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# Adaptivity

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## Abstract

*This short paper gives an overview of my PhD thesis plans and some observations on the topic.*

*Goal of the project: to find out the properties and processes that make systems adaptive.*

*Project status: information gathering phase (2<sup>nd</sup> year of my PhD studies).*

## 1. What

**Adaptation** in general is a process through which a system restores, maintains or increases its fitness when outer and inner environments change, or increases its fitness in a nonchanging environment. Adaptation can be observed at different levels (single individual / object / part, group, society), at different time scales, etc.

My thesis, in its currently very general formulation, is: **"The properties and processes causing adaptivity in various systems are similar (when described at a suitable level of abstraction), or at least form a small number of different classes."**

**Related keywords:** adaptivity, learning, flexibility, elasticity, plasticity, context-dependency/-dependence, context-awareness, self-organization, (self-)adjustability, (self-)reconfigurability, feedback, resilience, evolution, conformance, ...

## 2. Why

The phenomenon of **adaptivity is obviously quite widely studied** in various systems. **However**, I have **not been able to find** any good interdisciplinary, yet thorough, source giving a **well-systematized overview of adaption** in different kinds of systems and of underlying processes of adaptation in specific cases and in general. Possible reasons for not finding such a source:

1. I have not searched well enough? In that case this source must be quite hard to find and is likely to be missed by many other searchers, too, as I have already done at least medium level searches from databases of scientific papers, from amazon.com and from elsewhere in the web. I do continue searching, of course: if not to find THE source, then at least to find numerous existing works on adaptation in specific fields of study.

2. The generalizations are impossible to make? This is not very likely as at least some (maybe a bit limited) generalizations HAVE been made. For example the notion of evolution can be used to describe slow adaptation in biological species as well as, for example, in the ideas moving around in a society (as suggested by memetics theory). Also, cybernetics has pointed out a general process important for adaptation, namely the feedback. Of course, it can be wondered whether there would be any use for very broad generalizations at all, as Kenneth Boulding (1956) says: *"... we always pay for generality by sacrificing content, and all we can say about practically everything is almost nothing."* But he immediately continues: *"Somewhere however between the specific that has no meaning and the general that has no content there must be, for each purpose and at each level of abstraction, an optimum degree of generality."* For the work on adaptation to have the biggest value, therefore, it should probably present in a systematic way the information **characterizing adaptation at different levels of abstraction:** starting from specific examples and going through various levels of abstraction up to the general notion of adaptivity.

3. Such an overview is just not written yet, though it would be possible, and **very helpful for designing adaptive systems**, as well as **for understanding and managing** the existing ones **more effectively**? Considering the discussion in previous two paragraphs I find this the most probable reason for not finding the aforementioned thorough source. Therefore, creating a work analyzing and systematizing the adaptation processes of various systems seems to be, in my opinion, well justified.

## 3. How

Methods of doing my work include:

\* **Studying** many different kinds of adaptation **by reading** articles, books, web sources, **talking** with (knowledgeable) people, **experimenting in silico** and otherwise.

\* **Contacting** specialists of **different disciplines** for finding out their views on the topic, what adaptation means in their field of work and asking for reading suggestions. There is a very large number of potentially interesting fields. To name just a few: biology, ecology, psychology, anthropology, culturology, linguistics, ur-

banistics, art, marketing, cybernetics, artificial life, etc., etc., etc.

\* **Identifying** the underlying **causes and mechanisms** of adaptation processes, and then **systematizing and generalizing** them **onto different levels of abstraction**.

\* **Suggesting applications** for the results and possibly creating a few example applications myself.

## 4. Your Help Welcome!

If you have any **comments** or **ideas** about my work and about the topic in general, or any **suggestions** about what I should read or whom I might find interesting to contact, then **please let me know!** There's no need to worry about the suggestions being too obvious or too obscure, too general or too specific! I would highly appreciate getting all of them! If you know anybody who might be interested in my research topic, then please encourage them to contact me and direct them to my homepage taivo.net!

## 5. Some observations...

As I am still in the information gathering phase, there is no novel knowledge I could present here. However, I have already processed quite a few sources and, to raise your interest and to get your thinking going on the topic, I will present some observations about adaptivity from various disciplines.

### 5.1. ...from human adaptability

One possibility to classify the ways humans adjust to external conditions during their lifetime would be (based on Moran, 2000):

\* Developmental adjustments – nonreversible physiological and morphological changes resulting from organismic adaptation to environmental conditions during the individual's growth and development. Especially noticeable when stress is extreme and constant. For example a child growing at high altitudes will develop larger lungs and chest capacity to adjust to prevalent low oxygen conditions.

\* Acclimatory adjustments – modest, reversible physiological adjustments to an environmental change or stress. Can occur in any life stage, not only during development.

\* Regulatory adjustments – an organism's relatively rapid physiological and behavioral responses to changes in its environment. Virtually all behavior is a form of regulatory response that either serves to maintain a stable relationship to the environment or permits adjustment to changes in that environment.

\* Cultural (and social) adjustments – the learned knowledge that people acquire as members of society. It is their most important means of coping as a species. Among the most common are clothing and sheltering strategies that enhance human chances to survive and live in relative comfort in a variety of environments. A

somewhat different example is religion, which in many cases allows to attribute personal guilt and misfortunes to the machinations of bad spirits, thus reducing personal anxiety and enhancing emotional state.

### 5.2. ...from evolution theory

From the perspective of evolutionary theory, the temporal reference frames relevant to adaptability would be (based on Brock, 2000):

\*  $t \leq$  life span of an individual. Most dynamic activity at this level can only be met by metabolic or behavioral adjustment. Phenoplasticity (the potential for variation of the body form developing from the same genotype, but in different conditions) also operates here.

