The Definition of Intelligence*

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Intelligence has been defined in many different ways, but an operational definition that would form the foundations of a measurement that is totally objective, applicable to any individual regardless of context, and not influenced by the method used to measure it, has not yet been developed. This article aims to provide such a definition.

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1. Introduction

What is intelligence? Is it really something that can be measured, and if so, is the so-called IQ (Intelligence Quotient) a reliable parameter to assess the intelligence of an individual? Above all, is there only one kind of intelligence or are there many? In the latter case, how do you compare them to each other? We will try to answer those questions starting with a new definition of intelligence.

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2. How Intelligence has been Defined

It is not the purpose of this article to summarize all that has been said and written on the subject. There is plenty of research about it. The fact remains that at the time of writing there does not yet exist a universally agreed academic definition of intelligence. Actually, there are many, such as the one signed by fifty-two researchers in the field in 1994 (Gottfredson, 1994), which states:

> A very general mental capability that, among other things, involves the ability to reason, plan, solve problems, think abstractly, comprehend complex ideas, learn quickly and learn from experience. It is not merely book learning, a narrow academic skill, or test-taking smarts. Rather, it reflects a broader and deeper capability for comprehending our surroundings — "catching on", "making sense" of things, or "figuring out" what to do.
>
> *«MAINSTREAM SCIENCE ON INTELLIGENCE» (1994)*

Although this definition is conceptually correct in its parts, it tends to define intelligence through a series of consequences of its use or effects, of which intelligence is the primary cause, such as to "comprehend complex ideas". Moreover, it refers to the definition of a variety of skills, difficult to define in their turn, such as the concept of "reason", or whose expression is questionable, as the metaphor of "catching on". Therefore, we cannot refer to it as a "scientific definition".

Another definition (Neisser et al., 1996), even more expressive, is the following:

> Individuals differ from one another in their ability to understand complex ideas, to adapt effectively to the environment, to learn from experience, to engage in various forms of reasoning, to overcome obstacles by taking thought. Although these individual differences can be substantial, they are never entirely consistent: a given person's intellectual performance will vary on different

> occasions, in different domains, as judged by different criteria. Concepts of "intelligence" are attempts to clarify and organize this complex set of phenomena. Although considerable clarity has been achieved in some areas, no such conceptualization has yet answered all the important questions, and none commands universal assent. Indeed, when two dozen prominent theorists were recently asked to define intelligence, they gave two dozen, somewhat different, definitions.
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> *«INTELLIGENCE: KNOWNS AND UNKNOWNS» (1995)*

It seems clear that this, more than a definition of intelligence, is in fact a declaration of powerlessness.

By the way, most every mind researcher and philosopher has tried in the past, as well as in the present, to give a definition of this faculty. It is not just a mere curiosity; now more than ever, it is important to figure out if a living being is intelligent or not, especially because we are beginning to accept the fact that life in the Universe is much more widespread than we thought in the past. It is possible that eventually we should wonder about the possibility of some other intelligent alien creature. Therefore, it is important to have a reference standard that can be used to recognize intelligence in a completely different entity too, not just human species.

Some definitions of intelligence speak of "Judgment, otherwise called good sense, practical sense, initiative, the faculty of adapting one's self to circumstances … auto-critique" (Binet, 1916), "The aggregate or global capacity of the individual to act purposefully, to think rationally, and to deal effectively with his environment" (Wechsler, 1944), "…the resultant of the process of acquiring, storing in memory, retrieving, combining, comparing, and using in new contexts information and conceptual skills" (Humphreys, 1979), "Innate general cognitive ability" (Burt, 1954), "The ability to deal with cognitive complexity" (Gottfredson, 1994), "Goal-directed adaptive behavior" (Sternberg, Jeffrey, & William, 1982),"The unique propensity of human beings to change or modify the structure of their cognitive functioning to adapt to the changing demands of a life situation" (Feuerstein et al., 1979).

As you can see these claims look reasonable and acceptable — we could also say that they are mostly true — but they seem to capture only some aspects of intelligence. If we compare the intelligence of a mathematician with that of a person with a great ability to make something by hands, for instance, or compare the latter's one with that of a great artist or musician, we realize that each of these definitions is somewhat lacking.

For example, the definition by D. Wechsler (Wechsler, 1944) and that by R. Feuerstein (Feuerstein et al., 1979) are very focused on a comparison between a living being and the environment that surrounds it. In fact, this ability is certainly one of the reasons why intelligence is one of the success factors of our species. Although it is likely that the interaction with the environment was a fundamental stimulus to the evolution of intelligence in our hominid ancestors, it does not explain enough about the different aspects of intelligence, such as creativity or artistic development of mathematical theories with no apparent practical application.

