Hierarchical Control of Action: Some Behavioural Findings and a Model

Rick Cooper
Nicolas Ruh
Denis Mareschal
Tim Shallice

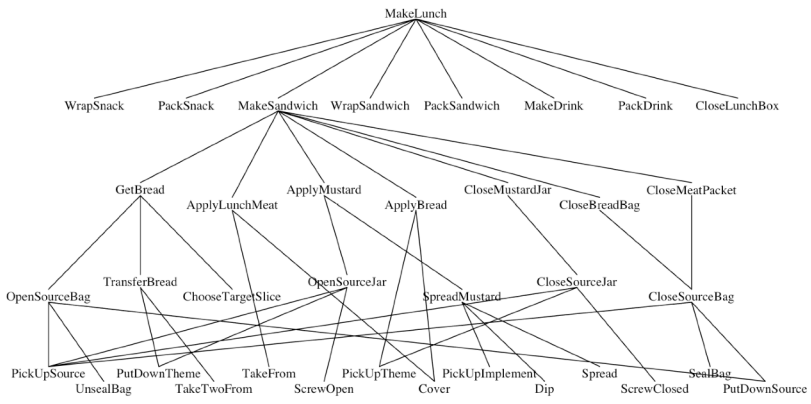
Serial Behaviour: Evidence for an Intermediate Level

- Action slips and lapses in normal, over-learned, behaviour (Reason, 1979, 1984; Norman, 1981):
  - Errors of capture, anticipation, omission, perseveration, object substitution
- Neuropsychological disturbances of action:
  - Action Disorganisation Syndrome: Sequential and object substitution errors in object-related goal-directed sequential action
  - Ideational Apraxia: Conceptual and sequential errors in over-learned object-related action sequences
  - Amphetamine psychosis: Increased rate of responding with reduced number of response categories
  - Bradykinesia: Slowed initiation of an action sequence

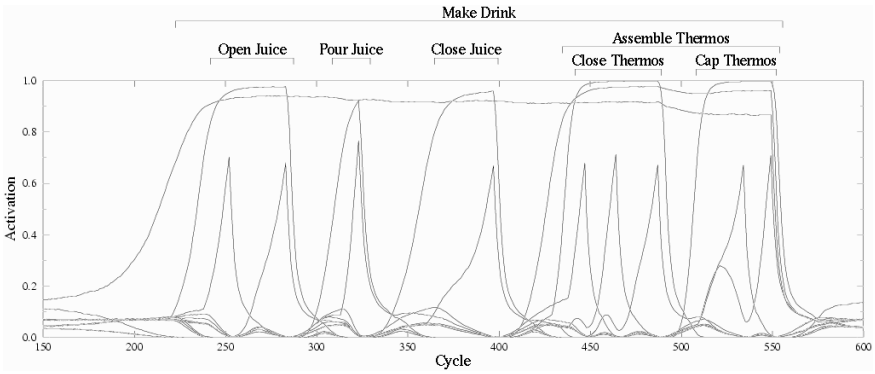
Hierarchical Control: Supporting Evidence

- What makes serial behaviour hierarchical?
  - The occurrence of subsequences in different contexts, or
  - The goal/subgoal structure of behaviour
- Anecdotal behavioural evidence for hierarchy:
  - Goal-directedness but note flexible subsequence concatenation
  - Chunking, transfer, canonicity, but note interleaving
- Phenomenology:
  - Willed control of action at multiple levels
- Experimental work:
  - Botvinick & Bylsma (2005)
  - Ruh, Cooper & Mareschal (2006; in preparation)

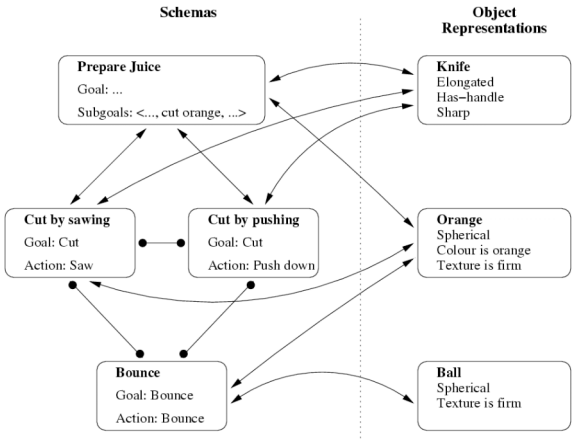
Cooper & Shallice Model: I Hierarchical Structuring of Schemas



