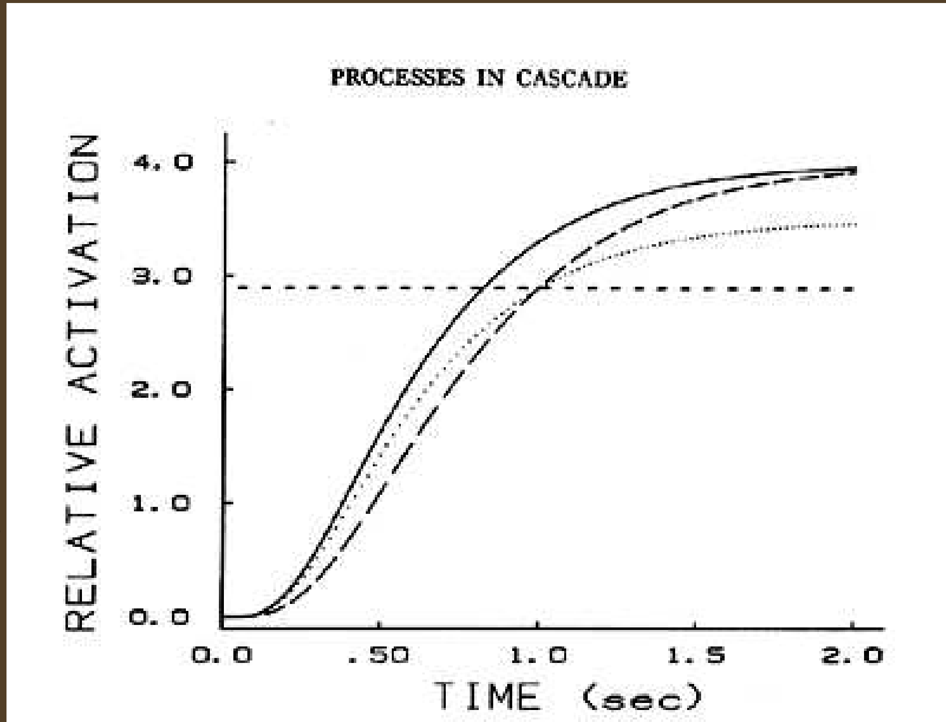




Possible connections between units at different levels of processing in a simplified hypothetical system for determining whether a string of letters is a word or a nonword.

Cascade model

- values in different units built up as a process of activation; activation functions follow an exponential function
- factor manipulations may affect either the rate of the process (rate of activation accumulation) or the asymptotic level
- → different outcomes possible when analysing the possible effects on two different factors



- simulations show that assumption of cascaded processes allows the emergence of additive effects of manipulations of individual processing stages

- additive effects may result e.g. if two factors affect the rate of two different processes

- different interpretation than AFM: interactions are possible if two manipulations affect two different processes → factor a the rate of process 1, factor b the asymptotic component of process 2

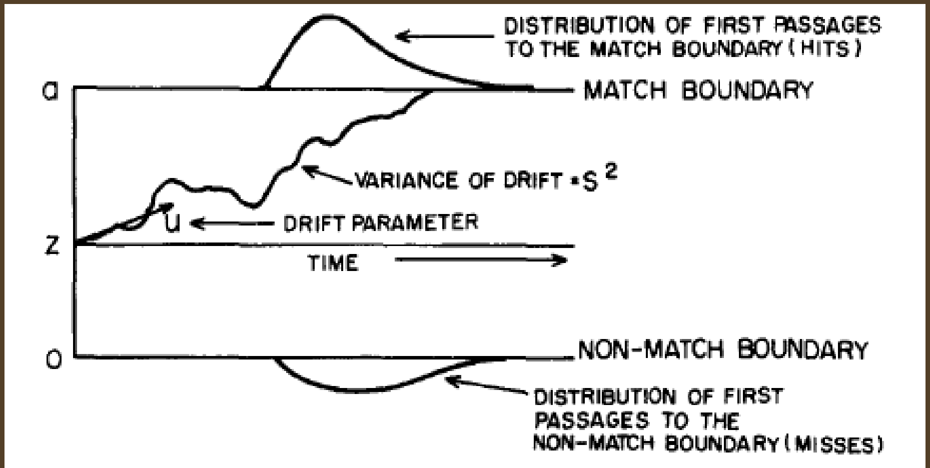
- But:

 - additive effects restrict the number of possible architectures

- Collecting additional evidence by measuring other parameters about the mental chronometry (e.g., LRPs)

Alternative theoretical presumptions: accumulation models

- Accumulation models:
  - – decisions are built up with accumulation of information