Let us also look at definitions such as the one by A. Binet (Binet, 1916), which refers to a number of terms of which there is not always a clear definition, such as the so-called "common sense", although it should be noted that this claim also gives evidence to the ability to adapt to circumstances, that is, to the external environment as an important element. It remains to be seen whether this represents intelligence, or is simply a consequence of it.

The most interesting definition is the one of L. Humphreys (Humphreys, 1979), since it tries to define intelligence based on its mechanisms. However, it is not an operational definition, that is, it is difficult to use it to plan a possible experiment that would allow an objective measurement of what we call "intelligence".

3. The Measurement of Intelligence

In order to give a definition of intelligence that is not only based on a particular aspect or feature of this faculty, we must first recognize that, apparently, it operates in many ways, and that proving to have it in a particular situation is compatible with not knowing how to use it in other cases. Once we have done that, we should understand what all these ways have in common, and why we could be smart in one situation and apparently incompetent in another. A classic example is that of a genius, perhaps a mathematician or a theoretical physicist who, though in his field has no rival, is quite clumsy in dealing with practical situations such as assembling or dismantling a mechanism, or making a simple drawing on a sheet of paper.

Obviously the mentioned activities imply some manual skills, and what we call "technique", that we can learn through education and training, but the greater or lesser capacity of certain individuals to perform specific actions is also a manifestation of intelligence and therefore it is important to understand why a very intelligent person in one matter shows awkwardness in another, even when he takes advantage of some education to improve his skills.

That said, how many types of intelligence are there? Raymond Cattel and John L. Horn define two different kinds of intelligence (Horn, Cattell, 1967):

> ...[I]ntellectual abilities are organized at a general level into two general intelligences, viz., fluid intelligence and crystallized intelligence and in terms of visual, auditory, memory and speed-of-thinking kinds of intelligence. …there are those influences which directly affect the physiological structure upon which intellectual processes must be constructed--influences operating through the agencies of heredity and injury: in adulthood development these are most accurately reflected in measures of fluid intelligence. In early (at birth, infancy and childhood) these influences affect both fluid and crystallized abilities. And on the other hand there are those influences which affect physiological structure only indirectly through agencies of learnings and acculturations: crystallized intelligence is the most direct resultant of individual differences in these influences.
>
> (HORN & CATTELL, 1967)

Later on the Cattel-Horn Gf-Gc theory was further developed (Cattell, 1987) and amalgamated with the Carroll's Three-Stratum theory (Carroll, 1993) to generate the Cattell-Horn-Carroll (CHC) theory.

CHC is one of the most well-known theories because it provided the basis for the famous test for measuring intelligence quotient, i.e. IQ (Stern, 1914). It refers to ten broad abilities, which in turn are divided into seventy narrow ones. Obviously, those abilities are not different kinds of intelligence, but it is also true that when one of them is prevalent over the others, it is natural to say that an individual has a particular type of intelligence. An example is people with exceptional memory abilities, which are not supplemented, however, by good problem solving capabilities.

The ten broad abilities are the following:

- *fluid intelligence*, that includes the ability to reason, form concepts, and solve problems using unfamiliar information or novel procedures;
- *crystallized intelligence,* that includes the breadth and depth of a person's acquired knowledge, the ability to communicate one's knowledge, and the ability to reason using previously learned experiences or procedures;
- *quantitative reasoning,* that includes the ability to comprehend quantitative concepts and relationships as well as to manipulate numerical symbols;
- *reading and writing ability*, that includes basic reading and writing skills;
- *short-term memory*, that is, the ability to apprehend and hold information in immediate awareness and then use it within a few seconds;
- *long-term storage and retrieval*, that is, the ability to store information and fluently retrieve it later in the process of thinking;
- *visual processing*, that is, the ability to perceive, analyze, synthesize, and think with visual patterns, including the ability to s tore and recall visual representations;
- *auditory processing*, that is, the ability to analyze, synthesize, and discriminate auditory stimuli, including the ability to process and discriminate speech sounds that may be presented under distorted conditions;
- *processing speed*, that is, the ability to perform automatic cognitive tasks, particularly when measured under pressure to maintain

focused attention;

- *decision* and reaction time and speed, which reflect the immediacy with which an individual can react to stimuli or a task.

