

Adaptive Systems

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Ecological Adaptation

Ideas in progress/regress

- ☞ Ashby did an excellent job in showing how adaptation could be the observable outcome of a system able to reconfigure itself so as to find new internal stability in the face of environmental disturbance.
- ☞ But we saw there were some problems that would prevent the use of this framework to account for every possible instance of adaptation (e.g. the problem of mal-adaptation).

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☞ How serious are these problems? Maybe it's only a question of taking the spirit of Ashby's ideas and extend them so that they would be a special case of a more general scenario for explaining adaptation.

☞ This is ongoing work, and many ideas are half-baked. Lots of room for improvement. Lots of things to throw out. (Hopefully not all of it!) Better taken as issues to think about.

☞ Precursors to some of these ideas: John Dewey, Maurice Merleau-Ponty, Kurt Goldstein, Jean Piaget, Ivo Kohler, Erich von Holst (see resources webpage for literature).

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A problem with viability

- ☞ Ashby and autopoietic notions of adaptation are based on the idea of survival or continuity of viability.
- ☞ *Mal-adaptation*, as a durable state, makes little sense as the risk of death cannot be tolerated for long periods and requires prompt adaptation.
- ☞ Strictly speaking, it is not entirely clear how an organism could be mal-adapted and not dead.
- ☞ If mal-adaptation means death, then what is the point of talking about adaptation. Shouldn't we simply talk about life and death?

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A problem with viability

- ☞ Are we missing something?
- ☞ Normal behaviour is *underdetermined* by the viability condition. Many behaviours are *possible* but only a few are *actually* observed.
- ☞ Why is that? Could that be the key for a description of mal-adaptation?

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The world upside-down

Experiments on the distortion of the visual field (Stratton, Ewert, Kohler, Taylor, Dolezal) show that over long periods of perceptual disturbance in human subjects, gradual behavioural and perceptual adaptation occurs. (Similar experiments in animals and with other sensorimotor disruptions).



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Adaptation is linked to *patterns of activity*, and may be confined only to those patterns (i.e., no adaptation by sitting and waiting).

Adaptation to grasping objects in an inverted visual field can happen by repeated trials at grasping. Adaptation to walking, by trying to walk. These work more or less independently.



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Re-adaptation is needed after taking off the distorting device.

Distortions: up/down, left/right, prisms, bi-colour, etc.

Similar experiments with auditory perception.



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Before adaptation → After 1 month



Unable to walk straight without touching something (Day 3)



Able to ride a bike (Day 34)

Recent replication by Sekiyama, *Nature*, 407, pp 374-377, (2000)

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The case for mal-adaptation

Mal-adaptation happens.

All you need to do is to introduce disruptions in your body that do not impede your normal *physiological* functioning and yet make normal patterns of *behaviour/perception* difficult or impossible. (Less extreme cases exist as well, e.g. injuries, environmental changes, etc.)

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✎ Prismatic distortion of the visual field will *not* kill you. It's not use to argue that it would eventually kill you if you were not able to adapt, because that would be a functional argument. It's not evolutionary adaptation that we are concerned with here.

✎ How can we describe this durable state of mal-adaptation? Why does it eventually lead to adaptation?

✎ If not directly putting survival at risk, how are distortions affecting the normal flow of organic activity? This is the key question. Can we still use some notion of essential variables, Ashby-style?

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Circular processes and invariants

✎ An aside.

✎ As a rule of thumb, or general hypothesis, whenever you have complex, durable processes with circular or reciprocal causality, you will observe the formation of some *spontaneous invariant organisation*. (Otherwise the processes will not be durable and/or distinguishable).

✎ Examples: Nest building, pheromone trails (products constrain production). Stigmergy. (also called historical processes)

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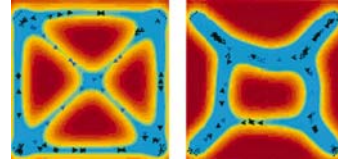
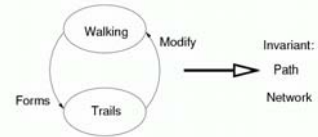
Trails on grass



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Trails on grass

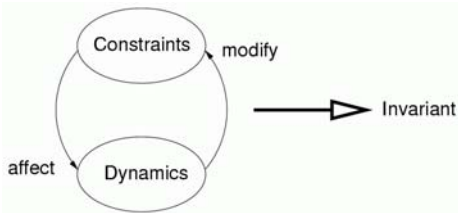


Model by
Helbing et al.
Nature, 388, pp
45 - 50, (1997).
(Remember
Pask's ear)

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Historical processes



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Sensorimotor coordination

- ✦ Can be viewed as a process of reciprocal causation. But it's difficult to be *aware* of it.
- ✦ Fluid behaviour becomes less and less conscious as it starts to rely on coherences of SM coordination.
- ✦ Surprise originates only when SM coordination is broken. (An unexpected obstacle, a contradiction between movement and proprioception, etc.)
- ✦ SM coordination can be organised into layers (individual movements, whole acts, chains of activity, etc.)

