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The network concept of creativity and deep thinking

Applications to social opinion formation and talent support

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Abstract
Our century has unprecedented new challenges, which need creative solutions and deep thinking. Contemplative, deep thinking became an "endangered species" in our rushing world of Tweets, elevator pitches and fast decisions. Here we describe that important aspects of both creativity and deep thinking can be understood as network phenomena of conceptual and social networks. "Creative nodes" occupy highly dynamic, boundary spanning positions in social networks. Creative thinking requires alternating plasticity-dominated and rigidity-dominated mindsets, which can be helped by dynamically changing social network structures. In the closing section we present three case studies which demonstrate the applications of the concept in the Hungarian research student movement, the Hungarian Templeton Program and the Youth Platform of the European Talent Support Network. These examples show how talent support programs can mobilize the power of social networks to enhance creative, deliberative, deep thinking of talented young minds, influencing social opinion, leading to community action, and developing charismatic leadership skills.

Keywords
Creativity, charisma, deep thinking, deliberative democracy, gifted education, social networks

Creativity and Deep Thinking: Introduction

Our century has unprecedented new challenges, which need creative solutions requiring deep thinking. As Daniel Kahneman described in his book, "Thinking, Fast and Slow" (Kahneman, 2011), fast thinking determines our own actions if we encounter a familiar situation. However, if an event occurs that violates the model of the world encoded by our fast-thinking neuronal system, our slower, contemplative thinking system becomes activated. This contemplative mode of processing allows the development of novel solutions by mobilizing a deep thinking process.

Though contemplative, deep thinking is publicized as a key ingredient of success (Byers, 2014), it has become an 'endangered species' in our rushing world of Tweets, elevator pitches and fast decisions. Conversation about contentious issues is often described as the soul of [deliberative] democracy (Dewey, 1927; Bessette, 1980; Habermas, 1984; 1987; Guttmann & Thompson, 2004; Neblo, Esterling, Kennedy & Lazer, 2010). Thus, the lack of time for deep thinking, as well as shrinking world-discourse, desire of "strong leaders" and pauperization of

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social response repertoire seem to be related phenomena. All of these do not only indicate changes in personal life histories, but also stem from the emergent properties of rapidly expanding, globalized social networks.

Deep thinking requires creative exploration and careful judgment of nontrivial responses. Quality thoughts need entirely new viewpoints leading to contexts that are out of our original comfort zone. In this process our starting idea is questioned, weakened by the emerging ambiguities and then becomes reframed by finding a new conceptual consensus at a higher level. Deep thinking embeds our starting idea to a high number of potential contexts, which helps to rephrase the starting idea in a more original way. It is important to emphasize that deep thinking, as creativity itself, requires the synthesis of alternating divergent and convergent thinking modes. On one hand, divergent thinking helps a holistic, flexible task-processing mode, on the other hand, convergent thinking induces a systematic, focused processing mode. We need both for the invention and optimization of nontrivial responses (Fischer & Hommel, 2012; Byers, 2014).

Creativity and Deep Thinking as Network Phenomena

Henri Poincaré defined creativity as connecting distant regions of human knowledge (Poincaré, 1908). He wrote: "*to create consists in not making useless combinations.... Among chosen combinations, the most fertile will often be those formed of elements drawn from domains which are far apart*" (Poincaré, 1908). This notion is supported by the recent analysis of 17.9 million scientific papers showing that the inclusion of unusual combinations of prior work often occurs in highest-impact science (Uzzi, Mukherjee, Stringer & Jones, 2013). From the network point of view, distant regions of human knowledge can be found in the NETWORK PERIPHERY (for a more detailed description of network-related terms, which are highlighted by SMALL CAPITALS, see the Glossary of Table 1). The NETWORK CORE is a subset of NETWORK NODES, which have a central position, and are densely connected. On the contrary, nodes of the network periphery are usually not connected to each other, but have much longer connection paths involving nodes of the network core. Thus, a combination of nodes at the network periphery, but not at the network core (which is densely connected anyway giving often-occurring, trivial combinations) of human conceptual or social networks results in a much higher probability of novel, creative solutions.

