ViewpointS: A Collective Brain

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Abstract. Understanding and forecasting brain functions is the major challenge of our times. The focus of this endeavor is understanding and forecasting learning events, such as the dynamic adaptation of beams connecting neuronal cards in Edelman's Theory of Neuronal Group Selection (TNGS). We have conceived, designed and evaluated a new paradigm for constructing and using collective knowledge by Web interactions that we called ViewpointS. By exploiting the similarity with the TNGS we conjecture that it may be metaphorically considered a Collective Brain, especially effective in the case of trans-disciplinary representations. Far from being without doubts, in the paper we present the reasons (and the limits) of our proposal that aims to become a useful integrating tool for future quantitative explorations of individual brain functions as well as of collective wisdom at different degrees of granularity. We are therefore challenging each of the current approaches: the logical one in the semantic Web, the statistical one in mining and deep learning, the social one in recommender systems based on authority and trust; not in each of their own preferred field of operation, rather in their integration weaknesses far from the holistic and dynamic behavior of the human brain.

Keywords: Collective brain · Collective intelligence · Knowledge graph · Knowledge acquisition · Semantic web · Social web

1 Introduction

On one side, today's research on the human brain allows us to visualize and trace the activity along the beams connecting the neural maps. According to the Theory of Neuronal Group Selection (TNGS) that G. M. Edelman made public more than thirty years ago, the dynamic adaptation of these beams is the key of individual learning all lifelong.

Each brain is unique and open on the world, both through the observation/action loop and through social interactions mediated by language. Both loops involve a complex multi layers network of neural maps bi-directionally interconnected by beams of neural terminations, the reinforcement of which is supervised by our homeostatic internal systems, also called system of values. On the other side, we live a digital revolution

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where the Web plays an increasing role in the collective construction of knowledge; this happens through the semantic Web and its ontologies, via the indexing and mining techniques of the search engines and via the social Web and its recommender systems based on authority and trust. Our goal is twofold: i) to exploit the metaphor of the brain in order to improve this collective construction of knowledge and ii) to better exploit our digital traces in order to refine the understanding of our learning processes. We have prototyped a Knowledge Graph built on top of Web interactions where resources (agents, documents and descriptors) are dynamically interlinked by beams of digital connections called viewpoints (human viewpoints or artificial viewpoints issued from algorithms). We-as-agents endlessly exploit and update this graph, so that by similarity with the TNGS, we conjecture that it may be metaphorically considered a Collective Brain evolving under the supervision of all our individual systems of values. Moreover, each viewpoint may embed a mental state, either in the shape of an emoticon, or as the result of a measure of brain activity. In the paper we open pathways and show their limits, hoping to have stepped forward in the direction of our goal.

In Sect. 2, we present a schematic view of the biological bases of cognition. We start by the "three worlds" of K. Popper (1978) who sets a simple framework where the interaction between minds can be studied. We re-visit the biological bases of cognition as described by the Theory of Neuronal Group Selection of G.M. Edelman (TNGS). According to the TNGS, the perception-action loop and the social interaction's loop mediated by language are regulated by our homeostatic internal systems, or system of values, that biologically ground our emotions, personality traits, motivation, ethics[1]. We illustrate "learning through interaction" as exposed by D. Laurillard or J. Piaget, in this schematic view.

In Sect. 3, we explore the collective construction of knowledge in the Web paradigm, assuming that a large proportion of the traces we produce and consume today are digital ones, managed by artificial systems governed by algorithms. We distinguish three distinct paradigms, respectively governed by logics, by statistics and by authority and trust. Thus it becomes a challenge to integrate these paradigms and describe how individual systems of values participate to learning events.

Section 4 is dedicated to the ViewpointS approach, as a candidate for answering the challenge. The metaphor of "neural maps interconnected by beams of neurons" led to the design of a graph of "knowledge resources interconnected by beams of viewpoints", where each agent can benefit from the traces of others and react to them by adding new traces. As a result, the combination of all individual "system of values" regulates the evolution of knowledge; we conjecture that it may be metaphorically considered a Collective Brain. In [1] we had presented some reflections about the potential exploitation of our ViewpointS approach as an environment for the elicitation and analysis of brain functions during interaction sessions. In particular, the key question was to understand and forecast – as much as possible supported by empirical evidence – cognitive

[1] From: http://www.acamedia.info/sciences/sciliterature/edel.htm#1 « Values - simple drives, instincts, intentionality - serve as the tools we need for adaptation and survival: some have been developed through eons of evolution; and some are acquired through exploration and experience. It needs to be stressed that "values" are experienced, internally, as feelings - without feeling there can be no animal life. »

and emotional events linked to serendipitous learning; we therefore proposed that each viewpoint would embed a mental state, either in the shape of an emoticon, or as the result of a measure of brain activity. It was expected that a "world of knowledge" structured in terms of proximity between and among documents, descriptors (tags) and agents would be likely to trigger serendipitous learning. In this paper we deepen these reflections.