Kevin McGrew has proposed a number of extensions to those abilities that include domain-specific knowledge, psychomotor ability and speed (McGrew, 2005). Others have added tactile, kinesthetic (Gardner, 1993) and olfactory abilities (Makino & Yano, 2010) and it is likely that the list is not yet complete.

Undoubtedly these categories are very useful, especially in relation to the measurement of what we call intelligence, but they are indirect measurements, that is, they do not measure the intelligence itself but the ability of an individual to apply it, so much so that according to the stress state of an individual, his personal involvement or his interest and personal motivations, these values can fluctuate quite a bit in the various tests.

In fact, it was demonstrated that IQ scores are strongly linked to mortality (Jokela, et al., 2009), health (Gottfredson, Susanne, & Deary, 2004), education, income (Strenze, 2007), occupational success (Kuncel, Nathan & Hezlett, 2010), parental social status (Neisser et al., 1996), and genetics (Haworth et al., 2010). Therefore, if what is being measured is dependent on so many external factors, we need to focus on much more basic and specific processes of the brain if we want to give a comprehensive definition of intelligence.

In the last couple of decades, several researchers have proposed a dual-process approach to intelligence, that is, theories in which intelligence is the result of two processes, an implicit (spontaneous), unconscious process and an explicit (controlled), conscious process. Many different pairs of terms have been used for that duality, as heuristic vs. analytic, tacit vs. explicit thought, intuition vs. reasoning, and so forth. It is not the purpose of this article, however, to discuss the differences between these models, as well as other models that deal with three or more systems, but rather to show that all these systems, although different from a functional point of view, have a common feature that can be defined and measured. Therefore, rather than positioning the intelligence in one or more systems, the goal is to show that intelligence is linked to a strictly functional aspect of any system of the brain, that is, the management of more or less extended relational schemas. We will see later what is meant by “relational schema”.

To avoid getting lost in the plethora of terms used to indicate the two types of processes in the dual-process theories of cognition, we say that they typically differentiate between Type 1 and Type 2 processes (Evans, 2008). In Type 1 processes, task representations are highly contextualized and influenced by biology and past experiences, whereas in Type 2 processes they are decontextualized, allowing to apply specific cognitive skills to a variety of task domains. In everyday language we can say that Type 1 processes are typical of specialists in a specific subject (i.e. the so-called gurus) whereas Type 2 processes are typical of generalists, that is, people with cross border skills and different kinds of professional experiences in different areas (lateral thinking).

According to dual-process theories, each individual is characterized by both types of processes, although to a different extent (individual differences). In fact, in a recent theory of intelligence, the Dual-Process (DP) Theory of Human Intelligence (Kaufman,2011), both controlled and spontaneous thought processes are important contributors to human intelligent behaviors. A similar theory has been proposed also in relation to how the brain acquires knowledge (Anderson, 2005). It deals with processing routes where Route 1 is related to basic central processes, and Route 2 is related to cognitive development.

There are also other theories that states that there are multiple systems (Aunger & Curtis, 2008) and in any case, even a dual-process theory is not necessarily a dual-system theory. For example, Stanovich distinguishes inside the Type 2 processes two different minds: a reflective mind, and an algorithmic mind, interacting each other, and both interacting with an autonomous mind related to Type 1 processes consisting of a heterogeneous set of systems (TASS) (Stanovich, 2009). In fact, as reported by Evans (Evans, 2008) and Stanovich (Stanovich, 2004), Type 1 processes should not be associated to a single system in the brain, but to a plurality of systems each one operating in response to its own triggering stimuli.

According to the tripartite theory of Stanovich (Stanovich, 2012), each mind has different functions and interact in a specific way with the other minds, described by a well-defined workflow. For example, the reflective mind can initiate the process that takes the algorithmic mind to override the autonomous mind.

We will see, however, that all those types of processes can be associated with the same definition of intelligence. We will also see that, according to that perspective, we can consider again Type 1 process contributing to intelligence even if the execution of those processes is mandatory when they encounter triggering stimuli, and they are not dependent on input from high-level control systems (Stanovich, 2012).

Differently from previous theories, therefore, I do not position intelligence in one or more specific systems, nor I associate it only to a specific type of processes, but I consider it an "ability of the brain", that is, the ability to manage relational schemas. To do that, all systems and processes are involved. I also state that the development of physical neuronal patterns may convert some — but not any — Type 2 processes in Type 1 processes, that is, our mind does not have a fixed and immutable structure, but has the ability to restructure itself to automate otherwise considered analytical processes.