In agreement with the ideas described before, in recent social experiments and simulations the accumulation of creative, high-complexity innovations required both the separation and occasional re-connection of distant social groups (Derex & Boyd, 2016; Michelucci & Dickinson, 2016; Reia, Herrmann & Fontanari, 2017). In an extensive study of Facebook comments, significantly greater attention was triggered by messages that combined topics that were seldom discussed together. These "cultural bridges" often induced new conversational themes that acted as "cultural trellises" (Bail, 2016). Similarly, Wikipedia users preferred links pointing towards the periphery of the Wikipedia network (Dimitrov, Singer, Lemmerich & Strohmaier, 2016) indicating a search for novelty not in the redundant Wikipedia network core, but in the non-redundant Wikipedia network periphery. These findings indicate that important aspects of creativity can be understood as network phenomena of conceptual and social networks.

The importance of the network periphery is also emphasized in the concept of innovation diffusion. The network periphery is a preferred position of innovators, because they may have contacts here with other social communities, and may become free from the social pressure of

the network core, which is enforcing conformity. Members of the network core are typically afraid of changing the status quo, which may jeopardize their prestigious position. Thus, traditionally behaving network core members seldom become innovators (Rogers, 2003; Valente, 2012).

Mihály Csíkszentmihályi emphasized the role of combinations of different cultural domains in the emergence of creativity and innovations (Csíkszentmihályi, 1999). Similarly, Mark Granovetter (Granovetter, 1973) highlighted the importance of non-redundant information in finding creative and efficient solutions to social problems. Granovetter's analysis demonstrated that non-redundant information often comes by crosscutting dense social circles (Granovetter, 1973). In agreement with these observations, the overlap between cognitively distant groups led to larger creative success assessing 12,422 video games and 139,727 career histories of video game developers (de Vaan, Vedres & Stark, 2015). However, both the number of network connections and the extent of creativity have limits to induce optimal community responses. On one hand, excessively diverse connections decreased the performance of creative artists making Broadway musicals from 1945 to 1989 (Uzzi & Spiro, 2005). On the other hand, excess individual creativity can be detrimental to society, because creators invest in their unproven ideas at the expense of propagating proven ones (Gabora & Firouzi, 2013). In addition, many individuals can benefit from the creativity of the few without being creative themselves by copying creators (Nepusz & Vicsek, 2013; Gabora & Tseng, 2014).

Deep thinking can also be enhanced by social networks. Meeting wise minds, distinguished thinkers or people with different social and cultural backgrounds helps to question and view the starting idea from many angles. This process introduces new viewpoints and novel contexts, which help to reframe and rephrase the starting idea in a more original way (Byers, 2014).

Creative Nodes: A Highly Dynamic, Bridging Network Position

The previous section summarized that unusual combinations of nodes preferentially residing at the network periphery of human conceptual and social networks can be a great source of creativity. What is the exact network position of the peripheral network nodes introducing creative ideas to the networking community? This section seeks an answer to this question.

Social network positions can be associated with three basic roles: that of problem solvers, problem distributors and, last but not least, 'creative nodes'. Most of the network nodes are ‘problem solvers’. Problem solver nodes are usually found at the PERIPHERY of the social network, have only a few contacts, which predominantly connect them to the central core of the network. Problem solvers are specialized to a certain task that they can perform with high efficiency. A few NETWORK NODES are ‘problem distributors’. Problem distributor nodes are often HUBS, thus have a much larger number of network neighbors than the average. These nodes have a CENTRAL NETWORK POSITION, and are usually connected with each other forming the core of the network. Problem distributors are specialized to distribute responses to challenges already experienced by the network. Both problem solvers and problem distributors have a rather predictable behavior. On the contrary, “creative nodes” exhibit an unpredictable behavior. Creative nodes are extremely dynamic, and continuously sample the entire network by frequent changes of their neighbors. Creative nodes often reside in the network periphery, and bridge distant network regions making shortcuts in the network structure (Csermely, 2008; Csermely 2009; Csermely 2013).