We then conclude by recapitulating our proposal that aims to become a useful integrating tool for future quantitative exploration of individual brain functions as well as of collective wisdom at different degrees of granularity. We are not yet sure if the collective knowledge emerging from our proposed Collective Brain will perform competitively with the existing separate paradigms respectively governed by logics, by statistics and by authority and trust. Our proposal has the limits inherent to any integrator; nevertheless, if it does not ensure scientific discovery, it may facilitate the process.

2 A Schematic View of the Biological Bases of Cognition

In this section, we start by adopting a well-known philosophical position where the questions of cognition and interaction can be addressed. Then we draft a schematic view of the lessons learned from Edelman about the biological mechanisms supporting cognition, and finally we use this representation within D. Laurillard's conversational learning scenario in order to test it against the question of knowledge acquisition through interaction.

2.1 The Three Worlds

To start with our analysis about minds in interaction, we need some philosophical default position; "the three worlds" of K. Popper [2] provides a relevant framework. Such a framework, which had already found an expression in the semantic triangle of Odgen and Richards [3], is in line with what J. Searle writes in [4]. In the following, we shall refer to the three worlds as W_1, W_2 and W_3, with the following definitions:

W_1 is the bio-physical world where objects and events exist independently from us, from our perceptions, our thoughts and our languages. Causal relations, insofar we are not directly implied by some event, are also considered independent from us.

W_2 is the internal world of subjectivity, where the perception of objects and events of W_1 leave traces in memory that are combined in order to participate to the construction of our own knowledge, our consciousness about the world, where intentions appear and the emotions that will be the trigger for our actions.

W_3 is the world of the cultures and languages, made of interpretable traces: signs, symbols, rules of behavior and rules for representing objects and events of W_1. W_3 is the support of communication among individuals; Odgen and Richards call "referencing" the process that binds within each individual W_2 the shared referents of W_1 to the shared symbols of W_3. Within W_3, we find all specialized languages of the scientific disciplines, as well as the language of emotions represented by smileys. Digital images, e.g.: a satellite image or the scan of a document, are traces interpretable by humans or by algorithms (machines).

W_1 is where it happens, W_3 is where we can communicate about what happens, and W_2 is where all the links are … this is why we are going to pay special attention to the internal world W_2.

2.2 The Internal World of the Mind

This section is a synthesis of the work of G.M. Edelman [5, 6], founder of the Theory of Neuronal Group Selection (TNGS).

There is neither correlation between our personality and the shape of our skull (despite the teachings of phrenology), nor localized coding of information; no autopsy will ever reveal any single chunk of knowledge available in the brain. The brain is not a computer, but a highly dynamic, distributed and complex system, maybe the most complex "object" of the known universe.

According to the TNGS, every brain is twice unique: first because its cellular organization results from the laws of morphogenesis. Most important, however, is Edelman's second reason for the brain uniqueness: the brain is a set of "neural maps" continuously selected according to the individual's experiences. These cards, or adaptive functional units, are bi-directionally linked one-another by a fundamental integrating mechanism: the "re-entry". This crucial hypothesis allows a functional integration requiring neither any "super-card" nor any "supervising program": the neural maps are like "musicians of an orchestra linked one-another by wires in the absence of a unique conductor". The bi-directional re-entry links are the result of a selective *synaptic reinforcement among* groups of neurons; similarly: the cards result from a *synaptic reinforcement internal* to each group of neurons composing them. These reinforcements are triggered and managed by the *homeostatic internal systems*, also called "*system of values*" of each individual.

Figure 1 (/left part of the figure) shows an observation-action loop that highlights several brain cards re-entering. The external world's signals enter, in this representation: the perception of an apple, and exit in order to produce a movement: grasping the apple. On turn: the movement modifies the signals perceived. This type of loops originates the *perceptual categorization* event, common to all organisms highly evolved. It is a peripheral process, somehow prisoner of the current time, but correlated in the hippocampus with the system of values and the experience of the past, what allows adaptation of the behavior according to the likelihood of benefits or dangers.

