Editorial

Wanted! Creative Quantum Physicists Around the Age of Thirty

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Introduction

The expressions "*genius*", "*skill*" and "*God-given creativity*" are generally taken to be synonymous. "*Creative thought*" is an expression we use to mean producing new, original, ingenious, and clever ideas which nobody has thought of before. A creative person or individual is one who works in new fields, makes new observations, and who makes new predictions and inferences.

The psychologist Mihály Csíkszentmihályi defines creativity in this way:

> "Creativity of a type to change culture definitively does not come about in the mind of a single person... In order for it to have an effect, the idea must be able to be expressed in a way that others can understand, it must gain the general acceptance of experts in the discipline, and finally it must be integrated into the cultural field to which it belongs." (from Andreasen, 2005).

One of the basic components of creativity is individual "freedom". New relationships, new viewpoints and new ways of description include new insights. A second component is usefulness, that is, suitableness of purpose. Usefulness is awaking new feelings in others and creating inspiration. The final component of creativity is that in the end it results in some kind of "product". That is, creativity needs to create something (Andreasen, 2005). A creative person is one who makes incomparable contributions to art, science, philosophy, physics or mathematics. If there is no contribution, we cannot speak of a measurable or knowable creativity.

For creativity to emerge in a group or an individual, there must be the following: 1. Freedom, novelty and a feeling of being at the edge, 2. Communication with a creative society, 3. An atmosphere of free and fair competition, 4. Craftsmen and patrons, and 5. Economic wellbeing, because "a teacher whose students do not surpass him is a bad teacher" (Arık, 1987; p. 87).

Creativity begins with the individual. That individual takes up a problem or asks a question, and goes in pursuit of a new conceptualization or a new view. These creative individuals need to be bright but don't need to be too bright. The characteristics of a creative personality are being open to experimentation and change, rebelliousness, individuality, sensitivity, playfulness, self-assertiveness, curiosity and simplicity. Creative individuals tend to view the world in an unprejudiced and individualistic way.

The basic characteristic of creative individuals is being open to new experiences and being able to see things which other people cannot see. Looking around them, they do not see the world with the blinkers of tradition. The greatest friend of openness to experimentation and adventure is the ability to cope with uncertainty. Creative individuals are not bound to the certainties of a black-and-white world, and they like and take notice of grey tones just as much.

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Grappling with unanswered questions and sailing in uncharted waters gives them more pleasure than routine tasks.

Creative individuals are adventurous. They love to discover. They don't like rules imposed from outside. They respond to that propelling force that comes from within them. Being open to feelings and information and the lack of set standards can create murky boundaries to identity and self. This can cause a tendency towards certain psychological illnesses and at the same time a tendency to mysticism. Such an individualistic person can seem strange to others.

Self-assertiveness is one of their important characteristics, because they are constantly met with rejection for their pushing the boundaries and their original viewpoints. All creative people, including physicists, have to get used to seeing their work suppressed or their projects not being financed.

For creativity, apart from the fact that creative people are generally a bit more intelligent than average, above a certain level the correlation between intelligence and real creativity is approximately zero. A very creative person is not one who is remarkably intelligent. Creativity is not a process of logic and reasoning. The source of creative ideas is mostly unclear, and they appear suddenly and spontaneously. Creative people are good observers, in spite of the idea that "*there is no objective observer who can remain outside the experiment*" advocated in Heisenberg's uncertainty principle. Because they are turned in on themselves, they sometimes come across to others as distant, cold, or even unfeeling.

Albert Einstein (1879-1955) and Henri Poincaré (1854-1912) described their creative processes many times. These two geniuses both emphasised that their discoveries came all of a sudden. Poincaré characterised his inspiration occurring in four stages. Creativity proceeds as internalisation, incubation, illumination and explanation. *Internalization* is a person's consciously digesting the data of the problem. Then at the *incubation* stage, the person subconsciously distances himself from the problem and the data which he has previously consciously internalized while going about his daily business. The most important stage is *illumination*. At this stage, the solution to the problem comes out unexpectedly. The final stage is *confirming and explaining* this instantaneously-appearing solution. The sudden solution is in fact the product of a long subconscious process (Poulantaz, 2001). As Poincaré said, in short, "*We prove with our logic, but invent with our intuitions. To do geometry requires more than mere logic.*"

Personality and Neurotransmitters

Our personality traits come in part from our genetic make-up, and also from our previous experiences and from our expectations at the moment when a behavioural response was formed. There are two basic components of human personality: temperament and character. Temperament is habit and skill, genetically determined and related to perceptions, while character expresses the individual differences at the base of concepts and in values. Temperament has more to do with genetics, while the character component relates more to cultural make-up. Temperament is related to our early childhood, while character matures with age.