In social networks the archetype of the creative node is the “stranger” described by George Simmel more than a hundred years ago (Simmel, 1908). The stranger's social position is very similar to that of the innovators mentioned before, who reside in the network periphery establishing contacts with other social communities and becoming free from the social pressure of the tightly bound network core (Rogers, 2003; Valente, 2012). Thus the stranger holds a certain objectivity that allows the development of novel ideas without being influenced by the opinion of others. Moreover, the stranger bridges different social contexts and cultural backgrounds in a way such that she/he belongs to all groups, yet at the same time does not belong to any of them. Malcolm Gladwell describes several of these “connector” persons in his book, “Tipping point” (Gladwell, 2002). These “creative node”-type connectors are interested in a substantial number of persons and information, which are different from each other.

Ronald Burt described a network position very similar to that of connectors or creative nodes as ‘structural holes’ (Burt, 1995). Structural holes are special node positions at the periphery of social networks, which connect persons, who do not know each other. Moreover, quite often the second and third neighbors of persons occupying structural holes do not know each other either. Thus, persons in structural hole positions become focal points of various, divergent information flows in the social network, which can not be combined by anyone else. This possibility allows surprisingly unusual combinations of different types of information making the structural hole network position a great potential source of creativity. Social network actors in this position may often introduce novel solutions to the whole social network acting as the source of novel community responses and decisions. In agreement with this role, powerful, social community-connecting network leaders have been referred to as “switchers” (Castels, 2004).

Creative node, structural hole and "switcher" network positions often have high NETWORK CENTRALITY, and may also become part of the NETWORK CORE. This latter phenomenon happens, when the creative solution offered by these actors becomes a regularly displayed, well-rehearsed response of the community requiring high reliability and efficiency. This is the process how the initial creative action becomes a repeatedly displayed, "business as usual"-type response of the community, incorporating the creative node to the "establishment" of the (smaller or larger) society.

Creative Nodes Increase System Plasticity Leading to Creative Solutions at the System Level

As discussed in the previous section, creative nodes introduce a larger range of potential responses to complex systems offering novel solutions (Csermely, 2008). A larger repertoire of potential responses is also referred to as a larger PLASTICITY of the COMPLEX SYSTEM. Plastic complex systems explore numerous potential solutions, and thus, are highly adaptive to even unexpected changes of their environment. However, PLASTIC SYSTEMS do not have a ‘memory’, thus they can not reliably and efficiently produce the same optimal response to a repeated stimulus. (Notably, this is very much in agreement with the unpredictable behavior of creative nodes as discussed previously.) When a COMPLEX SYSTEM needs a highly accurate, reliable and efficient repetition of a previously optimized response, it becomes RIGID. As a “price” of their reliability and efficiency, RIGID SYSTEMS have a rather limited set of responses, and can not adapt to unexpected changes of their environment. In agreement with this general characteristic, plastic social networks have a much less defined, and much more

dynamic structure than rigid social networks. plastic social networks have much less hierarchy and a much higher number of horizontal, dynamic contacts than rigid social networks. Democracies have plastic social networks, while dictatorships develop and require a rigid social network for their survival (Gáspár & Csermely, 2012; Csermely, 2015). Creative nodes break the rigidity of social networks introducing a large number of dynamic, non-hierarchical, horizontal contacts, which often become the sources of innovation and creative action.

In agreement with the general picture outlined in the previous paragraph, increased plasticity of human neuronal cells was demonstrated to be characteristic to exploratory, creative periods (Ostby et al., 2012; Schlegel et al., 2013; Tagliazucchi et al., 2014). Positive emotions broaden the response repertoire (Fredrickson, 2004), increase the plasticity of the brain's mindset, and boost creativity. On the contrary, a rigid personality efficiently performs optimal solutions of previously practiced situations using previously fixed mental and behavioral sets displaying decisiveness and predictability. Extreme plasticity develops an inconsistent and undependable personality. Extreme rigidity leads to stubborn behavior, which perceives ambiguous situations as 'threats' (Schultz & Searleman, 2002). Thus, optimal levels of creativity require alternating plasticity-dominated and rigidity-dominated mindsets.

