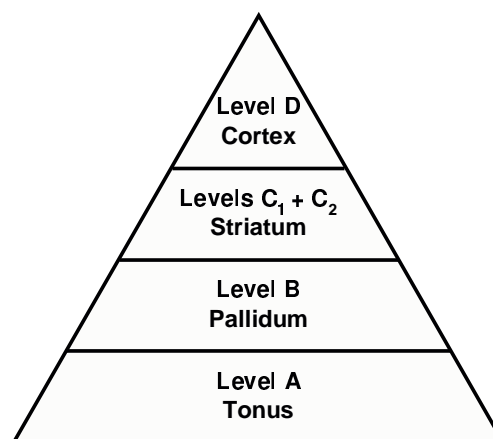


Dexterity and its Development

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Bernstein in his book, establishes the following hierarchical, multi-level structure for the human brain:

- **Level A** – The “**Tonus**”, the oldest brain center, in humans in charge of trunk and neck control, namely posture. Its origin may be found in soft-bodied creatures as worms, starfish and such. This Level resides deep in the brain center (oldest area).
- **Level B** – The “**Pallidum**” the second oldest center, in human in chare of extremities (arms and legs) control. Its origin may be found in first ground living creatures as amphibians and lizards. This level is adjacent to level A, deep in the brain center.
- **Level C** – The “**Striatum**” is the level of “**Space**”. This center is in a process of transition (evolutionary transition) from the brain center to the youngest brain area – the Cortex. At the present state, it still partially resides in both places. Therefore, it is divided in two sub-centers C_1 (in the brain center) and C_2 (in the Cortex).
 - In humans, C_1 is in charge of movements requiring power and force such as sports and gymnastics. Its origin may be found in the first worm-blooded animals such as birds.
 - In humans, C_2 is in charge of movements requiring accuracy and delicacy as needle wiring and clockworks movements. Its origin may be found mainly in mammals.
- **Level D** – The “**Cortex**”¹ is the highest and the youngest level, in charge of pre-planned action series and not just isolated movements. It is mainly identified in humans, however, traces of it exists in higher primates, such as Chimpanzees, Gorillas and Orangutans.

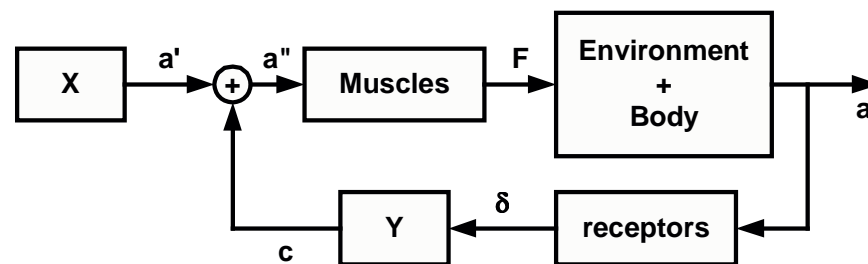


There is a major difference between the first three levels (A, B and C) and forth one. While the first three are automated (instinctic) ones the last one is cognitive. This, easily leads to the understanding why most animals that lack the “**Cortex**” existence are mainly driven by instincts and there level of learning (or training) is quite limited, while humans are mainly cognitive driven and are highly trainable. Furthermore, even in humans, new skills are acquired by means of “**Cortex**” involvement, and only after these skills have been well learned, namely automated, stabilized and fixated, they are abandoned by the “**Cortex**” and their activation is carried out by lower levels.

¹ The “**Cortex**” is actually an anatomic area in the brain, and not a functional, neural center. However, since it is mainly identified with humans, that are the only one really capable of pre-planned action series, it is frequently related as a functional entity and not just an anatomic one.

In order for one to fully comprehend the meaning of the above skill acquisition (training) it must be explained what is difference in the brain between an untrained skill and a trained one. Is it the correct command that has been acquired? Or may be it is something else?