In humans as well as in some higher mammals, there is a second level of categorization, supported by cards situated in the temporal, frontal and parietal areas. Beyond the immediate cartography of the world, humans may shape some durable concepts (*conceptual categorization*) that consider the past and/or the future. The activation of the bi-directional links binding the two zones of categorization - perceptive and conceptual – correspond to the emergence of a primary conscience, as it appears in Fig. 1 (/right part of the figure)

Finally, the human brain parts specialized in language (the Wernicke and Broca areas), also linked bi-directionally to the two categorization areas, play a major role in the emergence of a *consciousness of a higher level*, enabling the human subject to "map" his-her own experience and study him-herself.

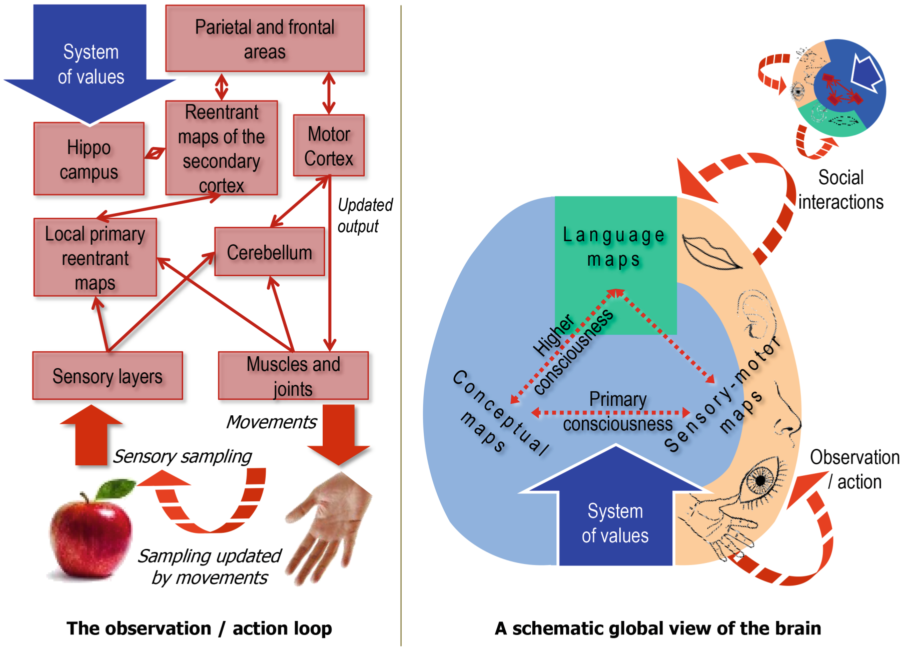

Fig. 1 The brain according to the TNGS of G.M. Edelman: a complex network of re-entrant maps in interaction loops with the world

The basic principles of the TNGS (selective reinforcement and re-entry) can explain all learning processes, from simple memorization to skill acquisition (reacting to a context by updating the perception-action loops) and knowledge acquisition (by evolving the conceptual categorization with the help of language, specifically during social interactions). All these processes are correlated to the memory of internal states, in such a way that learning is selected according to the advantages that they offer to the subject, i.e., is regulated by our system of values.

A kernel element learned from the TNGS, very relevant for us, is the following one. Since the supports for knowledge consist of a "physiological complex and adaptive network of neural maps interconnected", the metaphor of "knowledge graph" seems to us justified. This metaphor, consequently, induces naturally to search for a topology allowing to define distances and proximity, like it was conjectured by the "zone of proximal development" of Vygotsky [7, 8].

2.3 Minds in Social Interaction

According to the two loops at the right of Fig. 1, we always learn through interaction: observation/action versus social interaction. These two loops clearly appear in D. Laurillard's work [9] when she analyzes the acquisition of knowledge in higher education; in her scenario, a student faces his teacher, they share a laboratory experimentation and simultaneously discuss it.

In [10] we have extended this scenario to interactions within a group of peers co-constructing a representation of a shared territory. In this multi-peers scenario, interactions occur through external processes at two levels: i) peers act in the shared territory i.e., act within the world W_1 of objects and events and ii) peers exchange personal views about their perceptions and actions i.e., exchange within the world W_3 of language.

While the actors exchange their inner views of the shared territory in the form of traces interpretable by the others, the assimilation / adaptation processes described by J. Piaget in [11] are activated within their internal worlds W_2. These internal processes can be interpreted in terms of series of re-entry loops according to the TNGS.