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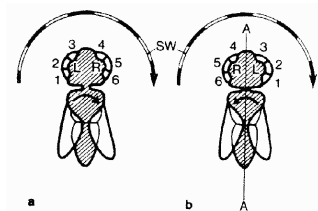
Ecological invariants

- ✦ The behavioural/perceptual manifestations of sensorimotor invariants. (Ecological: they involve organism and environment).
- Preferred postures (Draw a circle in the air)
- Self-coordination
- Perceptual invariants (e.g. angle of horizon, size and colour constancy)
- No flow associated with voluntary eye movements
- 3D objects (visual flow + self-generated kinaesthetic information)
- Ritualized relational patterns (wolf ritual fights, coordinated flight, duetting, flocking)

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E.g. Image centring (von Holst)



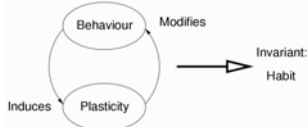
Coordination can often be the result of simple feedback mechanisms. (Re-attendance)

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Beyond the organism: Habits

K. Goldstein, J. Dewey, W. James, M. Merleau-Ponty, P. Guillaume, N. Bernstein, I. Kohler and others have used the term "habit" to describe how the body, as an ecological entity, sets itself into preferred patterns of action and perception.



"Preferred" does not imply teleology. Behaviour induces plastic changes which facilitate further behaviour, which induces plastic changes,..., and so on, until a behaviour pattern is found that induces little or no plastic change.

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Breakdown and recovery

- Habits have different degrees of organisation. From sensorimotor coherences to the concatenation of movement into whole acts, and further.
- Small disturbances can be compensated for, due to the stability of the invariant structure; but radical disruptions may either lead to the *total/loss* of the habitual pattern or may allow for the conservation of some *invariant residue* of the original organisation. From this a modified organisation may "grow".

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- Example: Grasping with inverted vision. The original organisation of grasping is disrupted (vision is perturbed).
- But much of the habit remains: proprioception and particularly the culminating event of touching and grasping the object.
- This could be the invariant that guides sensorimotor re-organisation.
- Another case: walking along a corridor. (Invariant: don't bump into walls.)

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Adaptation: habit re-organisation

- An extended framework for adaptive behaviour, to account for mal-adaptation.
- Ashbyan-like theory: an invariant guiding change.
- Instead of essential variable for survival, essential variables that maintain the residual organisation (e.g., the culminating event of grasping). Keep changing until these variables return to their "normal" values (until you start grasping again).

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- Key difference:** Physiology does not stop, so Ashbyan adaptation starts as soon as the disturbance is introduced. In contrast, a behaviour pattern may not be constantly enacted which means that **no habitual adaptation will occur without action**.
- Fits with data as only certain habits show adaptation: those that the subject tries to re-enact.
- Re-organization can mean the partial loss of the original habit which would explain why re-adaptation is necessary once you take the goggles off.
- (But it is possible to adapt to both conditions depending on the schedule for wearing the goggles. This could also be accounted for by this framework)

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Whence plasticity?

- In the above examples it is clear that sensorimotor re-organisation occurs by means of plastic changes within the organism. But this need not be so. The framework is more general.
- What "adapts" is not the individual but the action/perception pattern. In other words, *the habit* as a distinct ecological entity.

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‡ Plasticity could occur anywhere: in the environment or in other organisms:

- Storage, use of space, (e.g., Philip Agre's record collection). Things you use more often tend to be more accessible (which contributes to their more frequent use)
- Relative coordination (e.g., an adult and a child, or two robots, walking at the same speed)
- Mother-infant interaction (coordination of infant movements with mother's speech, facilitation, etc.)

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Many open questions

- ‡ How can we define a habit in a useful manner?
- ‡ What is the completion of an act?
- ‡ How can we identify the invariants that modulate re-organisation? What is residual organisation?
- ‡ Would this extended Ashbyan framework suffice to explain every case of adaptation?
- ‡ Could we design habitual patterns of behaviour as we can design robotic architectures?
- ‡ Is Ashby's Homeostat already an ecological adapting machine?
- ‡ Are we not sliding back unwittingly into teleology?

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‡ We are leaving out the consequences of these ideas for explaining *social adaptation*, the formation of social structures, norms, hierarchies, Bourdieu's *habitus*, Vygotsky, etc.

‡ The most interesting implication in this area is that the process of adaptation *needs not* be directly beneficial for the organisms involved. As long as they survive, the invariant may take control of the underdetermination of their behaviour

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But never, never wear this...



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