Today, tests have been developed to measure character and temperament. Cloninger has established a seven-factor personality model. This model is composed of four temperament and three character dimensions (Cloninger *et al.,* 1993). The four components of temperament are novelty seeking, harm avoidance, reward dependence, and persistence. The three components of character are self-directedness, cooperativeness and self-transcendence.

The novelty-seeking personality type comprises qualities such as a genetic tendency towards discovery, frequent investigative activity, impulsive decision making, overestimation of the possibility of getting a reward, quick-temperedness, and unrestricted active avoidance. In the *harm-avoidance personality* there is a hereditary tendency towards preventing or stopping behaviour. It shows such passive avoidance behaviours as a pessimistic anxious state, fear of uncertainty, shyness of strangers, and quickly getting tired. In the *reward-dependent* personality, a behaviour always

appears of learning by previous reward or punishment. A reward-dependent personality is one which shows feeling, social connectedness, dependence on the approval of others and showing off. *Persistence* is exhibited in resistance to the extinguishing of a behaviour pattern when no reward is obtained.

Studies showing the operational state of the brain have found a relationship between the novelty-seeking personality and the level of dopamine. At the same time, there is high serotonergic activity in a harm-avoiding personality, and a reward-dependent personality is related to an increase of noradrenaline in the brain. An increase in glutamate has been found in the brains of those with a persistent personality (Enna and Beer, 1981; Wang *et al.,* 1998). Our personality traits shown to the outside vary in accordance with the relative distribution levels and balance of these neurotransmitters in the brain. Each one of us has a different personality, but only some of us have a *creative personality*.

Age, Creativity and Dopamine

Age is another significant factor for creativity. Most mathematicians make their most important discoveries between the ages of 20 and 30 (Andreasen, 2005; Stern, 1978). Anyone making a mathematical discovery after the age of 50 is an exception. Similarly, a simple analysis of physicists gives remarkable results (Table 1 and Figure 1). Creativity may be a function of personality characteristics, but the balance between neurotransmission systems which provides motivation and enables persistence and the ability to focus on the topic in question is affected by age. This balance is constantly changing with age.

Increased dopamine is connected to creative thought in the same way that it is closely related to various psychiatric illnesses and psychoses. Psychosis is generally associated with dopamine. According to the accepted dopamine hypothesis, psychosis is formed because of excessive activity in certain areas of dopamine neurons in the brain (*mesolimbic pathways*). One of the two important pieces of evidence supporting this hypothesis is that source dopamine suppressants (antipsychotics) reduce psychotic symptoms, while medications which increase the activity of dopamine (such as amphetamines and cocaine) trigger psychosis in some individuals.

Table 1. The years and ages at which famous quantum physicists made their discoveries or proposed significant changes. Ordering on the table is not by name or date. With those who made more than one significant creative contribution, the younger age is taken. Average age values on this table were found to be n=20 for physicists, average age 31.9, and age range 22-44. Date of birth can be derived from age at discovery and year of discovery.

Physicist	**Significant Discovery**	**Year of discovery**	**Age**
Max Planck	Planck constant	1900	42
Niels Bohr	Bohr Atom model	1913	27
Werner Heisenberg	Uncertainty principle	1927	26
Wolfgang Pauli	Pauli exclusion	1925	25
Erwin Schrödinger	Wave equation	1926	28
Satyendra Nath Bose	Bose-Einstein condensate	1924	30
Albert Einstein	Photon	1905	26
Brian Josephson	Josephson equation	1972	33
Abdus Salam	Electroweak interaction	1967	41
Steven Weinberg	Electroweak interaction	1967	34
Sheldon Lee Glashow	Electroweak interaction	1967	35
Richard Feynman	Diagrams	1941	23
Hugh Everett	Many-worlds interpretation	1957	27
Pascual Jordan	Quantum field theory	1929	22
Ernest Rutherford	Nucleus model of the atom	1909	40
John Bell	Bell inequality	1964	36
Alain Aspect	Entanglement	1980	33
James Chadwick	Discovery of the neutron	1932	41
Max Born	Probability density	1926	44
Henry Moseley	Atomic numbers, *x*-ray energy	1913	26
		Average age (n=20)	31,9