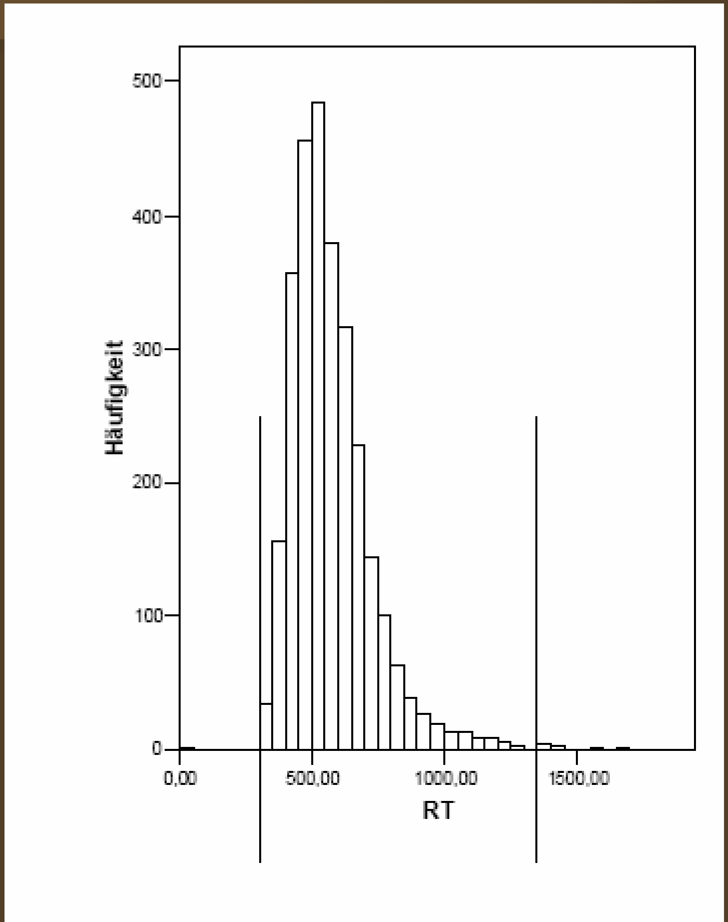


Stochastic diffusion model of Ratcliff (1979); see also E.J. Wagenmaakers

3. Problems and pre-conditions for sufficient use of RTs

- Clever design of the experiment – control of confounding factors:
  - psychological factors influencing RTs and their measurement (practice, alertness, sequence [order] effects..)
  - optimization of measurement (e.g. measurement of response force, execution time, determination of thresholds)

- Use of mean/median, outlier correction



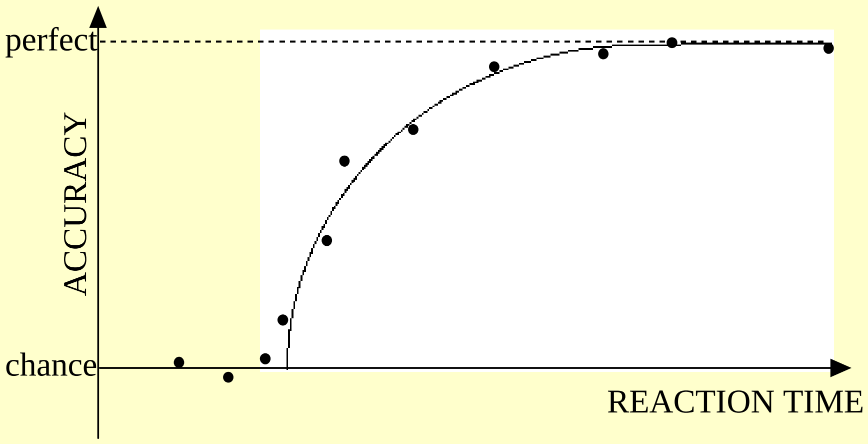
- Left skewed response time distributions
- Very fast RTs at the left and slow RTs at the right tails
- May be caused by factors not of interest in the experiment
- For example!
- What to do?
- Outlier procedure:
- Fix an upper and lower boundary
- (Mean +- 3SD)

3. Problems and pre-conditions for sufficient use of RTs

- Speed-accuracy trade-offs, consider error rate for interpretation

- analysis of response time distributions

Relation between response speed and accuracy can be influenced by instruction, deadlines, payoffs, “Respond-now”-signals



SPEED-ACCURACY TRADEOFF FUNCTION

(for one task + condition + subject)

points represent different deadlines or payoffs)

You cannot get all what you want:

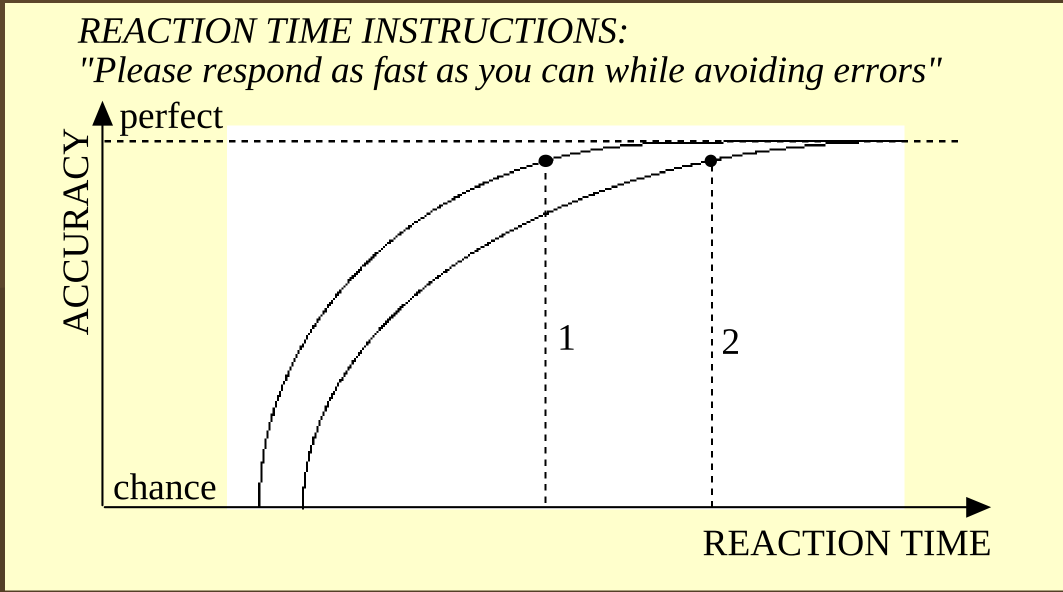
Either fast responses and many errors

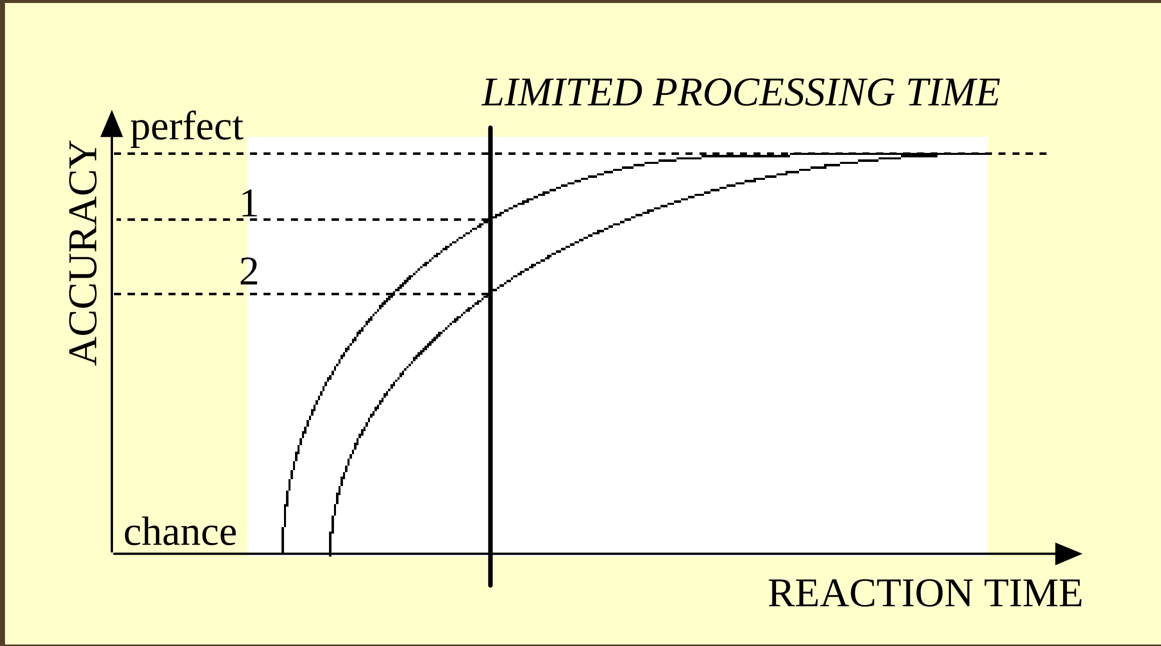
or slow (relatively) but correct

Method 1:

Hold constant accuracy level of participants and compare response times

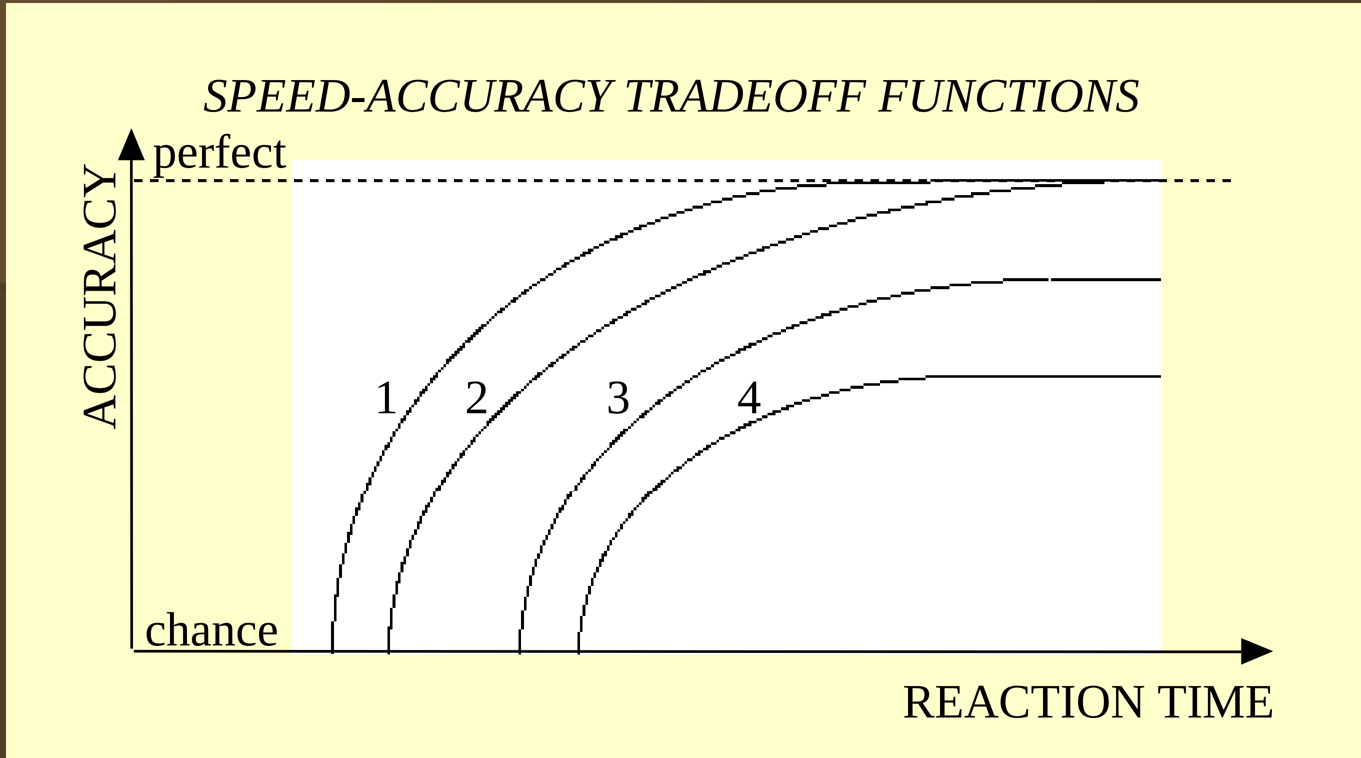
(5-8 % error)





Method 2:

Hold constant the maximum processing time & compare conditions

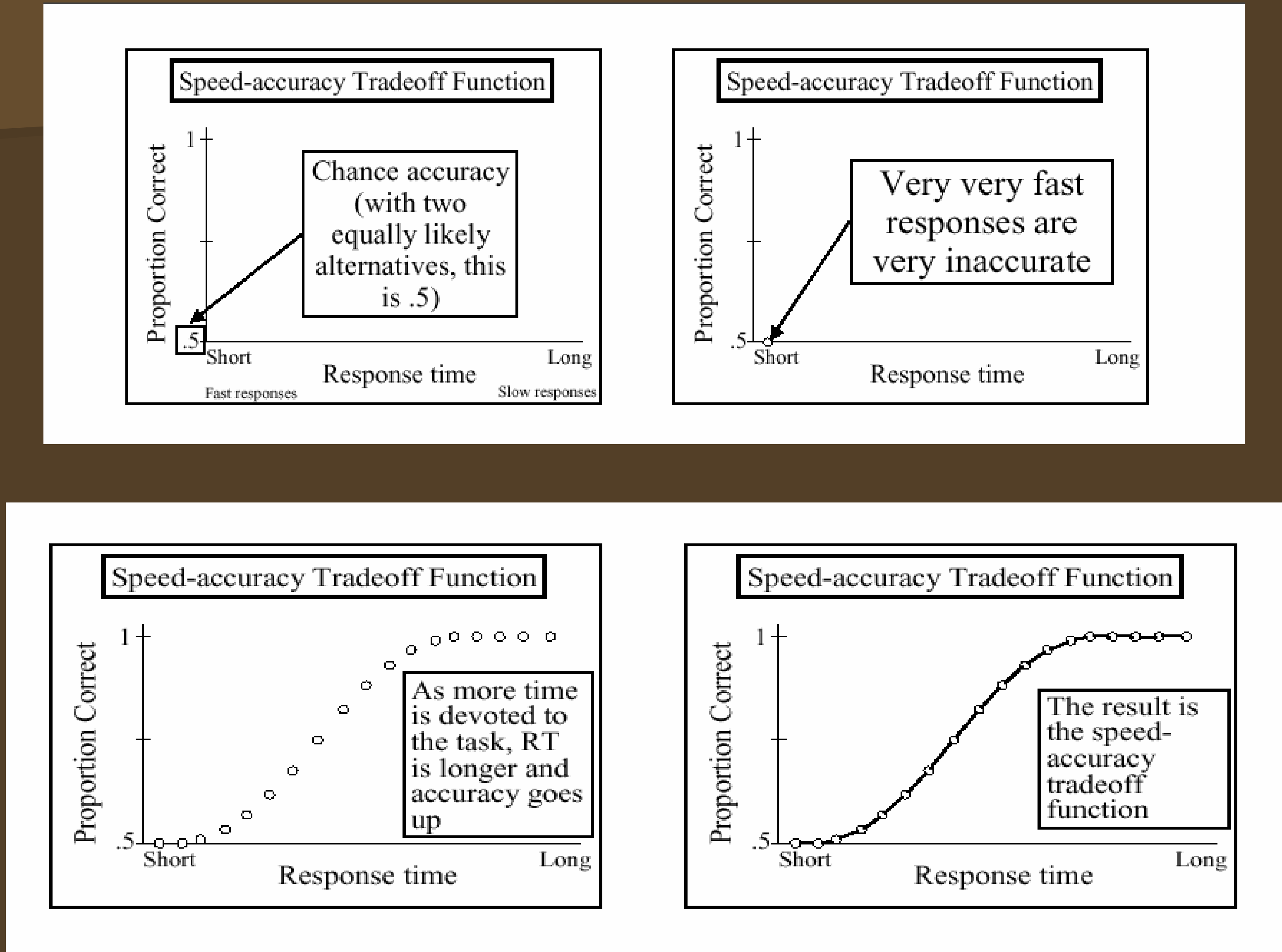


Comparison of conditions with different asymptotic accuracy:

=>necessary to measure the whole trade-off function by varying deadlines, payoffs, etc. (very effortful)