Campbell's (Campbell, 1960) and Simonton's (Simonton, 1999) "blind-variation and selective retention model of creativity" is, in fact, describing the same plasticity-rigidity alterations that were described above. Creative thinking proceeds *via* shifts between generative and evaluative mindsets (Fischer & Hommel, 2012; Gabora, 2013; Sowden, Pringle & Gabora, 2015). Importantly, brainstorming involves separated plastic (idea-generating) and rigid (idea-selecting, idea-combining) segments (Osborn, 1953). Last but not least, team creativity was demonstrated to be enhanced by rotating leadership and contribution (Gloor et al, 2014), which imply shifts of more plastic and more rigid social roles within the social network as described in the starting paragraph of this section.

The role of creative nodes is often played by talented people in social networks (Csermely, 2008; Csermely 2013). This is not only because a high level of creativity is one of the key potential ingredients of talent, but also because talented people often require a large input of novel information. This 'information-thirstiness' drives talented people to the information-rich social network position of creative nodes. In the following section I will describe possible applications of the network concept of creativity and deep thinking outlined in this paper to the support of talented people. In addition, I will show how talented people may use their creativity and deep thinking to influence social opinion and community action.

Application of the Network Concept of Creativity and Deep Thinking to Talent Support and Social Opinion Formation

Optimal development of talented people needs the support of social networks (Csermely, 2013). As Eva Gyarmathy wrote recently: "*Talent is the result of a highly efficient and active network-based functioning emerging in a network of diverse factors. Understanding and promoting it can best be achieved through a network of provision. Thus, gifted education and talent support itself should strive for a network-based structure*" (Gyarmathy, 2016). Talent support networks may help the development of creativity and deep thinking via three major factors.

First, talent support networks may expose talented people to various novel situations and new acquaintances, which cross-cut social circles and cultural boundaries. Such exposures give an

access to novel information and provide a novel context of previously acquired information. This is particularly efficient, if the novel acquaintances (either having a similar age or being substantially older than the talented person) are talented, creative people themselves.

Second, an extensive number of repeated exposures of talented people to groups with different social and cultural backgrounds may increase their networking ability, which accepts and even utilizes such situations for gaining access to novel information. Networking is a key success factor in a modern society (Christakis & Fowler, 2011; Csermely, 2009). Thus the acquisition of successful networking strategies is crucial for talented people. Safety seeking is a networking strategy, which makes a safety net around the self in the form of a tightly interwoven cluster of family and best friends. The other networking strategy, novelty seeking, builds on this safety net. Novelty seeking requires the establishment of far-reaching social network contacts, which are bridging large gaps in social networks. Novelty seeking networking strategy needs a lifestyle, which is open for gross changes. This lifestyle treats novel situations as exciting challenges instead of conceiving them as a calamity, which are difficult to cope with. This could be observed even in infants, where a sight of an object that violated expectations was received as a source of excitement and increased the depth of learning. Infants became engaged in enhanced exploration and hypothesis-testing behaviors that reflected the particular kind of violations seen (Stahl & Feigenson, 2015).

A novelty seeking mindset is important for successful networking. It is important that talent support networks organize the exposure of talented people to various novel situations in way such that the, often unusual, character of talented people is accepted by the novel environment. This increases the "I am safe" feeling of talented people during novelty seeking and encourages them to make even larger excursions out of the "comfort zone" of their original social network.

Last but not least, talent support networks may (and should) initiate discussions on major questions of mankind allowing the practice of creative, contemplative, deliberative, deep thinking, as well as the development and defense of moral judgments (Sternberg, 2007). Importantly, joint projects, especially good purpose actions implying social responsibility may deepen the commitment of talented people to find creative novel solutions serving the benefit of mankind (Renzulli, Koehler & Fogarty, 2006).