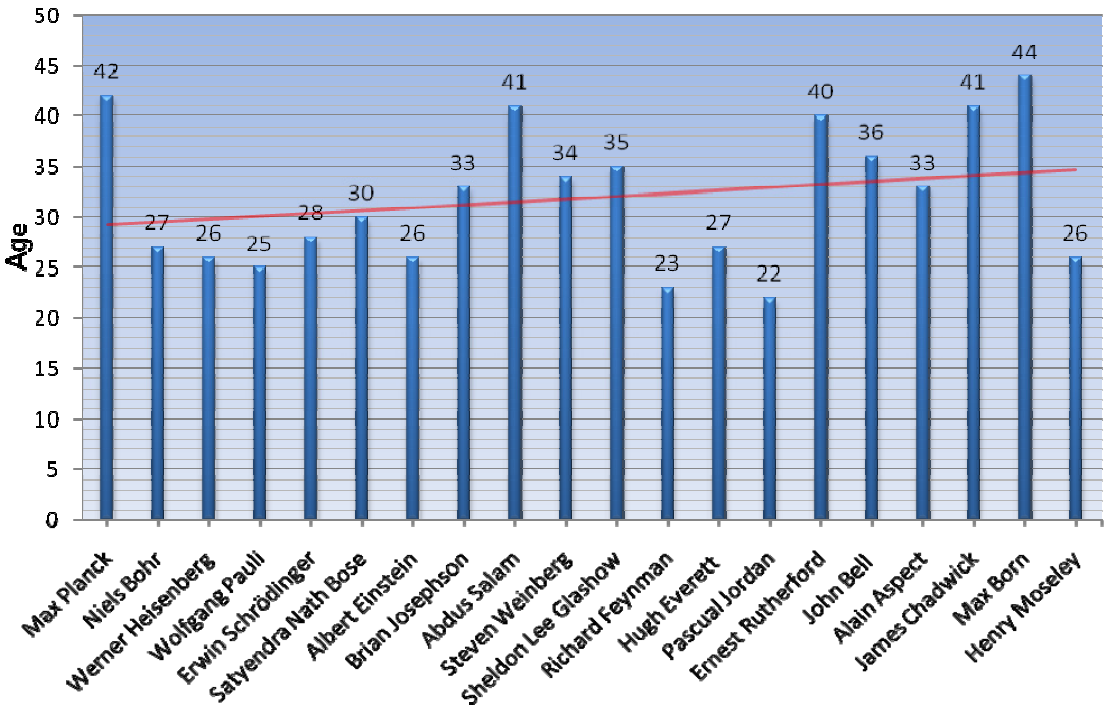

Figure 1. A different view of the ages at which famous physicists made their discoveries or proposed significant changes, or their age of greatest creativity. *Red line*: mean age trendline (©*NeuroQuantology*).

With age, a decrease in neurotransmitters and their functions can generally be seen; it is not only the number of brain cells that decreases with age: presynaptic and postsynaptic changes also occur. Presynaptically, there are changes in neurotransmitter synthesis, storage, secretion and re-uptake. Postsynaptic changes occur in the receptors to which neurotransmitters bind, and in the secondary messenger system. For example, there is a reduction of around 6% every ten years in dopamine D1, D2 and D3 receptors in the brain after the age of 20 (Enna *et al.,* 1981; Wang *et al.,* 1998). This reduction has a direct effect in a chain reaction from neurotransmitter to cognitive function. The reduction is not only restricted to dopamine: a reduction can be seen in all neurotransmitters including serotonin. (Wong *et al.,* 1984; Wang *et al.,* 1998).

Cells which contain dopamine are concentrated in two different parts of the brain, the ventral tegmental area VTA and the substantia nigra (SN) pars compacta. The dopamine system causes incentive activity in addition to many other activities, and focuses the attention. There are at least four different dopamine sensors. D1 and D2 are concentrated in the depths of the brain, D3 in the limbic system and the nucleus accumbens, and D4 in the mesocortical system (Figure 2 and 3).

Dopamine is of critical importance in personality and behaviour through the system which extends from the VTA to other areas of the brain (Depue and Collins, 1999). Of course, like all neuro-anatomical pathways, the pathway is expected to show anatomical and functional differences between individuals. Although there are many different theories of personality, the importance of the VTA-DA extensions on personality has often been emphasised (Cloninger *et al.,* 1993; Netter and Rammsayer, 1991; Zuckerman *et al.,* 1991). Although it provides extrovert or pleasure-seeking behaviour, this pathway also functions in other psychotic illnesses and aggressiveness. The chemical stimulation of dopamine pathways causes both extroversion and pleasure-seeking, and when plotted as a response curve, is *U*-shaped (Netter and Rammsayer, 1991). Of course there many kinds of sub-types of dopamine receptors: in particular, D4 receptors have been found to be associated with novelty seeking and the expectation of reward (Benjamin *et al.,* 1996; Ebstein *et al.,* 1996).