As consequence of all the above processes (external and internal), the inner views tend to synchronize and yield a shared representation. This may be called collective knowledge acquisition. We propose that what happens on the Web is a generalization of this prototypical scenario.

3 Humans in Web Interaction

The change in our lives that we have been experiencing since when Internet has gained a significant place, often called the digital revolution, has been theoretically addressed by several authors, among which S. Vial [12] and D. Cardon [13] for respectively the philosophical and sociological approach. This revolution has suggested a significant hope: Internet as a "space of shared knowledge" in the sense given by Gruber in [14] i.e., a space providing tailored advice on top of collected knowledge, structured data and high level automated expertise and able to bring in new levels of understanding. If we refer to the conceptual framework of K. Popper presented previously, Internet as a support for a huge set of digital traces interpretable by humans but also by machines is therefore part of W_3, the world of cultures and languages. This numeric space is far from being homogeneous in its contents however, and the approaches to co-build shared knowledge are multiples. Hereafter, we consider three paradigms.

The first paradigm is governed by the *logical* evidence: we usually call semantic Web this part of Internet logically structured where humans interact with databases encoding the knowledge of experts according to a conceptual scheme or ontology established by consensus. This mode has the advantage to give logical responses to correctly formulated questions (and only to questions with such a property) and allows one to be helped by algorithms during the conversation in order to delegate to them part of the job. But it has problems and limits. The first reason is that each ontology does only represent a fragment of the reality, and the consensus it reflects is necessarily local and temporary. Another reason is that the query languages are formal languages that assume a closed world – what is rarely the case –, at the same time requiring a certain learning effort in order to be used properly. And finally, interconnecting ontologies and supporting their evolution with time in a rapidly changing world are very heavy and costly processes. Various approaches based on automatic alignment [15], machine learning [16] or instance evaluation [17] exist; however the task is huge and never ending, due to the fact that each ontology's evolution is domain-dependent [18].

The second paradigm is governed by the *statistical* evidence. The issue is to exploit techniques of data mining, i.e: scan without too many assumptions a corpus, also called data set, of tweets, sequences, clicks, documents, … and detect regularities, frequencies, co-occurrences of items or terms. In other words: to feed suitable algorithms with the big data in order to reveal regularities. This approach has the advantage to contribute to make the digital world W_3 visible by reducing it to a synthesis produced by the mining algorithms. However, the simplicity of these descriptions must pay a price to the expressiveness or even to the effectiveness: we often just see the surface, the "syntax" and not the depth, the "meaning". Today, a simple question with three independent keywords on Google may give very disappointing results. Further: what is even worse, is that any inferential statistics – the only one allowing us to take significant decisions - requires to select the data to analyze according to the goal chosen for the analysis, not independently from the objective. Therefore, the statistical space very often has interest for describing some apparent phenomena, rarely for interpreting them in order to abstract and cumulate the knowledge associated to their meaning; i.e., build chunks of science.

The third paradigm is based on authority and *trust*, and builds upon light traces such as 'likes', 'bookmarks' and 'tweets'. The algorithms of the social Web propose services of information search and recommendations by applying methods of graph analysis and exploiting the various personal, subjective and spontaneous contributions available on it. They clearly operate in an open world. However, the quality of their responses is hardly to be evaluated by logical criteria neither their stability assured along time.

The semantic Web project [19] aimed somehow at subsuming the three paradigms described above within the first one i.e., building up upon *logics.* After a first enthusiasm on the integration of ontologies (in order to assure interoperability among subdomains) it seems that the purely logical approach has its limits, even if they are daily pushed forward. In spite of the difficulties, the dream of Gruber and many others to fuse the three spaces: humans, algorithms and contents in order to profit from the emerging collective wisdom is very actual. Due to the digital revolution we have never been so near to the goal, and the following section aims to offer a potential way to explore this intriguing hypothesis and perhaps realize concrete steps towards significant progress in the direction of subsuming the three paradigms within the third one i.e., building up upon *trust* towards 'peers', would they be humans, databases or mining algorithms.

4 The ViewpointS Approach Discussed and Exemplified

This section first briefly recalls the ViewpointS framework and formalism for building collective knowledge in the metaphor of the brain - a detailed description can be found in [20, 21] - and then illustrates them through an imaginary case.

