MODELING SENSORIMOTOR HABITS WITH NEURO-ROBOTICS
A Reappraisal Of The Habit Concept In Psychology

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ABSTRACT
Recent trends in cognitive science have seriously undermined the notion of representation (symbolic or sub-symbolic) as a building block for theory construction and modeling in cognitive science (Stewart et al. 2011). The current lack of a clear theoretical building block for dynamical, embodied and situated cognitive approaches calls for a re-appraisal of the notion of habit as developed by early pragmatists (James, Pierce and Dewey) and continental philosophers (Köhler, Goldstein, Merleau-Ponty). Whereas contemporary computational neuroscience and machine learning approaches (Daw et al. 2005) still appeal to probabilistic association conception of habit, we propose a richer notion by modeling habits as self-sustaining behavioural neural patterns where activity-dependent plasticity shows an extended temporal structure. We illustrate this point with some work on evolutionary robotics, implementing a combination of Hebbian and homeostatic plasticity (Turrigiano 2000, 2007). In our robotic models, this mechanism is capable to generate sensorimotor development, reinforcement learning, spontaneous habit formation and re-habituation to sensorimotor disruptions (Di Paolo 2000, Barandiaran and Di Paolo 2010). We conclude that a richer notion of habit can significantly contribute to the foundations of cognitive science, opening up the possibility to model poorly understood psychological phenomena.

The notion of habit in contemporary cognitive psychology and neuroscience
Under the influence of behaviourism the notion of habit was reduced to its scientific formulation as a probability correlation between stimulus and response. In contemporary computational neuroscience and machine learning habits are conceived as reactive behaviour or probabilistic associations between stimulus categories (or measure of states in a problem domain) and action patterns (representing a set of motor commands that might alter the functional space of the problem environment).

What is a Habit?
A sensorimotor neurodynamic perspective
• HABIT = plastic and self-sustaining pattern of behaviour generated by emergent neurodynamic structure
• The stability of a habitual behaviour is coupled with the stability of the neurodynamic pattern that generates it.
• Its plasticity allows for processes of assimilation and accommodation, together with the increasing structuration.

Operant Conditioning with homeostatic plasticity

Spontaneous habit formation

When both food sources are profitable the agent develops a “preference” to choose the food on its right (that this behaviour is not an innate preference can be shown on early trials not biased systematically towards the right).

Evolutionary robotics and re-habituation to visual inversion: a Piagetian interpretation

Re-habituation to visual inversion is a well documented psychological phenomenon (Köhler 1946). Whereas it would take 1st operation to invert the visual field for a computerized device it takes weeks to adapt to this condition, and free behaviour is required to achieve it. Di Paolo implemented homeostatic plasticity in a robot artificially evolved to do phototaxis and maintain synaptic stability. After optimization the robot’s vision was inverted, leading to synaptic instability as a result, until a new synaptic configuration was capable to react photic sensorimotor contingencies and stability was regained. See model, controllers and explanation below.

Piagetian interpretation: the agent assimilates the light (A), visual inversion takes place and the agent accommodates (B), when reaching equilibrium it assimilates the light again (C).

Truncated History of the Notion of Habit

“Concrete habits do all the processing, recognizing, storing, evolving, organizing, and responding necessary in their formation, operation, and reorganization” J.DEWEY

“When we look at living creatures from an outward point of view, one of the first things that strike us is that they are bundles of habits”. W. JAMES

The notion of habit was truncated by the epistemological constraints of early behaviourism and the latter cognitivist turn. Current dynamical modeling techniques in robotics (implementing recent findings in machine learning) allow to recover a richer notion of habits: plastic sensorimotor contingencies generated-by and inducing-stability into neurodynamic structures. We have shown that phenomena of re-habituation, operant conditioning and spontaneous habit formation can be modelled within this framework. The way is open for more complex cognitive tasks that build, from the bottom-up, increasingly organized networks of habits through a process of equilibrium between assimilation and accommodation of sensorimotor patterns.

CONCLUSION

The history of the habit notion was truncated by the epistemological constraints of early behaviourism and the latter cognitivist turn. Current dynamical modeling techniques in robotics (implementing recent findings in machine learning) allow to recover a richer notion of habits: plastic sensorimotor contingencies generated-by and inducing-stability into neurodynamic structures. We have shown that phenomena of re-habituation, operant conditioning and spontaneous habit formation can be modelled within this framework. The way is open for more complex cognitive tasks that build, from the bottom-up, increasingly organized networks of habits through a process of equilibrium between assimilation and accommodation of sensorimotor patterns.

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