As a consequence, even if I agree with Stanovich that the actual measures of intelligence in use assess only algorithmic-level cognitive capacity, I add that performing many times the so-called intelligence tests, moves some algorithmic abilities to the autonomous mind, thus acquiring greater capabilities in performing these tests and then getting a higher IQ score (Flynn, 1987). By using a computer science jargon, we could say that some software function have been moved to firmware.

Such an increase of IQ score, however, does not correspond to an increase of intelligence, because does not change the size and complexity of the relational schemas that are managed, but only the speed in managing them. Hereinafter, I propose to call such an ability by using a different term (taxagyniosis).

There is not a conflict, anyway, between my theory and the dual-process models or the Stanovich's theory. All those models are focused on describing how our minds work and associate different roles/functions to specific subsystems. My approach is based instead on what these systems process. If we wanted to use the computer jargon, we could say that the current models are function-centric while mine is data-centric.

4. A different Approach

So let us go deeper: the goal is to find a definition

1. simple but encompassing all the cases described above;
2. capable of detecting a mode of measurement that is independent of the context;
3. non-trivial, that is, even if generalized must still be usable.

The first objective means that the definition should not conflict with evidences and widely accepted established theories. The second objective means that the definition should give the possibility to hypnotize a measurement process that is not affected by the process itself and that is very little influenced by external factors to the subject of measurement. The third objective simply means that such a definition must be useful, that is, has practical implications.

To achieve these objectives, let us begin to see what all the various kinds of intelligence — the skills that we mentioned earlier — have in common. For example, what unites an artist and a theoretical physicist, a skilled mechanic and a great gymnast? Note that I have not added the latter by chance, because knowing how to use the body in a coordinated manner is also an expression of intelligence (Smits-Engelsman & Hill, 2012).

First, we have to deal with a certain amount of stimuli and information. Some are external, that is, they are related to the environment that surrounds us; others are internal, that is, they are part of what we have learned or what is innate for us, if not of our own physiology. Here already we see some of the abilities mentioned above. Consider external stimuli, for example: they come to us through the senses, which are handled by visual, auditory, tactile, olfactory, and gustatory abilities, as well as by the ones related to the sense of balance (Gaerlan, Alpert, Cross, Louis & Kowalski, 2012) or the sensitivity to motion (Reichardt, 1961). In reality, this is a limited list. If we just focus on the tactile ability, we should divide the sensitivity to heat and cold, pressure and pain (Weber, 1996); some researcher stated that human beings, albeit to a lesser extent to other animals, have a certain sensitivity to electric and magnetic fields too, even if electroreception and magnetoception in humans are controversial (Baker, Mather & Kennaugh, 1983).

Let us say that in general there are sensory stimuli, a more or less marked reactivity to them, and an interpretative ability of the brain to one or more combinations of stimuli. Not for nothing, it usually says that we see by the brain, not by the eyes. Change blindness is one example of how sight is related to the way in which the brain processes images that it receives from eyes (McConkie & Rayner, 1976).

In reality, stimuli and information are not entirely independent, but it is important to distinguish them. A stimulus can become information if processed by the brain, while information, such as a repressed memory, can unconsciously generate a stimulus (McFarland, Warren & Crockard, 1985).. There are however stimuli that can be considered as such, for example, a sound, as well as pieces of information that do not necessarily generate a stimulus, such as a mathematical formula. Obviously, a sound, once related to previous memories can generate information, while a mathematical formula, if applied, can lead to a result that generates fear or curiosity. We will get to that shortly. Let us say for now that stimuli and information are two different elements, although sometimes bind in a one-to-one correlation.

Let us go back to stimuli. We have said that there are interior ones: some are internally generated and are the result of chemicals produced by the body whose functions are extremely varied. Classic examples are hormones. Others are more related to our brain and the information stored in it. Each stimulus, internal or external, in fact, causes a reaction in the brain that can lead to light memories of previous stimuli and information that are going to add to those received (Clark, Maisog & Haxby, 1998). These mechanisms can be conscious or unconscious. Just consider, for example, the experiments of classical conditioning conducted by Ivan Pavlov (Pavlov, 1927) and Edwin Burket Twitmyer (Twitmyer, 1905).

Conditional reflexes are the consequence of well-defined and acquired relational schemas, both logical and physical (neuronal). In fact, as may occur for Type 1 processes, where task contextualization can lead to erroneous judgment and rash decision making, a conditional reflex may generate a response to a stimulus that is misleading. In fact, the conditioned response is the same of the unconditioned response even when the conditioned stimulus is not followed by the unconditioned stimulus.