Cooper & Shallice Model: II
Temporal Nesting of Subschemas



Cooper & Shallice Model: III
Schema/Object Interactions



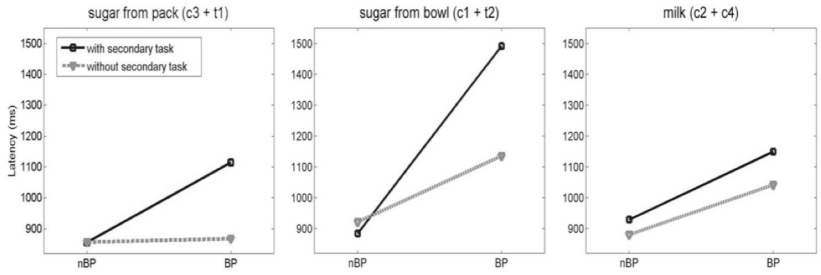
Cooper & Shallice Model: IV

- Strengths
  - Plausible account of routine slips and lapses
  - Good account of Action Disorganisation Syndrome (noise in schema network, object networks or both)
  - Good account of Ideational Apraxia (disconnection between schemas and objects)
  - Qualitative simulations of disorders of rate
- Limitations
  - No quantitative simulations of disorders or rate or RT effects
  - Primitive account of visual attention
  - No learning!

Ruh et al: Experiment 1 Method

- 40 subjects learned a set of hierarchically structured tasks (beverage preparation) from feedback on task completion
- Tasks were presented on screen, and required ordered drag and drop operations to make tea/coffee
- Two hour-long training sessions; 112 trials in total
- On 50% of trials participants also completed a secondary task (auditory monitoring)
- Primary dependent measure:
  - Latency between mouse clicks either when “picking up” the spoon (nBP) or “picking up” the first ingredient (BP)

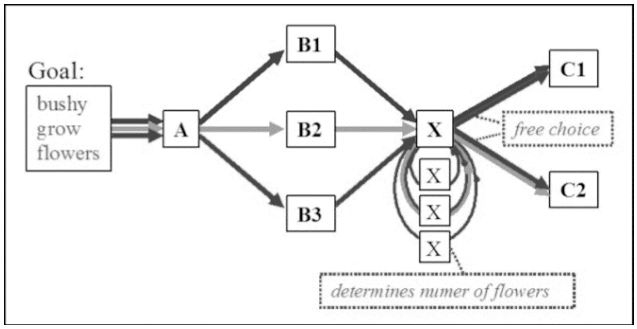
Ruh et al: Experiment 1 Results



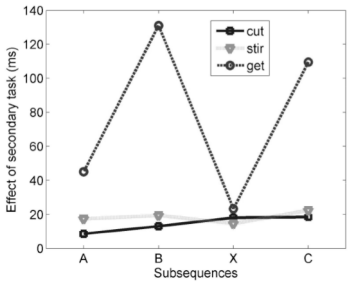
Between-action latency at branch points depends upon task experience and presence of a secondary task

Ruh et al: Experiment 2 Aims and Method

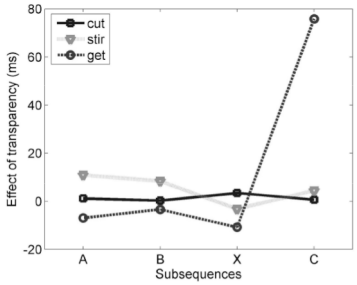
- Aim: Explore effects of task frequency, environmental cues
- 19 subjects; 200 trials over 3 sessions
- 6 task variants, learned through instruction and feedback:



Ruh et al: Experiment 2
Selected Results



Selection of invariant actions is unaffected by secondary task, but selection at branch points is



Selection of C is speeded when the pot is transparent, but all other actions are unaffected

Conclusion

- Empirical:
  - Selection difficulties occur when low frequency responses must be chosen, environmental cues are absent, temporal dependencies are involved, or attentional processes are diverted
- Modelling:
  - Cooper & Shallice capture the patient data, but not learning data
- Ultimate goal:
  - A network that learns to settle while remaining instructable at multiple levels and sensitive to both higher goals and environmental contingencies
  - This may combine IAN and SRN concepts