In the ViewpointS approach, the "neural maps interconnected by beams of neurons" are transposed into a graph of "knowledge resources (agents, documents, topics) interconnected by beams of viewpoints". The "systems of values" of the agents influence the viewpoints they emit, but also the way they interpret the graph.

We call *knowledge resource*s all the resources contributing to knowledge: agents, documents and topics. We call *viewpoints* the links between *knowledge resource*s. Each *viewpoint* is a subjective connection established by an agent (Human or Artificial) between two *knowledge resources*; the *viewpoint* (a_1, {r_2, r_3}, θ, τ) stands for: the agent a_1 believes at time τ that r_2 and r_3 are related according to the emotion carried by θ. We call Knowledge Graph the bipartite graph consisting of *knowledge resources* and *viewpoints.* Given two *knowledge resources*, the aggregation of the beam of all connections (*viewpoints*) linking them can be quantified and interpreted as a proximity. We call *perspective* the set of rules implementing this quantification by evaluating each viewpoint and then aggregating all these evaluations into a single value. The *perspective* is tuned by the "consumer" of the information, not by third a part "producer" such as Google or Amazon algorithms; each time an agent wishes to exploit the knowledge of the community, he does so through his own subjective *perspective* which acts as an interpreter.

Tuning a perspective may for instance consist in giving priority to trustworthy *agents*, or to the most recent *viewpoints*, or to the *viewpoints* issued from the logical paradigm. This clear separation between the storing of the traces (the *viewpoints*) and their subjective interpretation (through a *perspective*) protects the human agents involved in sharing knowledge against the intrusion of third-part algorithms reifying external system of values, such as those aiming at invading our psyche, influencing our actions [22], or even computing bankable profiles exploitable by brands or opinion-makers [23]. Adopting a *perspective* yields a tailored *knowledge map* where distances can be computed between knowledge resources, i.e. where the semantics emerge from topology as well as from our own system of values expressed by the tuned perspective.

The shared semantics emerge from the dynamics of the observation/action loops. Agents browse the shared knowledge through the *perspectives* they adopt (observation), and reversely update the graph by adding new *viewpoints* expressing their feedback (action). Along these exploitation/feedback cycles, shared knowledge is continuously elicited against the systems of values of the agents in a selection process.

To illustrate this, we develop below an imaginary case where learners have to select resources inside an Intelligent Tutoring System (ITS) to which a Knowledge Graph is associated. They wish to learn about the topic 'apple' and from step1 to step4 the learners adopt a 'neutral' perspective which puts in balance all types of viewpoints (issued from the logical or mining paradigms, or from the emotions of the learners). However at step5 where B chooses a perspective discarding his own viewpoints in order to discover new sources of knowledge. What is figured in the schemas is not the Knowledge Graph itself, but the views (also called Knowledge Maps) resulting from the perspectives; in these maps, the more links between two resources, the closer they are (Fig. 2). AQ1

Step1 illustrates the initial state of the knowledge. A, B and C are co-learners in the ITS (linked as such within the logical paradigm); the blue arrows represent their respective systems of values, which play a key role both in the choice of *perspectives* and in the emission of *viewpoints.* D_1, D_2 and D_3 are documents that a mining algorithm has indexed by the topic/tag 'apple'.

Step2: A is a calm person who has time; she browses through D_1, D_2 and D_3 and has a positive emotion about D_1 and D_2 (she likes both and finds them relevant with respect to 'apple'); the capture of this emotion results in linking D_1 and D_2 to her and reinforcing the links between the documents and the topic 'apple'. B is always in a hurry; he asks the Knowledge Graph the question "which is the shortest path between me and the topic 'apple'?". According to the paths in the diagram, he gets a double answer: B-A-D_1-'apple'and B-A-D_2-'apple'.