In fact, there is another type of stimulus or internal information, i.e. that generated by the brain as a result of processing of stimuli and information that have come from the environment or from the rest of the body. Therefore, we are dealing with a dynamic system continuously evolving, from which comes the concept of thought, reasoning, planning and the like.

An important aspect to highlight is that this set of stimuli exists in any situation we are in, that is, it exists whether we are talking about a mathematician who tries to solve a problem, or a painter who is combining the right colors to represent the leaves of a tree, or an athlete who is preparing to try to break the record in the long jump. Each of these people, in order to achieve their own objectives, combines stored information and internal stimuli with information and stimuli acquired in real time (Gold & Shadlen, 2007).

It is important to note that reaction speed is not necessarily a key factor here. There are uses of intelligence in which the individual has neither need nor motivation to be fast, and others in which the speed is physiological to the objective, such as the ability to make quick decisions by a fighter pilot in combat (Forstmann et al., 2010).

Therefore, speed is an important factor but not a necessary one. What is necessary then and, above all, how may this need be quantified in order to develop a method of measurement that discriminates among different levels of intelligence?

When we spoke of stimuli, we assumed an aspect, that is, a relationship between them. A more or less complex system of stimuli and information is useless to a living organism if each element remains isolated. Therefore, to correlate these elements is a fundamental aspect so that they can be used for some purpose. Obviously not all the elements in question are correlated to all others: if we would like to give a visual representation of this system, we should use a graph in which each node is an element, that is, a stimulus or a piece of information, and each segment is a correlation between them (West, 1996). We called it a relational (logical) schema, to distinguish it from physical schemas, that is, neural patterns.

Obviously, each node must be connected to at least one other node. Moreover, some nodes may form more or less dense clusters, especially if we introduce a metric for which the shorter the distance between the nodes, the greater the correlation between the same. In fact, a characteristic of this type of graphs is that each of its components, whether it be a node or a link, can have a weight, that is, it can be considered more or less important. In terms of the graphical representation, we could color in a different way the different types of nodes — internal and external stimuli, information stored or received from outside — by intensifying or fading the color tone depending on the weight of the node, and use just the metric mentioned to indicate as well the weight of each correlation.

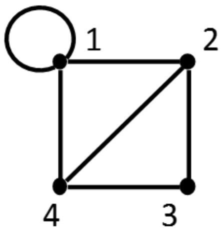
Well, the definition of intelligence proposed here is based in fact on an individual's ability to generate and manage more or less complex graphs of this type: "Intelligence is the ability to develop and manage relational schemas." (Dario de Judicibus, 2004).

As you can see, this definition does not come about if the various nodes are stimuli or memories; they have to do with the environment or remain encased in some mental cogitations; if they concern a complex mechanical mechanism or deal with the production of a musical melody. The focus is not so much on the nodes, as on the correlations and thus on the complexity and size of the corresponding graph. Focusing on links rather than nodes provide us with that degree of decontextualization that allow us to apply this definition to a wide range of situations.

The interesting thing is that no matter what a graph represents, it is always possible to define a metric on the complexity of the same. For example, according to David L. Neel and Michael E. Orrison, the linear complexity of a graph can be defined as to be the linear complexity of any one of its associated adjacency matrices (Neel & Orrison, 2006). Note that an adjacency matrix is a means of representing which nodes of a graph are adjacent to which other nodes.

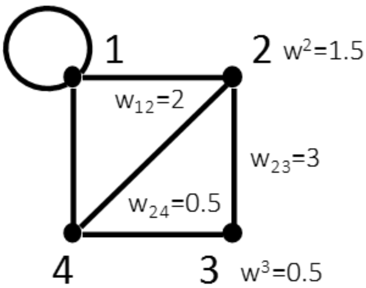
Obviously, in our case, we may want to introduce a measure that, firstly, takes into account the weight of the various correlations and, secondly, the significance of the various nodes, even if in the first approximation we decided to ignore the latter. In a traditional adjacency matrix, a_{ij} entry can be 1 or 0, depending if node i is connected or not to node j. Correlation weights can be introduced by changing the value of the entry, that is, to allow for entries values different by 1 when nodes are connected. Nodes weights can be introduced by multiplying all the entries related to a specific node (matrix row) by a specific value.

