Computational modelling as an approach to neural mechanisms of Negative Priming

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Abstract

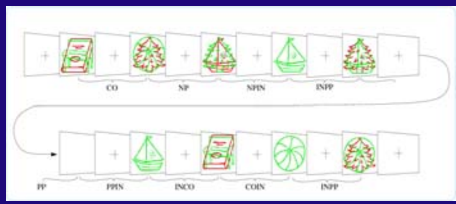
Negative Priming (NP) = phenomenon of selective attention; slowing of reaction time (RT), if an presented target in trial n was congruent to the distractor in trial n-1.

Theoretical Problems:
- NP-effect is very universal; has been found in a wide variety of experimental contexts [3]
- Non of the current discussed models is able to explain all the effects, because the growing body of empirical evidence is very complex.

Perspective of the project:
- Using a computational approach to NP to consider the neurophysiological basis of NP-processes and also aging effects at a later time
- Intergration of all relevant cognitive processes in one model
- Derive more specific and also quantitative predictions (than possible from the other more abstract models)
- Successive examination of new predictions in behavioral experiments

Negative Priming - Paradigm

Exampel of Negative Priming task – identity priming – voicekey RT-recording [4]
- successive presentation of superimposed drawings – response to stimulus 500 ms
- Instruction: „Name the green target object while ignoring the red distractor obejct."

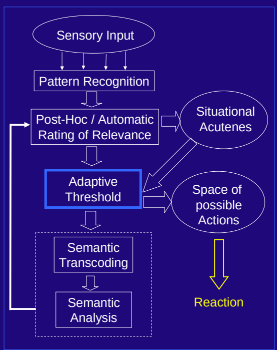


Priming conditions:
- CO = control
- NP = negative priming
- PP = postitive priming
- NPIN = single object (previous distrator)
- PPIN = single object (previous target)
- COIN = single object
- INCO = control (after single object)
- INPP = control (previous single target)

- Standard NP-effect = difference between NP- and CO-trials
- expected reaction time relations: NP > CO > PP > IN

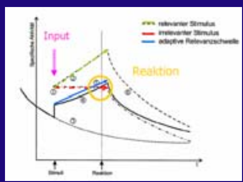
Imago-Semantic Action Model (ISAM) [2]

- Models processes in selective attention, yields good results when applied to hte negative priming paradigm
- Aspects that distinguish the ISAM from other models of selective attention involve an adaptive activity threshold as well as a semantic feedback loop

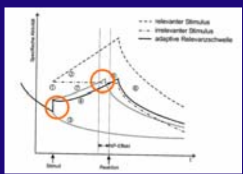


Kabisch (2003)

- adaptive threshold depending on the activity in the whole system
- Not only negative priming but all sorts of priming effects (e.g. postitive priming) can be explained in terms of that model



Activation curve (principle)



Activation curve (NP-trial)

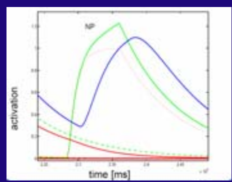
The ISAM was chosen because of:
- Specific assumptions refarding neuronal and semantic representation of stimuli and contextual cues
- Quantifiable formulation of activation-response processes

Computational Implementation of ISAM

- Mechanisms of ISAM are implemented in terms of differential equations
- doubly-indexed variable for each object i (as target or as distractor)
- adaptation of represented stimuli-activation towards external activationlevel

$$\frac{1}{\alpha}\frac{dx_i^\nu}{dt} = I_i^\nu - x_i^\nu \quad \text{if } x_i^\nu < I_i^\nu$$

$$\frac{1}{\beta}\frac{dx_i^\nu}{dt} = I_i^\nu - x_i^\nu \quad \text{if } x_i^\nu > I_i^\nu$$



Simulated activation curve (NP-trial)

- external stimulus-activation is influenced by the semantic feedback-loop:

$$\text{distractor } \delta : I_i^\delta = 1, \text{target } \tau : I_i^\tau = 1 + \xi \cdot \Delta t$$

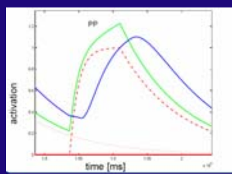
- Distractor-target interference between identical objects, eliciting NP-effects

$$\frac{1}{\beta}\frac{dx_i^\tau}{dt} = -x_i^\tau - \zeta \cdot x\delta_i$$

- Adaptation of the global activity threshold (a weighted sum of all activations present in the system)

$$\frac{1}{\gamma}\frac{d\theta}{dt} = \bar{x} - \theta$$

$$\bar{x} = \frac{1}{2} \cdot \left(r^\tau + r^\delta + \sum_{i=1}^{n} (x_i^\tau + x_i^\delta) \right)$$