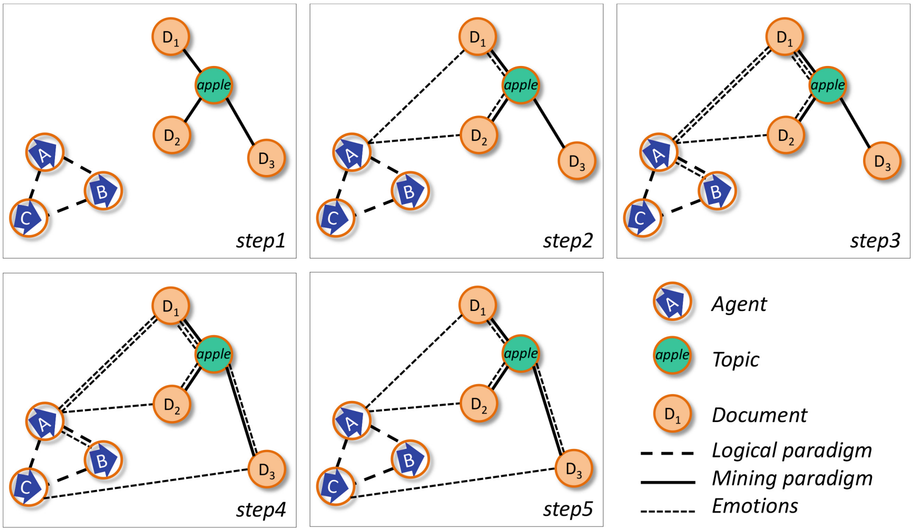

Fig. 2 The network of interlinked resources evolves along the attempts of the learners A, B and C to "catch" the topic 'apple' through performing the modules D_1, D_2 or D_3

Step3: B has a positive emotion about D_1 but not about D_2; this results in reinforcing the path B-A-D_1-'apple'. If he would ask his question now, he would then get only D_1.

Step4: C likes to explore; rather than taking a short path she browses through D_1, D_2 and D_3 and has a positive emotion about D_3 (she likes it and finds it relevant with respect to 'apple'); this results in linking D_3 to her and reinforcing the linking between D_3 and the topic 'apple'. At this stage, if A, B and C would ask for the shortest path to 'apple', they would respectively get D_1, D_1 and D_3.

Step5: B is not fully satisfied by D_1; he asks again for a short path: but in order to discover new sources of knowledge, he changes his perspective: he discards the viewpoints expressing his own emotions. This new perspective yields the view drawn in the figure, B-A-D_1-'apple', B-A-D_2-'apple'and B-C-D_3-'apple' have the same length i.e., D_1, D_2 and D_3 are equidistant from him. He may now discard D_1 (already visited) and D_2 (already rejected) and study D_3.

Along the five steps of this imaginary case, the evolution of "knowledge paths" follows the metaphor of the selective reinforcement of neural beams, except that this reinforcement is not regulated by a single system of values, rather by a collaboration/competition between the three systems of values of A, B and C. The three co-learners learn as a whole, in a trans-disciplinary way: the dynamics are governed by emotions and topology, not by logics.

5 Conclusion

Starting from the three worlds proposed by K. Popper (the external world of objects and events, the internal world of mind and the world of language: interpretable by humans and machines), we have explored the internal world by following the Theory of Neuronal

Group Selection (or Neural Darwinism) of G.M. Edelman. Learning and understanding rely on a complex network of re-entrant neural maps, i.e., maps connected by beams whose force is continuously reinforced – readjusted by the events of our life. These learning phenomena are regulated by our system of values and occur mainly through social interactions.

We have re-visited these elements within the paradigm of the Web and reformulated the question of the emergence of a collective knowledge partially supported by algorithms. The ViewpointS approach offers a formalism as well as a metaphor able to integrate most if not all these elements: we have illustrated through an imaginary case how to produce and consume knowledge in a trans-disciplinary mode.

Within ViewpointS: logical inferences of the semantic Web, statistical recommendations of the mining community, authority and trust of the social Web may all be exploited within the world of digital traces interpretable by human or artificial agents. Since both the construction of the graphs and their use, occur as a result of spontaneous activities of the humans, we conjecture with Edelman that these choices are regulated by the individual system of values that include instincts, culture, personality traits, shortly: affect [24]. As a consequence, we speculate to be facilitated in the goal to measure these values during the interactive activities constructing and using our knowledge graphs and maps in order to understand and forecast human brain behaviors [25].

Since ViewpointS integrates the logical, the statistical and the social Web, it is evident for us that we gain in the integration but we loose with respect to the advantages of each of the three approaches taken individually. For this reason, we are not yet sure if the collective knowledge emerging from ViewpointS graphs and maps (our proposed Collective Brain) will perform competitively with a similar wisdom emerging from each of the three crowds.

Nevertheless: as it has been always the case in the synergies between technological developments and scientific progress, the developments do not ensure scientific discovery, rather may facilitate the process. For instance: Galileo's telescopes did not directly produce the results of modern astronomy, but enabled a significant progress. We hope and believe that our proposed Collective Brain will have a positive impact in understanding and forecasting some aspects of human cognition.

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Chapter 4

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