For example, given a graph Γ, the adjacent matrix A_Γ according to the traditional graph theory is:



$$\begin{pmatrix} 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 \\ 0 & 1 & 0 & 1 \\ 1 & 1 & 1 & 0 \end{pmatrix}$$

If we define nodes and connection weights, however, we can change the adjacent matrix as follows[1] :



$$\begin{pmatrix} 1.00 & 2.00 & 0.00 & 1.00 \\ 3.00 & 0.00 & 4.50 & 0.75 \\ 0.00 & 1.50 & 0.00 & 0.50 \\ 1.00 & 0.50 & 1.00 & 0.00 \end{pmatrix}$$

As for the speed of acquisition of information and response to stimuli, as well as the ability to generate or to recollect more information, when I initially developed this definition, in November 2004, and mentioned it in a previous article, I also defined the following corollary: “The more broad and complex are the schemas that an individual develop and manage and faster this happens, the more intelligent he/she is” (Dario de Judicibus, 2004).

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[1] The notation uses subscript (lower) indexes for links and superscript (upper) indexes for nodes.

Further research took me to still consider valid the first part of this claim, but not the second, although the speed in reacting, in deciding, in understanding, in developing and solving a problem often is associated with higher intelligence. There are in fact highly intelligent individuals who need to mull over the information a lot before reaching a conclusion, but often they reach conclusions that other individuals, although faster, cannot even imagine. Therefore, the speed is certainly a useful factor from a practical standpoint, but it is suggested that it should not be used in the definition of intelligence.

It is also true, anyway, that under the same problem or situation, if two individuals arrive at the same result at different times, it is tempting to attribute to the faster a higher degree of intelligence. However, if we deal with the problem of defining intelligence, in addition to looking for a simple, measurable, and useful definition, there is an implicit goal to find one that would be applicable to all cases. This means that, contrary to what has been done up to now, the definition should allow us to compare the intelligence of a scientist with that of an artist, an athlete, or a scholar. Since these individuals face very different challenges and have different needs in terms of responsiveness, we have to separate the speed factor from the definition of intelligence or any of its corollary.

However, this does not mean that this property should not be taken into account, so it is necessary a specific definition for that factor: “Taxagyniosis is the speed in developing and managing relational schemas” (Dario de Judicibus, 2012).

Let us consider an athlete who is contemplating the jump to be made: he takes all the time he needs, and then, once started, he acts very quickly, possibly making changes to the movement taking into account any factors that could not be assessed in advance. Therefore, taxagyniosis is vital in the execution, whereas it has a limited role in the preparatory phase, although obviously an athlete cannot spend hours thinking before making a jump. Taxagyniosis can play an important role in artistic activities where the artist “runs off” a creation.

Actually, what often happens when dealing with a problem, is that intelligence allows us to build our graph by selecting, combining, and generating more and more nodes and correlations, while the taxagyniosis comes into play at certain times to speed up the process. Hereinafter we will correlate taxagyniosis to the existence of neural patterns, which match specific relational schemas.

Some people can speed up the whole building whereas some other people proceed in jerks, perhaps more slowly at first and then faster and faster as the pattern is composed. These two faculties, used together, are the basis of human beings' ability to deal with problems that lie ahead and then to carry out all the tasks that we have seen in the description of the various definitions of intelligence discussed above.

It remains an open question: if a person has a good intelligence and a certain level of taxagyniosis, why can he actually use it very well in certain situations whereas he may find difficult to exploit in other ones? We can identify two causes, which may act independently or together.

The first reason is obvious. We have said that intelligence is the ability to develop relationships of any kind among a set of stimuli and information from a variety of sources. We have therefore focused our attention on relationships, rather than on the nodes. The latter, however, play an important role, especially with regards to the internal elements. If you have to deal with a problem and you do not have the knowledge to do it, although you may be intelligent, it will be very difficult for you to succeed. Of course, some result could be achieved by reasoning, but large gaps in knowledge cannot always be filled with the logic starting from other notions. Similarly, if you have not trained your body or your hands to operate certain movements, your brain will not have the ability to apply certain psychomotor skills when needed. The genius who has never even assembled a toy car certainly will not be able to assemble a complex mechanism only thanks to his intelligence. Maybe he will understand immediately how it has to be assembled, but it does not follow that he will be able to apply such understanding.

The second reason is less obvious but equally important and explains why certain individuals, however intelligent and well motivated, are not able to overcome their limitations in certain areas no matter how much they commit. We talked about relationships and probably most of you have thought of some logical, rational connection, but there is a family of relationships that has nothing to do with logic; they are emotional relationships (Izard, 1993). The choice of a color, the aesthetic sense, the artistic creativity, all apply to mental schemes in which a large number, if not exclusive of correlations among the various elements, is emotional and not rational (i.e. cognitive).