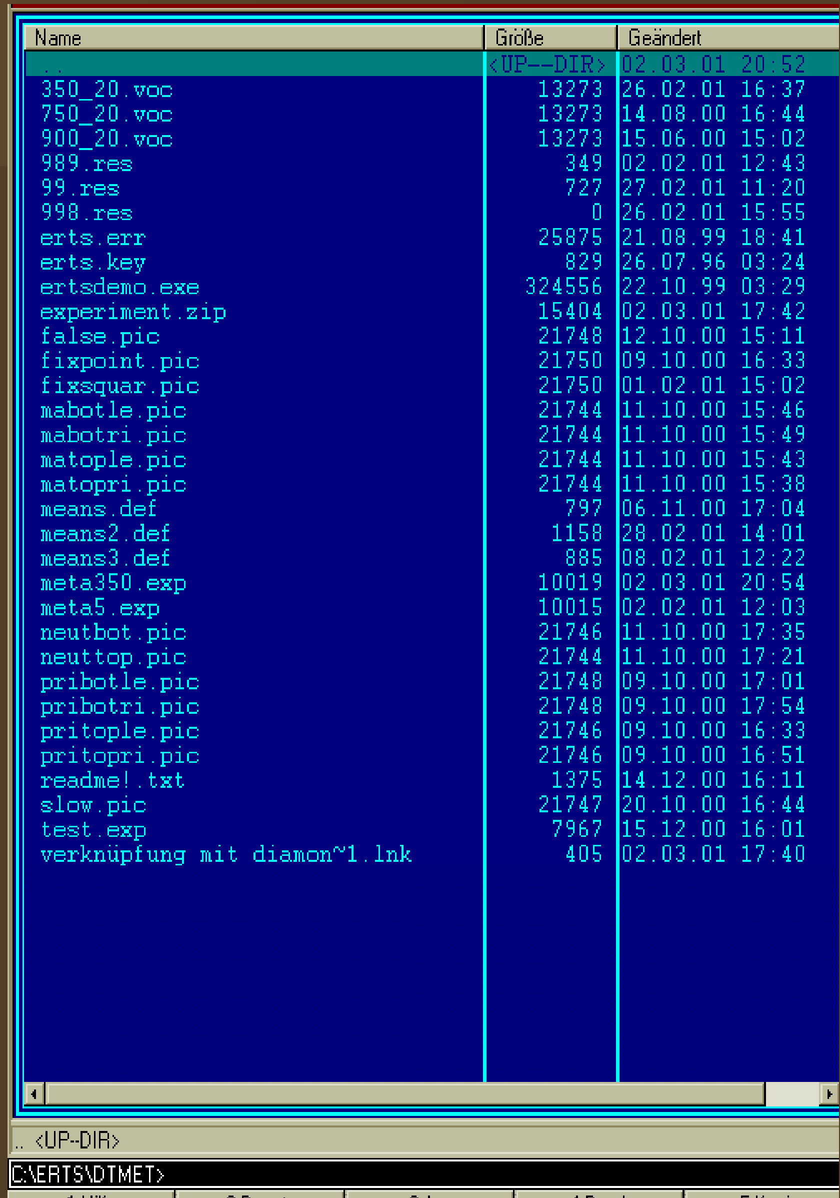
Difficulty relation: 4 > 3 > 2 > 1

Speed-accuracy Trade-off (in detail)