These three actions (1. exposure of talented people to novel situations and new acquaintances cross-cutting social circles and cultural boundaries; 2. increase of the novelty seeking networking ability of talented people; 3. discussions of talented people on major questions of mankind and good purpose joint projects) enrich talented people with a mindset and social skills that enables them to influence social opinion and lead community actions. In agreement with this, creative, deep thinking is considered as a core element of leadership skills, which is required for the development of strategic and visionary thinking (Puccio, Mance & Murdock, 2011). If creative deep thinking is not only the output of a single mind, but summarizes the essence of a new trend in community thinking, the leader may strongly engage the followers' self-concepts in the interest of the mission, thus may develop charismatic leadership (Shamir, House & Arthur, 1993). This requires extreme openness, understanding and humbleness of deep-thinking, talented people.

Three Case Studies Showing the Application of the Network Concept of Creativity and Deep Thinking to the Support of Talented People

In this section I will list three personal case studies of talent support networks, where the above three social network-related factors developing creativity and deep thinking (exposure to novel situations; development of networking skills; encouragement of deep thinking and good purpose actions) were experienced.

Case study 1: Hungarian Network of Research Students (http://www.kutdiak.hu/en/). In 1996 the basic aim of the network was to give internationally acknowledged scientists as mentors of the students' research projects. This aim was successful, as evidenced by the 300 to 500 scientific projects completed annually in 20 years (Csermely, 2003). Importantly, mentor-student pairs often made a bridge between the social circles of the high-level intellectuals and the original social group of the talented young person in a remote village or small town (Csermely, 2003). However, rather unexpectedly, the real value of the action turned to be another factor. The movement survived more than 20 years by now giving research opportunities to more than 10,000 young students because of the strong social network it built between the students themselves. Various scientific conferences, and, most importantly, an annual one-week research camp for the best 80 students of the country made a very strong social cohesion between a large variety of talented young people. Importantly, the contemplative, creative, deep thinking of the students was deepened by the fact that the movement is directed by the students themselves. As an example of this emerging ownership feeling, student members of the research camp each year set aside a good deal of time to discuss the future aims, means and finances of the action (Csermely, 2003).

Case study 2: The Hungarian Templeton Program (http://templetonprogram.hu/en) was established by the Hungarian Talent Support Network (http://tehetseg.hu/en) in 2015. The primary aim of the program was to support young people, who have exceptional cognitive talent and are between ages of 10 and 29. After the mobilization of more than 20,000 applicants using the intensive help of the Hungarian Talent Support Network 314 young people became Hungarian Junior Templeton Fellows. Fellows received a one-year intensive, personalized development program. Interviews with Fellows indicated that Fellows considered mentorship, as well as the exposure to novel situations and social contacts as the most important benefits of the program. The self-organization of the Fellows' network led to an e-book on the "Big Questions of our Time" and several joint good purpose actions. Fellows decided to continue their networking activities after the end of the development program, forming an alumni network.

Case study 3: The European Talent Support Network was established by the European Council for High Ability (http://echa.info) in 2014 to increase cooperation between organizations in gifted education and talent support, to share best practices and to organize expert, student, and mentor exchanges. By the end of 2016 the Network had close to 300 cooperating organizations from 50 countries of Europe and other continents (http://echa.info/high-ability-in-europe/#). After the successful first European Youth Summit in March 2016 (http://www.youthsummit.eu/) the Network established a Youth Platform, which became a fast-growing group of talented young people. Youth Platform members enjoyed and greatly appreciated the opportunity to learn the approaches and opinions of talented young people from several continents. Members initiated several joint actions including the involvement in the discussion of the 17 Sustainable Development Goals adopted

by 193 UN countries in 2015 (http://pathwaysproject.online/), as well as the help of talented young refugees and talented young people with disabilities.

In summary, all the three case studies indicate a high level of deep thinking and social responsibility among young talented people helped by these actions. It will be an important future task of talent support practices (such as the talent support networks described in this section) to use the networking and learning techniques described in this contribution to increase creativity, deep thinking and the efficiency of talent support further.

Conclusions

In conclusion, this paper describes that key aspects of creativity and deep, contemplative, deliberative thinking can be understood as network phenomena of both human conceptual and social networks. 'Creative nodes' change their network position, and dynamically occupy various inter-domain positions in social networks. Creative, deep thinking is promoted by alternating exploratory, plasticity-dominated and evaluation-promoting, rigidity-dominated mindsets. Alterations of these mindsets can be helped by changes in social network positions. Quite many types of talented people become bored, if not receiving a large input of novel information. This 'information-thirstiness' brings talented people to the information-rich social network position of creative nodes.