This type of relationship has a very peculiar characteristic that rational relations have not. A logical relationship can connect two nodes in a positive or negative way, that is, I can say that A is related to B or that A is not related to B. A lack of relationship then, ironically, is a relationship itself and we often use this type of negative relationship in the reasoning. An example is Occam 's razor (Soklakov, 2002). In the case of emotional relationships, however, while the positive relationship tends to unite with each other node, the negative keeps them at a distance, that is, tends to exclude them (Jung, Wranke, Hamburger & Knauff, 2014). It is not a logical exclusion but a real expulsion from the diagram that prevents the brain correlating that node to others. In fact, such a mechanism of rejection (i.e. that refusal) prevents the completion of the schema.

In practice, some people cannot use their brains in certain areas because they reject some of those elements that serve to complete the corresponding schemas. In essence, there are aspects that we refuse maybe because they unearth painful memories, repressed events, trauma, or simply because the cultural conditioning impressed when we were kids turned them into taboos (Gatewood, 1993). Often this happens at an unconscious level so that even if at the cognitive level we want to reach a certain goal, on a subconscious level we are not available to deal with everything we need to achieve that goal. There are evidences that cultural variations affect the way individuals perceive the world too (Chua, Boland & Nisbett, 2005).

Another factor that prevents correctly managing a schema is myside bias, or confirmation bias, that is, the tendency to search for, interpret, or recall information in a way that confirms one's beliefs or hypotheses. In practice, the schema is altered to achieve in any case a specific result. Recent researches demonstrates that the magnitude of the myside bias shows very little relation to intelligence (Stanovich, West, & Toplak, 2013).

5. The Physical Connections

So far, we have spoken of logical schemes, but the brain is also a physical organ and is formed by neurons, which interconnect with each other in a dynamic way. Without these connections, nothing we have said so far makes sense. In fact, it is evident that a relational schema must also correspond to some physical connections between individual neurons.

It is not said that every mental scheme has a well-defined physical counterpart in a two-way relationship, of course, but there is certainly a strong correlation between how neurons are connected and what patterns we can or cannot generate. Some relations, in fact, as well as the logical ones, often take already tested paths and therefore the connection is fast because, in fact, it already exists; others, like the ones related to the body movements, may need to be developed from scratch if the movement is unusual and never experienced previously.

We define a neural pattern as a connected subset of a biological neural network that is actively involved in some mental process. For example, all the connected neurons that are involved in taking a decision. Again, if we want to use a computer science jargon, we can say that relational schemas are logical data structures, whereas physical neural patterns deal with how those data are stored.

Neural patterns do not apply only to reasoning, anyway. Classic examples such as martial arts show that, once you learn a technique, you need to repeat it countless times before being able to internalize it. Our brain has in fact to create a series of new neuronal connections to learn a movement that is not natural to us. It often happens that after trying for days, suddenly, as if by magic, the technique will become spontaneous and from that moment we will apply it almost “without thinking”, in response to a series of well-defined stimuli, such as a particular type of attack by our opponent (Roberts, Bain, Day, & Husain, 2013).

Therefore, we can say that cognition can be somehow embodied in action so that the motor system can participate in what is considered as mental processing. This can be done by both trying an action several times (Wollesen, Bettina & Voelcker-Rehage, 2013) or looking at someone else performing that action (Rizzolatti, 2004).

In addition, our brain has areas dedicated to specific tasks. Typical examples are the visual cortex and the areas devoted to language (Brodmann, 1909), such as the motor (or Broca's) and the sensory (or Wernicke's) speech areas, or even the auditory association cortex. There are however many other ones and new ones are constantly discovered. For example, Xiaoke Chen recently found four areas of the brain devoted to the reception of tastes: sweet, salty, bitter, and umami (Chen, et al. 2011).

It is therefore clear that if a relational schema needs to involve some specialized areas and the corresponding neural connections are damaged or have some disease that alters their functioning, that situation will have an effect on our ability to complete the pattern. For example, those who suffer from aphasia, that is, that have lost the ability to bind a meaning to specific words, are in the same condition as an individual that visits a country where people speak a language that is totally unknown to him.

Now, let us imagine performing an intelligence test on a talented American writer's ability to read and write, and let us do it in the Chinese language. Unless he knows that language well enough, he will fail in full. You will say that it is patently obvious if not trivial! True, but this also means that a test of intelligence that requires the development of certain mental patterns in a person who has the objective impossibility to build such schemes can lead to a meaningless result. We all agree that it makes no sense for someone who does not know Chinese to take a test in to that language, but there are other limits that are much less obvious and that could adversely affect a test simply because we are not aware of them. As far as language is concerned, for example, people who speak different languages do indeed think differently and even flukes of grammar can profoundly affect how people see the world (Casasanto, 2004). Cultural background can also affect metaphor interpretation and, in general, understanding of statements in other language, even in bilingual individual (Littlemore, 2003).