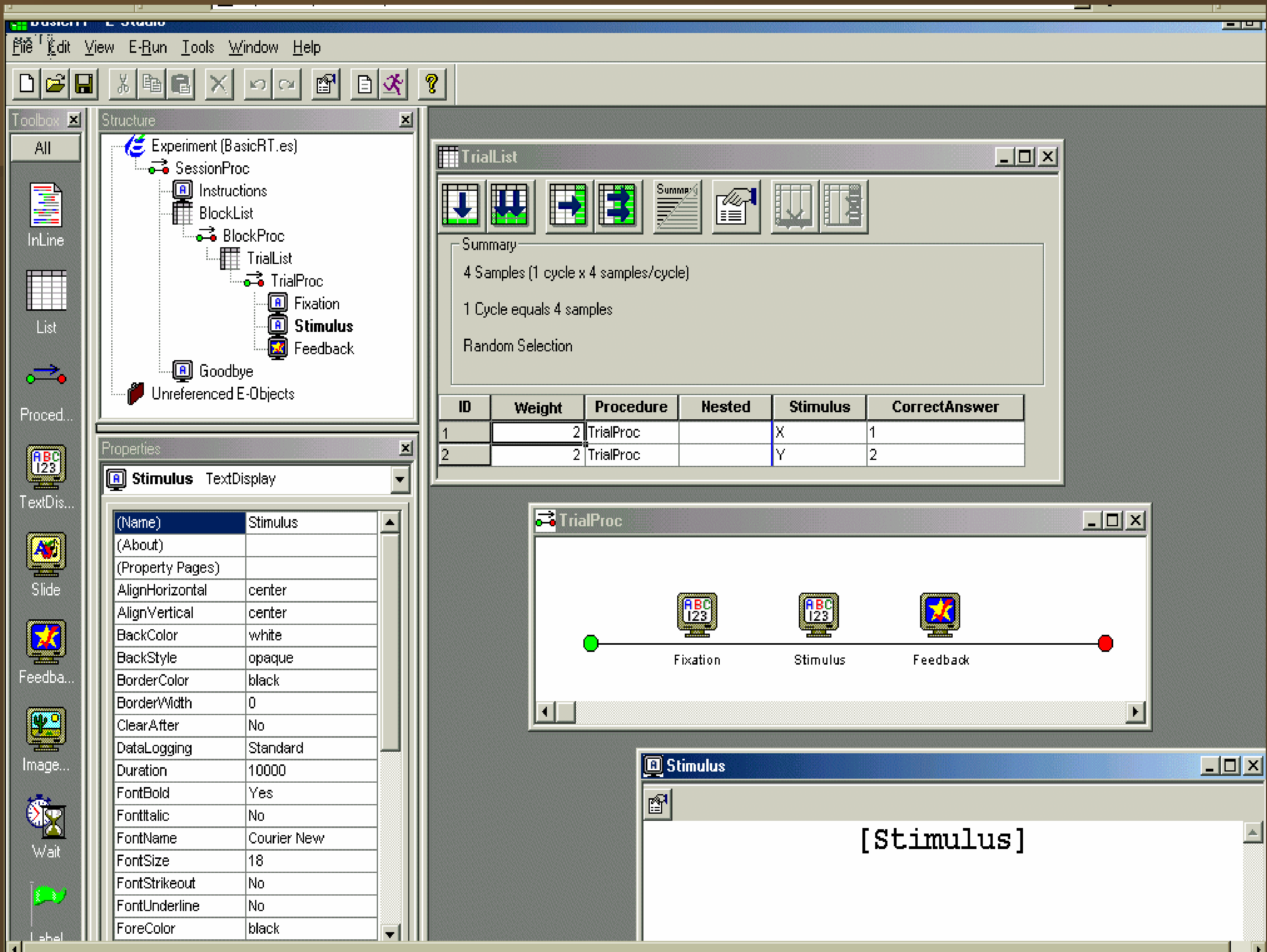


Software-Beispiele

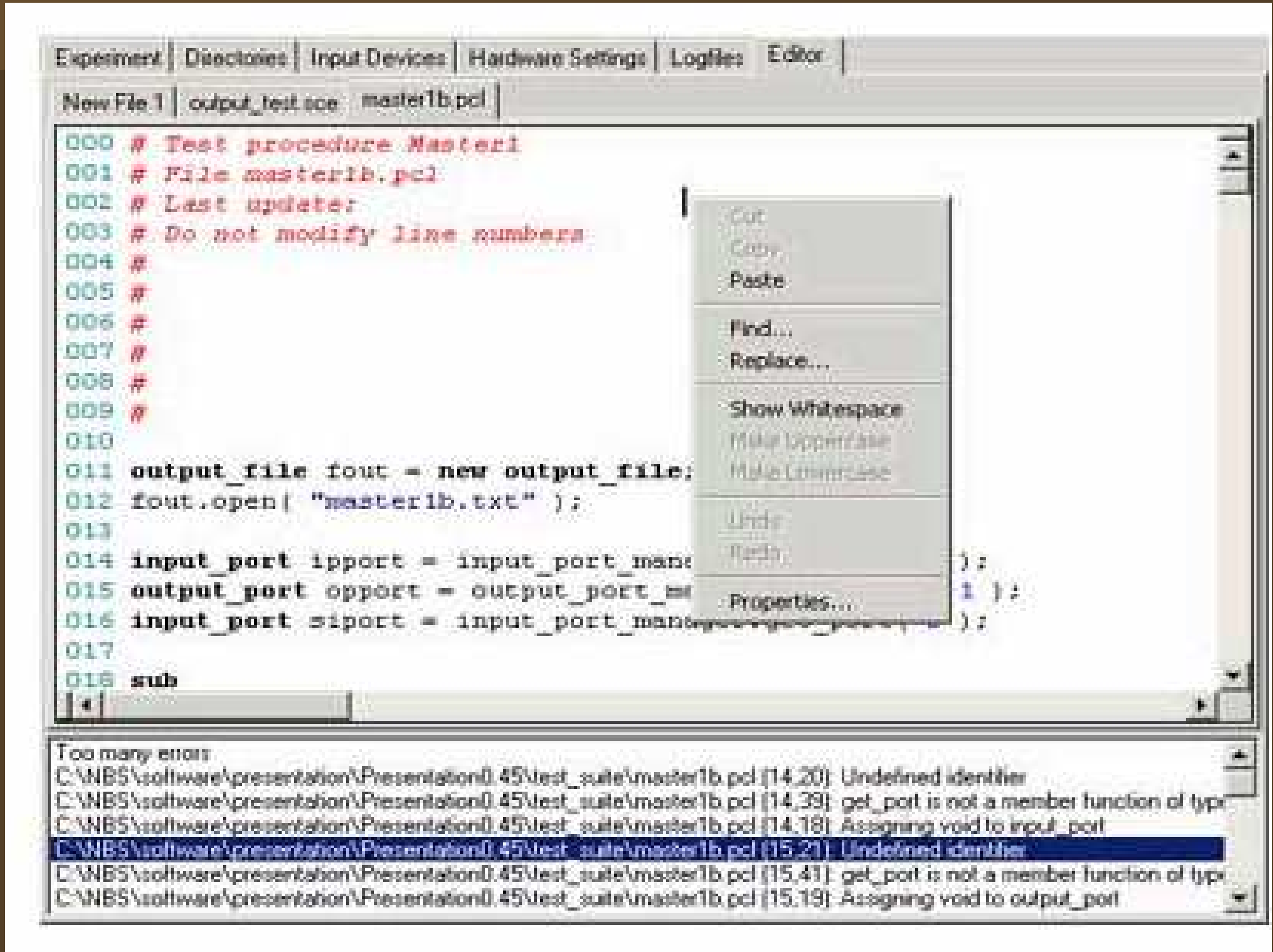
http://www.erts.de



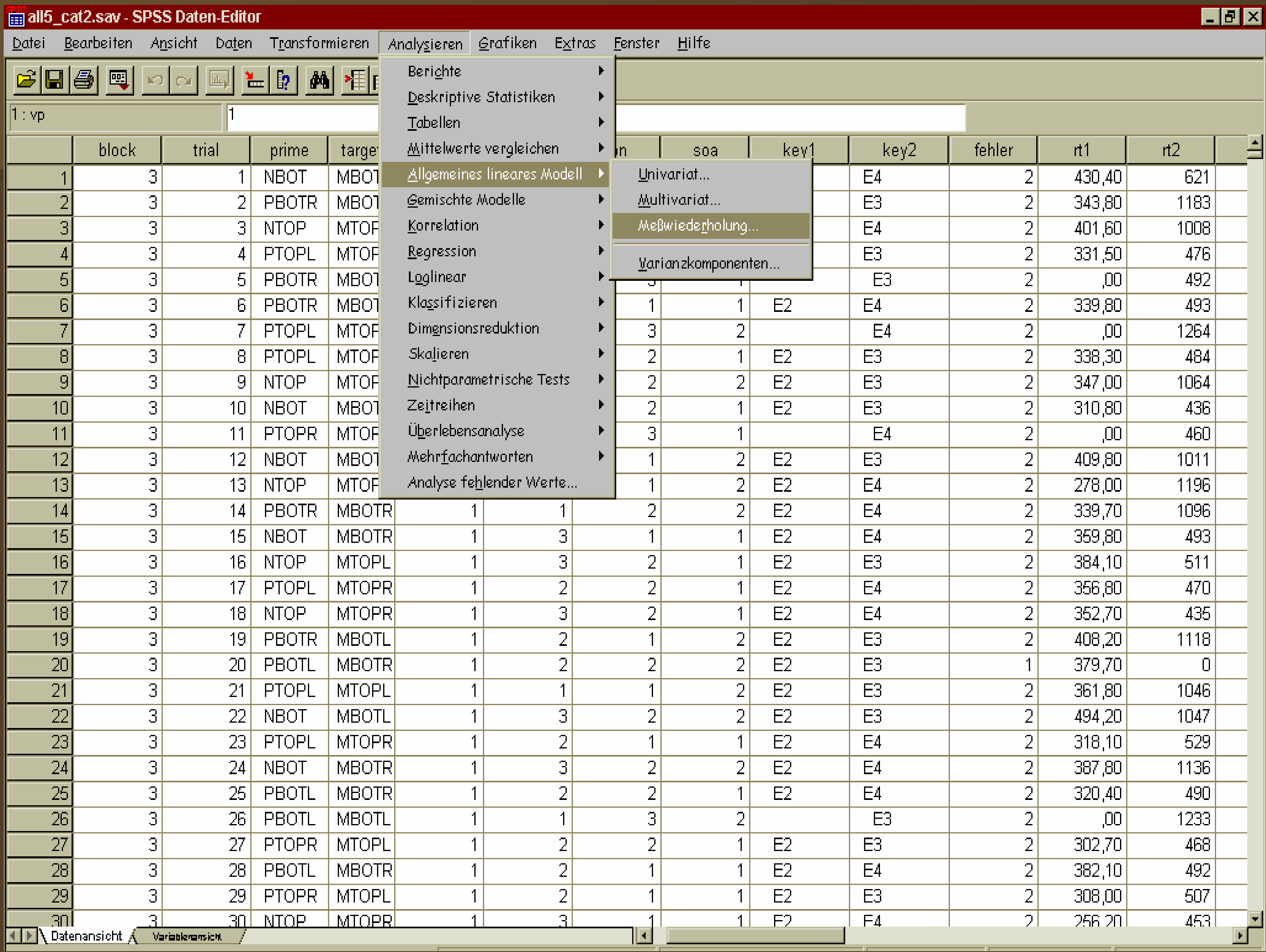
http://www.pstnet.com/products/E-Prime/



http://www.neuro-bs.com/presentation



SPSS


all5_cat2.sav - SPSS Daten-Editor
Datei Bearbeiten Ansicht Daten Transformieren Analysieren Grafiken Extras Fenster Hilfe
Berichte
Deskriptive Statistiken
Tabellen
Mittelwerte vergleichen
Allgemeines lineares Modell
Gemischte Modelle
Korrelation
Regression
Loglinear
Klassifizieren
Dimensionsreduktion
Skalieren
Nichtparametrische Tests
Zeitreihen
Überlebensanalyse
Mehrfachantworten
Analyse fehlender Werte...
Univariat...
Multivariat...
Meßwiederholung...
Varianzkomponenten...
1 : vp
block trial prime target soa key1 key2 fehler rt1 rt2
Datenansicht
Variablenansicht