An Integrated Theory of the Mind:

1. Introduction:
    a. Separated modules not satisfactory
    b. Cognitive architecture as described by Newell, explain how all components of mind work together for coherent cognition
    c. Advantages: can solve real-world problems, integrate data from cognitive neuroscience methods
2. Overall theory, ACT-R (Adaptive control of thought- rational) Theory
    a. Modules & buffers: Visual, motor, declarative, goal
    b. Central production system, coordinates behavior
        i. Information in modules encapsulated, communicate through what is available in buffers
        ii. Buffer limited to single unit of knowledge (chunk)
        iii. Mix of serial and parallel processing
        iv. Production rules
            1. Basal ganglia; striatum, pattern-recognition function, Pallidum – conflict resolution, Thalamus – production of actions
            2. Critical cycle: buffers hold representations represented by external world, patterns in buffers are recognized, a production fires, and buffers are updated for next cycle
3. Modules
    a. Perceptual-motor module
        i. Visual system
            1. Dorsal where system
                a. Visual location module & buffer
                b. How it works: Production system species a series of constraints, where system returns a chunk representing a location meeting those constraints
            2. Ventral what system
                a. Visual object module & buffer
                b. How it works: Provide a chunk specifying a visual location, causes the what system to shift visual attention, process the object there, and generate a declarative memory chunk representing the object
            3. Dual task results
                a. Parallel threads of serial processing in each module
                b. Both tasks pass through production execution bottleneck; can avoid interference if demands on production system spaced out and not using same perceptual-motor systems
    b. Goal module
        i. Keep track of steps to accomplish goal, partial results
        ii. DLPFC results; involved in subgoals, maintaining goal state
        iii. Likely multiple regions including parietal cortex
    c. Declarative module

i. Activation of chunk= base-level activation + Sum over units(attentional weighting of elements relevant to goal * strength of association)

ii. Base-level activation, depends on how long ago, how often activated in past

iii. Threshold for probability of retrieval, Latency equation

d. Procedural system

i. Selects the production rule with highest utility to apply

1. Probability of rule achieving goal - cost in time of using rule

2. Learning adjusts costs and probabilities based on successes, strength of prior for production adjusts learning

3. Production complication; New production will dominate if cost is less

4. Applications of ACT-R architecture

a. Understanding acquisition of human skill with a complex real-world system

i. Tactical decision making task simulation of tasks for an anti-air warfare coordinator

ii. Air tracks shown, Information boxes, Function keys bound to commands (changes depending on subtask)

iii. Identifying intent, airframe type

1. Subtasks: selection, search, select air track managing, updating mode (identify intent, airtype with key binding changing), save

2. Model learns task: Production compilation and learning(Procedural), location learning crucial

b. Brain imaging study:

i. Artificial algebra task, asked to apply operations and key in answer

ii. Prefrontal (goal), Motor (manual), Parietal (operations holding problem representation, subgoals)

iii. Activity in imaginal, manual and retrieval buffers predicted BOLD activity in parietal, motor and pfc

iv. Results:

1. Motor area: onset of keying

2. Parietal: transformations in imagined equation, sensitive to complexity not practice

3. Prefrontal: retrieval of algebra facts, sensitive to complexity and decreases with practice

4. Caudate nucleus of bg (learning of new procedural skill)

5. Conclusions

a. Time-sharing between pfc areas, not all in bg bottleneck

b. ACT-R useful for integration, where we are in various parts of problem represented in modules

c. Modules bring right memories, right rules to use for context; application to real data shows the model's usefulness