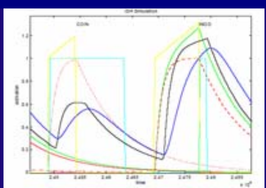
Simulated activation curve (PP-trials)

- global activity threshold successively cuts off irrelevant stimulus representations as it adapts toward the present activation, eventually leaving only one possible reaction

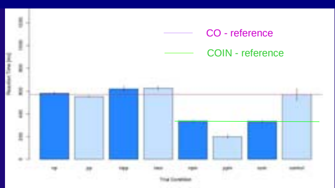
Predictions of the Computational Model

Predictions about settings e.g. absence of a distractor (single-object trials)
- Systematic slowdown of reaction time after single object trials

⇨ Possible consequences for „traditional" NP-dataanalysis
systematically overestimation of CO-reaction time = underestiamtion of NP-effects, overestimation of PP-effects



Activation curve (after a single object trial)

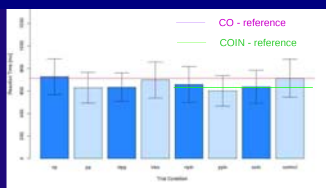


Predicted effects – mean reaction times

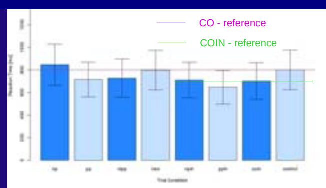
Experimental Data

Experiment

Task:	identification priming - voicekey recording of reaction time
Participants:	32 younger adults (19-35 years) and 32 older adults (60-78 years)
Procedure:	420 trials in 10 blocks; 30 seconds break after each block
Material:	Displays were generated by 9 different objects (see above NP-paradigm)



younger adults – mean reaction times



older adults – mean reaction times

Statistical Analysis - Repeated measures analysis of variance (ANOVA):
Factors: priming condition (within subjects) x age group (between subjects)

1. Successive analysis of CO-reference vs. all other priming conditions
   - overall RT main effect of age – younger adults are faster than older adults
     e.g. NP: $F(1,62) = 16.84$; $p = .001$
   - effect of CO vs. INCO is not sign.
     $F(1,62) = 2.39$; $p = .127$
   - effects of CO vs. all other priming conditions (NP, PP, INPP, PPIN, NPIN) are sign.
     e.g. INPP: $F(1,62) = 119.36$; $p = .000$
   - interaction of age group x priming condition in cases of NP, NPIN, PPIN and COIN
     e.g. NP: $F(1,62) = 13.35$; $p = .001$
2. Separate analysis of COIN-reference vs. NPIN and PPIN
   - effects of COIN vs. NPIN and PPIN are sign – standard priming for single objects
     NPIN: $F(1,62) = 20.66$; $p = .000$; PPIN: $F(1,62) = 58.86$; $p = .000$
   - but no interaction of age group x trialcondition

Conclusions and Outlook

Successful Implementation of ISAM
- reproduce experimental data and priming effects in a wide range of settings (qualitatively and quantitatively)

Experimental Data confirm the **predictions of the model** only in part
- slowdown of reaction time after single object trials - smaller than predicted
- Aging interaction effects of NP- and IN-trials - contrast to recent metaanalysis suggesting age-invariant negative priming [5]

Further optimization of the implementation:
- Calibration of the model to adapte the activation curves of single-object-trails to experimental findings
- Make the model more realistic – basing the dynamic units of the model on neuronal network assumptions (dynamics of the threshold, process of feature detection) [1]
- Consideration of intra- and interindividuell variance
- Implementaion of age releated variables to simulate the experimental aging effects

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References:

[1] Herrmann, M., Ruppin, E. & Usher, M. (1993). A Neural Model of the Dynamic Activation of Memory. *Biological Cybern*, 68, 455 – 463.
[2] Kabisch, B. (2003). Negative Priming und Schizophrenie – Formulierung und Empirische Untersuchung eines Neuen Theoretischen Ansatzes. *Dissertation*, Friedrich-Schiller-Universität Jena.
[3] Tipper, S.P. (2001). Does negative priming reflect inhibitory mechanisms? A review and integrationof conflicting views. The Quarterly Journal of Experimental Psychology. 54A, 321-343.
[4] Titz, C., Behrendt, J., Hasselhorn, M. & Schmuck, P. (2003). Ist der Negative Priming Effekt zur reliablen Abbildung interindividueller Differenzen kognitiver Hemmung geeignet? *Zeitschrift für Differentielle und Diagnostische Psychologie, 24 (2),* 135-147.