Therefore, physical connections are important. Learning is one of the mechanisms used to develop connections of a certain type. You can study the Chinese language, as you can obviously do for trigonometry. However, there are people who find easy to learn other languages, as well as others who are even struggling with their own. Similarly, there are people who have a great capacity for abstraction and others who need every concept to be aided with practical examples (Ellison,1908). Learning and commitment being equal, in fact, different individuals get different results.

But if on the one hand learning really helps to change the neuronal structures in order to facilitate the development of certain schemas, and on the other the ability to develop and manage them is the foundation of intelligence, it follows that learning does not only help to increase our knowledge but actually affects the intelligence itself. In substance, a person who since he was a child lived in a stimulating environment and was seriously engaged in studying will not only be more scholarly than others will, but also more intelligent (Hebb, 1947).

Now it is easy to see how, as stated previously, both Type 1 and Type 2 processes deal with relational schemas. The difference is that Type 1 processes are related to schemas where physical connections are already well established, whereas Type 2 processes causes changes in the actual physical connections of neurons. This is why Type 1 processes are usually faster and requires less energy but do not generates new schemas. We could say that Type 1 processes can be associated to an "evolutionary" model whereas Type 2 process can be associated to a "revolutionary" model of relational schemas.

Note that this has a significant consequence, that is, all intelligence tests based on solving specific categories of problems, as for instance IQ Tests, affect the result of the test itself. In fact, the more an individual is solving those kind of problems, the more the logical connections generates physical connections that move the processes from Type 2 to Type 1. Practically, IQ tests measure the ability to solve IQ tests, not intelligence. To measure intelligence according to the definition provided in this article, it is necessary to propose to the subject tests based on managing more and more decontextualized complicated schemas to avoid establishing physical connection patterns that can be used to solve more quickly other schemes.

6. Conclusions

Now we have all the elements to answer the questions asked in the introduction of the article. First, we can say that intelligence is the ability to develop and manage more and more large and complex patterns of relationships. Such ability is a basic process that is underneath any other cognition process. For example, Type 1 processes are based on that ability when there are neural patterns that matches specific logical schemas, whereas Type 2 processes involve the creation of such physical connection when new logical schemas arise. The speed in managing such relationships is no more part of the definition of intelligence but is a different ability, called taxagyniosis, which is affected by several internal and external factors, such as neural connections and cultural background.

The consequence is that it is not possible to measure high-level processes because the process of measurement itself is going to affect the resulting values. On the other hand, if we focus only on that very basic process, we can measure the complexity of decontextualized schemas and use such a measurement as an indirect measure of intelligence. It is important to test intelligence on generic schemas to avoid that other factors may affect the result of measurement. Therefore, we need to measure the importance (node weight) of the nodes of a schema, the strength (connection weight) of relationships between nodes, and calculate the linear complexity of the corresponding adjacent matrix.

Thus, we cannot compare different kinds of intelligence — for example, the ability to solve a mathematical problem with respect to the ability to write a novel — if by "intelligence" we use the previously mentioned definitions, for example those of CHC Theory, but we can compare the measurements of intelligence, as defined in this article, that are underneath the corresponding logical and creativity processes.

Eventually, changing the way we define intelligence, allows us to distinguish between the very basic process that represents the core of cognition processes, and all the other higher-level processes that apply such ability to many different situation, as solving technical problems, creating pieces of art, using tools or our own body in work or sports activities.

Appendix

The term taxagyniosis is a neologism that was coined following the same etymological path of the term intelligence. According to some etymological dictionaries, this derives from the Latin intĕr (between, among) and legĕre (collect, select, read)[2]. Therefore, the intelligence is the ability to bind, gather together and therefore “form concepts”.

At first I thought of joining celeritĕr (quickly) and legĕre, but the sound was not particularly pleasant, so I turned to the Ancient Greek: in that language αναγιγνώσκω means “to master” or “to read”, whereas “quickly” can be translated as τάχα.

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[2] Other possible etymons are intŭs and legĕre, i.e. “insight”, and in, tel, and legĕre, i.e. “deeply understand remote things”. However, they are questionable interpretations since the former — commonly adopted – demonstrate a forcing in the way intŭs should change, while the latter assumes the presence of the Indo-European prefix */tl/, very common in modern Greek (τηλε) and used, for example, in the words telephone, telepathy, and television, but very rare in Latin.

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