As an application of the above concept, through three case studies we showed that the exposure of talented people to novel situations and new acquaintances (especially those cross-cutting social circles and cultural boundaries); the increase of their novelty seeking networking ability, as well as discussions on major questions of mankind and good purpose joint projects increases creative, deep thinking. Moreover, these actions enriched talented people with a mindset and social skills that enables them to influence social opinion and lead community actions.

Future studies are required to elaborate the quantitative effects and relative efficiency of the 1.) exposure to novel situations; 2.) increase of networking skills and 3.) discussions of major questions of mankind and related good purpose joint projects to induce creative, deep, visionary thinking and to increase leadership skills. It will be an important future task of talent support actions to use these techniques to increase the potential of talented people to influence social opinion, lead community action and develop charismatic leadership skills.

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Table 1 *Glossary: description of the network-related terms used in the paper*

NETWORK-RELATED TERM*	**Description**
CENTRAL NETWORK POSITION	Centrality of a network node defines the relative importance of the node within the network. There are various measures of network centrality representing node importance in local network structure, in the structure of the whole network, or both.
COMPLEX SYSTEM	Complex systems display 'emergent properties', i.e. properties that can not be predicted from the behavior of the parts of the complex system. Life and consciousness are primary examples of emergent properties displayed by complex systems.
HUB	A hub is a highly connected node of the network. Usually a hub has more than 1% of total network connections.
NETWORK	A network is a simplified description of a complex system defining the system as a set of its building blocks (nodes) and their connection structure. In a social network nodes are people and their connection structure characterizes their friendship or acquaintanceship.
NETWORK CORE	The core of the network is a set of a limited number of network nodes (usually: hubs), which are densely connected with each other. Core nodes have a high centrality in the network and are surrounded by nodes of the network periphery. In social networks core nodes are often members of the social 'elite'.
NETWORK NODE	The network node is a single building block of a network. Network nodes are also called as actors in sociology. Social network nodes are connected with network edges representing their friendship or acquaintanceship. Connections can be weighted representing the strength of the interaction.
NETWORK PERIPHERY	Most nodes of a complex network form its periphery. Peripheral nodes have a low network centrality and are preferentially connected to core network nodes. Peripheral network nodes are usually not connected to each other: their connections are primarily indirect, and involves bridging nodes belonging to the network core.
PLASTICITY OF A COMPLEX SYSTEM	Functional plasticity of a complex system can be defined by the number of the potential responses of the system. A plastic system has a high number of potential responses. Thus plastic systems are adaptive to unexpected changes of their environment. However, plastic systems can not reliably and efficiently produce the same optimal response to a repeated stimulus.
RIGIDITY OF A COMPLEX SYSTEM	Functionally rigid systems have a low number of potential responses, which may be as little as a single response. The response of a rigid system is usually a highly optimized, very efficient response to a repeatedly occurring change in its environment.

*Terms described in this Glossary are highlighted by SMALL CAPITALS in the text.

Author Biography

Peter Csermely is a professor of network science of the Semmelweis University (Budapest, Hungary; http://linkgroup.hu). In 1995 he launched an NGO providing research opportunities for >10,000 high school students. In 2006 he established the Hungarian Talent Support Council (http://tehetseg.hu/en) running a talent support network involving >200,000 people. From 2012 he is the president of the European Council for High Ability (http://echa.info) and organized the European Talent Support Network having members from >50 countries. He received the 2013 International Award for Creativity of the World Council for Gifted and Talented Children and the 2016 Lifetime Achievement Award of the Hungarian Talent Support Council. He published 13 books and 270 research papers with citations over 13,000. Prof. Csermely is a member of the Hungarian Academy of Sciences and Academia Europaea, as well as an Ashoka, Fogarty, Howard Hughes, Rockefeller and Templeton Awardee.