In order to cope with the above question, a more basic question has to be answered. How movements are carried out? Based of the hierarchical, multi-level structure, actions and movements are carried out by couples of centers $\left(\frac{X}{Y}\right)$, where the first (X) is taking the leading role, providing the required action, while the second (Y) fulfills the background role, supporting the required action with all necessary corrections. The process may be schematically presented in the following block diagram:



Where a' is the required action command, provided by the leading level (X), needed to perform the required action a . δ^2 is a feedback signal, provided by neural receptors in the various body organs and the skin, to the background level (Y). c is the required correction, provided by the background level (Y), in regard to feedback signal δ , needed to compensate for deviations in the required action a , due to environmental perturbations and body short comes. a'' is the combined command activating the muscles. And finally, F is the force generated by the muscles.

In all cases, where action series exist, and not just a single isolated action, where planning and scheduling is required, the leading level is D. In the other cases level, C may be the leading level. Level A is always required and therefore is not explicitly mentioned.

Now the question of what differs a trained skill from an untrained one may be answered. The answer is not the required command provided by the leading level, rather then, the required corrections provided by the background levels. Therefore, for already acquired skills the terms automatized, stabilized, fixated are appropriate, since all of them take place at the lower, background levels. Not at the cognitive level D, that always requires attention. An already trained movement is one that the background levels required for its activation, are fully equipped with all necessary corrections, and therefore, may be carried out automatically without the intensive care of the cognitive level.

² Additional feedbacks exist at the local level of the muscles. However, these feedbacks are not provided to the brain centers, and therefore, are out of the scope of this discussion.

Under the above scheme the following movement categories exist:

Category	Description	Example
$\frac{D}{C_1}$	Powerful, static ³ action series.	Releasing a stuck object.
$\frac{D}{C_2}$	Delicate, static action series.	Assembling a wristwatch.
$\frac{D}{(C_1)(C_2)}$	Both powerful and delicate, static action series.	An orthopedic surgery.
$\frac{D}{(C_1)(B)}$	Powerful, dynamic action series.	Moving a piano.
$\frac{D}{(C_2)(B)}$	Delicate, dynamic action series.	Intercepting a flying fly.
$\frac{D}{(C_1)(C_2)(B)}$	Both powerful and delicate, dynamic action series.	Slalom skiing.
$\frac{C_1}{B}$	Powerful, dynamic action.	Weight lifting.
$\frac{C_2}{B}$	Delicate, dynamic action.	Wiring a needle.

Bernstein introduced the concept of “**Dexterity**”. It is easier to understand the meaning of dexterity if some of its characteristics are presented first. Dexterity may be in one of three basic levels – none, hidden or evident (apparent). In order for it to be apparent it has to do with the environment’s features and not just the actor, as it will be explained later.

In order for dexterity to exist several prerequisites have to be fulfilled:

- The skill must be performed in an automatized, harmonic, fluent manner. Meaning, the skill is fully stabilized at the background level and all its corrections have been trained and are available.
- The skill must be performed efficiently and successfully. Meaning, on top of the manner the skill has been performed its outcome must be successful. For example, no dexterity may be accounted to a rings’ gymnast, who performed an excellent exercise but eventually landed clumsily on his face.
- The environment the skill is performed in must be dynamic, quickly changing and surprising. No dexterity may be apparent in a Marathon or a triathlon race. In those sports the feature required is endurance and not dexterity. The athletes competing must maintain a constant pace in order to reach the ending line in a good time. That directly contradicts the requirement of quick adaptations and agile resourcefulness.

The definition of dexterity is the capability to perform harmonically, efficiently and successfully in a dynamic, quickly changing, surprising environment. The world champion in downhill slalom skiing must be dexterous. He must have performed very efficiently and very successfully, otherwise he would not be the world champion, and he did in a fast, harsh environment. The same cannot be said about the Marathon world champion.

³ The difference between static and dynamic is rather the extremities’ functioning is required.