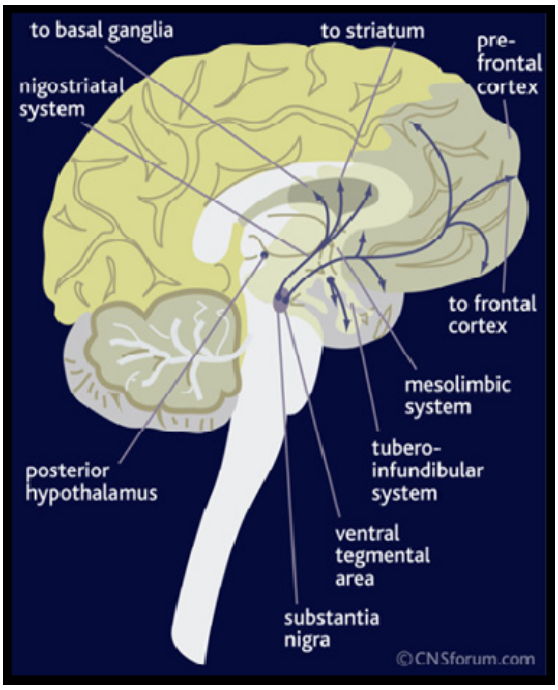

Figure 2. Dopamine is transmitted via three major pathways. The first extends from the substantia nigra to the caudate nucleus-putamen (neostriatum) and is concerned with sensory stimuli and movement. The second pathway projects from the ventral tegmentum to the mesolimbic forebrain and is thought to be associated with cognitive, reward and emotional behaviour. The third pathway, known as the tubero-infundibular system, is concerned with neuronal control of the hypothalmic-pituatory endocrine system. *With permission, The Lundbeck Institute.*

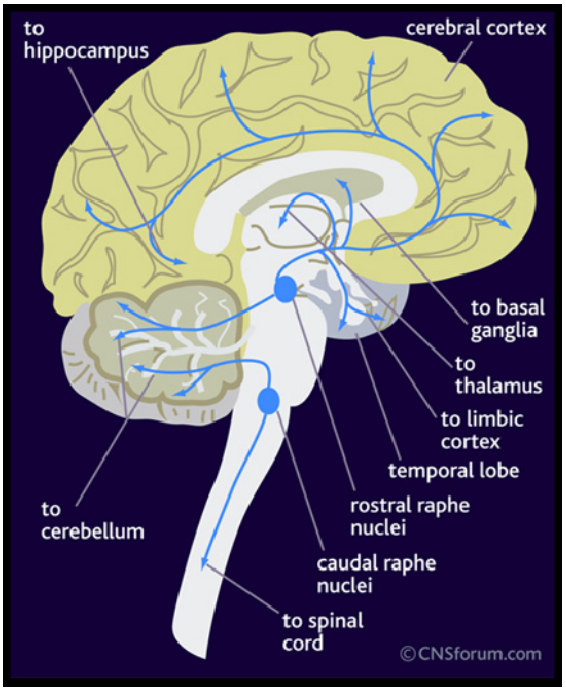

Figure 3. The serotonin pathways in the brain. The principal centres for serotonergic neurones are the rostral and caudal raphe nuclei. From the rostral raphe nuclei axons ascend to the cerebral cortex, limbic regions and specifically to the basal ganglia. Serotonergic nuclei in the brain stem give rise to descending axons, some of which terminate in the medulla, while others descend the spinal cord. *With permission, The Lundbeck Institute.*