\*  $T =$  time taken for fixation of a given allele (alleles are the variant forms of a gene) and its dispersal through subpopulations of a sympatric gene pool (sympatric = occurring in the same or overlapping geographical areas). Much genetic adjustment within  $T$  will be transitory (allelic changes that are reversible within  $T$ ).

\*  $T_c =$  "ambient speciation time", i.e. the time for accumulated genetic changes in separated gene pools of the same gene reservoir to reach that point at which the rejoining of the populations would lead either to extinction of one of the gene pools or to the emergence of two separate species. Here genuinely evolutionary change happens.

Using these time frames, several components of the adaptive response can be defined:

\* Primary adaptive equilibrium – periodicity of environmental parameters  $< t$  and changes in environment are generally met by behavioral + metabolic adjustment and phenoplasticity.

\* Secondary adaptive equilibrium – periodicity of environmental parameters in the range  $(t, T)$  and adaptive response is manifested in ambient genetic allomorphy (frequency fluctuations of allelomorphic genes (a gene having several possible forms) in a population).

\* Tertiary adaptive equilibrium – periodicity of environmental parameters in the range  $(T, T_c)$  is met by recurrent mutations.

\* Evolution – periodicity of environmental parameters  $> T_c$  and adjustment happens through realization of adaptive *potential*, as opposed to adaptive *capacity* (as in previous three points).

### 5.3. ...from human workforce adaptability

Pulakos et. al (2006) propose 12 constructs that should be relevant for predicting adaptability of individual employees, and 7 constructs for predicting team adaptability.

Individual differences predictors of adaptive performance:

\* Cognitive ability – the ability to understand and use language ( $\approx$  general intelligence). Cognitive ability

would be expected to enhance adaptability in situations that require learning and problem solving.

\* Practical intelligence – the ability to solve ill-defined problems, for which there may be multiple solutions and multiple ways of obtaining them; to learn and apply knowledge to everyday, ill-defined problems.

\* Originality – the ability to come up with unusual or clever ideas about a given topic or situation; the ability to develop creative ways to solve a problem.

\* Emotional stability – person remains level-headed, even-tempered and calm when confronted with adversity, frustration, or other stressful / difficult situations. Also displays an awareness of mood and tends to be adaptable to even rapidly changing situations.

\* Openness – person is receptive to new environments and events; is curious and broad-minded; displays broad interests. Individuals high on openness tend to display traits such as tolerance, curiosity and inquisitiveness when confronted with novel situations. Thus they are less likely to perceive change as stressful, and more likely to adapt more effectively. Openness is also positively associated with identity flexibility.

\* Cognitive flexibility – change is perceived as a challenge or opportunity for further development. People who feel positively about change are more likely to explore their environments and have better knowledge of available resources that can help them to cope with change.

\* Achievement motivation – person shows desire to achieve results and master tasks beyond others' expectations; sets difficult and challenging goals and works hard to accomplish them; shows a drive to succeed. High achievers tend to have a willingness to assume a substantial degree of responsibility for solving the problems they face.

\* Cooperativeness – person works effectively with others toward a common purpose; shows willingness to give and take in an effort to achieve group goals; develops constructive relationships.

\* Sociability – person feels at ease in social situations; is outgoing; enjoys meeting new people. Sociability should aid in forming positive and productive interpersonal relationships, which can themselves be adaptive or which can serve as a buffering mechanism for dealing with other stress or change situations.

\* Social intelligence – person understands situationally appropriate social behavior; understands the feelings, motivations and behaviors of others and acts appropriately upon them; finds solutions to interpersonal problems.

\* Physical ability – involves adjusting to challenging environmental circumstances (heat, noise, cold, ...) as well as adjusting weight and muscular strength to become proficient in performing physical tasks.

\* Domain-specific knowledge – knowledge of a specific content domain that may facilitate dealing with the particular situation.

Likely predictors of team adaptability:

\* Individual adaptability. Including even one team member with a low level of general mental ability, extroversion, agreeableness, or conscientiousness can significantly reduce team productivity.

\* Team motivation and attitudes, e.g. belief in team's success, commitment of the members to the team & to its commitments, encouraging members to speak their minds, and backing each other up instead of saying "it's not my job".

\* Adaptive mental models: to perform effectively, team members should share common or overlapping cognitive representations of task requirements, procedures, and role responsibilities. This allows team to coordinate actions implicitly, which is typically more effective than overtly communicating who needs to be doing what.

\* Team experience. Updates / develops mental models. "Routines" to carry out adaptive processes are built up. Successful experience may also increase confidence and emotional stability, successful cooperation may increase cooperativeness, etc.

\* Team heterogeneity in terms of areas of expertise, organizational background / positions, gender, race / ethnicity, etc. Variation in people leads to variation in ideas, but also to difficulties in exchanges of information, in interactions among team members, and in establishing shared mental models. Higher degrees of heterogeneity have been linked to less technical communication among team members and also to poorer team performance under conditions of time pressure and stress. Therefore, there should be enough diversity to allow for the generation of new and innovative ideas, but not so much diversity that team members have difficulty interacting and establishing common ways of interpreting the environment.

\* Team leadership. Team leader – any member of the team to whom others look for guidance. Serves as a role model and helper, and can therefore influence team members' attitudes and mental models.

\* Team type, e.g. membership stable vs. changing frequently; a team brought to existence to address a specific task vs. a permanent team that addresses issues as they arise, etc.

## 6. Conclusion

There is a large body of literature available on adaptivity in specific contexts, but apparently no thorough well-systematized interdisciplinary source exists yet. I am working towards creating it.

## 7. Acknowledgements

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