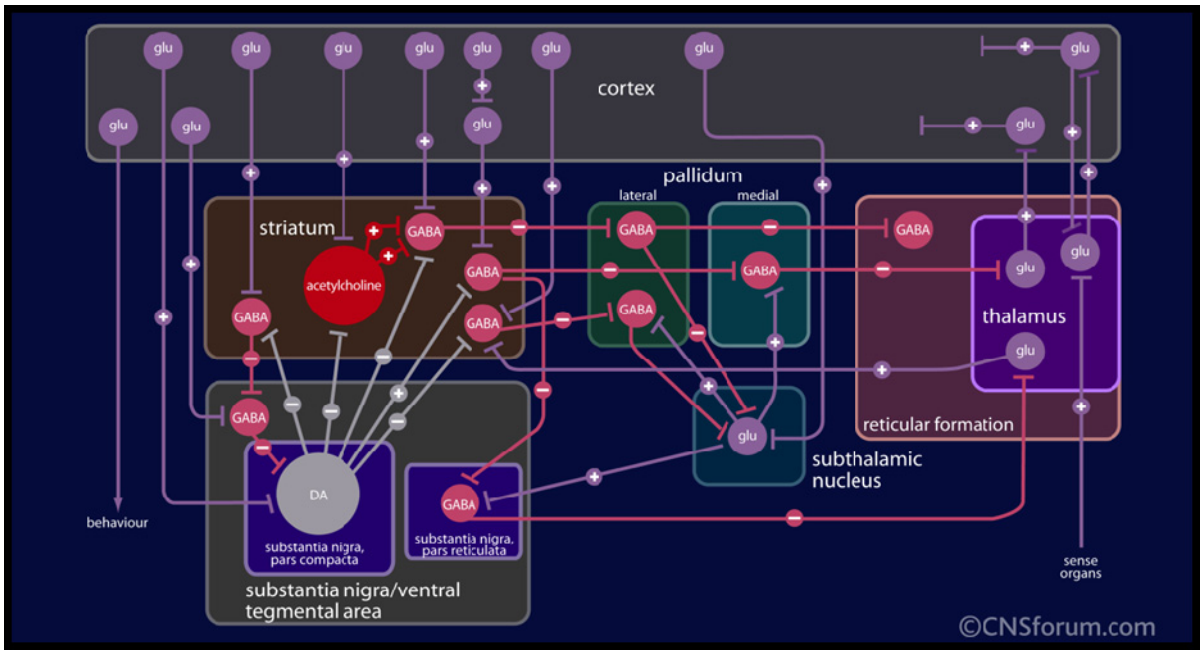

Figure 4. The relationship between the dopamine and glutamate pathways in the normal brain. Stimulatory glutamate projections from the cortex activate dopamine pathways in the substantia nigra pars compacta. Dopamine is the predominant neurotransmitter in the substantia nigra and there are both stimulatory and inhibitory dopamine projections from this structure to other parts of the brain. Dopamine is predominantly inhibitory on the striatum, which affects the transmission from the striatum to the cortex and can elevate the transmission of sensory information to the cortex. If transmission through the thalamus becomes excessive, confusion and psychosis, as seen in schizophrenia, can occur. Excessive transmission through the thalamus may be caused by either an increase in dopaminergic or a decrease in glutamatergic activity; increased levels of dopamine and decreased levels of glutamate have been implicated in the pathogenesis of schizophrenia. *With permission, The Lundbeck Institute.*

It has to be admitted that reducing creativity and human personality to a single neurotransmitter is a gross oversimplification (Figure 4). It is certain that creativity and personality come about by a balance of many other neurotransmitter systems, CCK, opiates, substance *P* (Kalivas and Stewart, 1991) glucocorticoids (Piazza and Le Moal, 1996), GABA (Le Moal and Simon, 1991), and neurotensin. Despite the complexity of the neurobiology of personality, at least it is a good start to be able to say that a neurotransmitter is dominant.

Just as much as genius and creative thought, a topic which must be taken into account in understanding the nature of information processing in the mind is the role of chaos science and chaotic behaviour in the nervous system. Walter J. Freeman is known as a leader in this field, and in particular in his work in the central olfactory system, he has performed important work demonstrating the chaotic and complex characteristics of neuronal information processing. Freeman and his team have shown in work performed over many years how the olfactory system forms a new activity pattern for a newly perceived smell; each new stimulus after that both forms new response patterns and stimulates activity in the previously set up neural network. They drew up phase diagrams which showed the chaotic characteristics of the communication network formed by millions of brain cells and that they had a higher dimensional and intrinsic organisation (Skarda and Freeman, 1987). Thus it is thought that this complex and indirect activity, which is a basic working principle of nervous system activity, in some way produces organized neuronal response, perception, and behaviour patterns out of chaotic and complex neuronal oscillations. This is because our neural system, continuously supplied with energy and consuming large amounts of glucose, and operating in close coordination, shows similar dynamics to the dissipative structures defined by Prigogine (Prigogine and Stengers, 1997). In the processes of formation of "new" elements in the mind, complexity science opens a door on to many new ideas.

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