Corso di Laurea Magistrale in Psicologia del Ciclo di Vita e dei Contesti
Curriculum: Psicologia Sociale e della Salute

Virtual Group Dynamics and Social Networks

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Collective Intelligence

Some Definitions

Collective Intelligence (1)

The working definition of collective intelligence that we're using is that *collective intelligence is groups of individuals doing things collectively that seem intelligent (Malone, 2008)*

Now, if you think about it that way, collective intelligence has existed for a very long time. Families, companies, and countries are all groups of individual people doing things that at least sometimes *seem* intelligent. Beehives and ant colonies are examples of groups of insects doing things like finding food sources that seem intelligent. And we could even view a single human brain as a collection of individual neurons or parts of the brain that collectively act intelligently. (Malone, 2008)

Malone, T. W. (2008). What is collective intelligence and what will we do about it. *Collective Intelligence: Creating a Prosperous World at Peace, Earth Intelligence Network, Oakton, Virginia*, 1-4.

Collective Intelligence

Some Definitions

Collective Intelligence (2)

Collective intelligence itself is a certain property of a group of beings which is expressed/observable and measurable. It is *not assumed* that the beings are cooperating or that they are conscious beings; nothing is assumed about the communication system; we do not even assume that these beings are alive (subsequently, a definition of *being alive* is not necessary). we can not assume willful cooperation for collective intelligence, or else the definition of cooperation would have to be very vague. (Szuba, 2001)

Szuba, T. (2001). A formal definition of the phenomenon of collective intelligence and its IQ measure. *Future Generation Computer Systems, 17*(4), 489-500.

Collective Intelligence

Some Definitions

Collective Intelligence (3)

In recent years, the concept of collective intelligence has been widely discussed from various aspects. One series of related work is inspired by the ***"Swarm Intelligence" phenomena*** that can commonly be observed in the biological world. For example, in an ant colony, highly-intelligent collective activities of the whole colony may emerge from the local interactions between the individual ants, which embody very limited intelligence *per se.* the collective intelligence of human groups is the idea that a human group may manifest higher capabilities of information-processing and problem-solving than any individual participant of that group does (Luo, 2009)

Luo, S., Xia, H., Yoshida, T., & Wang, Z. (2009). Toward collective intelligence of online communities: A primitive conceptual model. *Journal of Systems Science and Systems Engineering, 18*(2), 203-221.

Collective Intelligence

Some Definitions

Collective Intelligence (4)

Collective intelligence is defined as the ability of a group to solve more problems than its individual members. It is argued that the obstacles created by individual cognitive limits and the difficulty of coordination can be overcome by using a collective mental map (CMM), i.e., for istance a common culture. (Heylinghen, 1999)

Heylighen, F. (1999). Collective Intelligence and its Implementation on the Web: algorithms to develop a collective mental map. *Computational & Mathematical Organization Theory, 5*(3), 253-280.

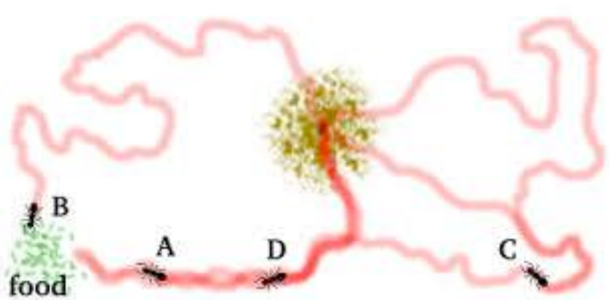
Collective Intelligence

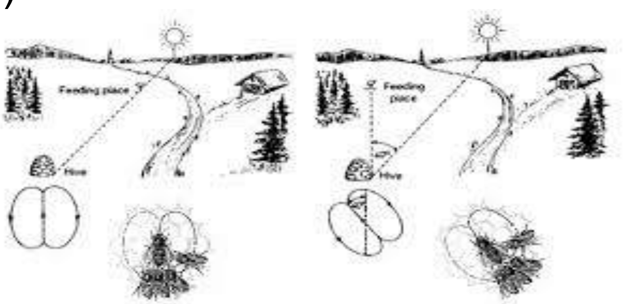
Theoretical Constructs and Models

Collective Intelligence

It is a paradox that the evaluation of the collective intelligence of social structures can be easier than the evaluation of the IQ of a single being.

- Many elements of collectively intelligent activity can be observed, measured, and evaluated in a social structure. We can easily observe displacements and actions of beings as well as exchange of information between beings (e.g. language or the ant pheromone communication system). (Szuba, 2001)





Szuba, T. (2001). A formal definition of the phenomenon of collective intelligence and its IQ measure. *Future Generation Computer Systems*, *17*(4), 489-500.

Collective Intelligence

Theoretical Constructs and Models

The Group Mind

Many Models of computations have recently been proposed and applied to collective intelligence. Experiments with chaotic collective inferences in a social structure with use of such models, demonstrate that a group (with some restrictions) can complete an inference with an appropriate conclusion, even when facing some internal inconsistencies, i.e. it can work as a *group mind.* *(Szuba, 2001)*

Szuba, T. (2001). A formal definition of the phenomenon of collective intelligence and its IQ measure. *Future Generation Computer Systems, 17*(4), 489-500.

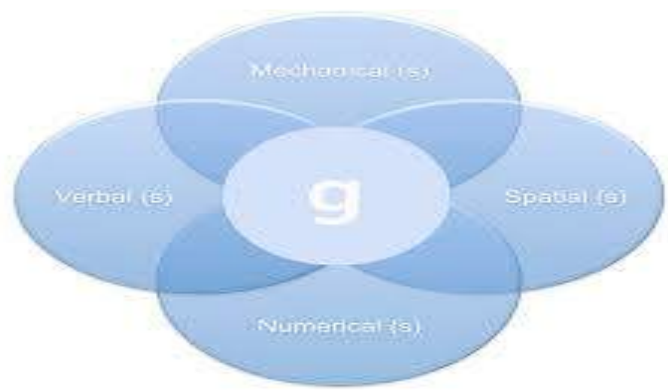
Collective Intelligence

Theoretical Constructs and Models

The C Factor of Collective Intelligence

The journal Science has recently published an intriguing paper by Woolley, Chabris, Pentland, Hashmi, and Malone (2010) in which evidence of a 'collective intelligence' or ***'c-factor' undergirding group performance*** on a variety of group tasks is presented.

- They argue that this is similar (but not strongly related) to ***g*** and its association with individual differences scales.



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Collective Intelligence

Theoretical Constructs and Models

The C Factor of Collective Intelligence

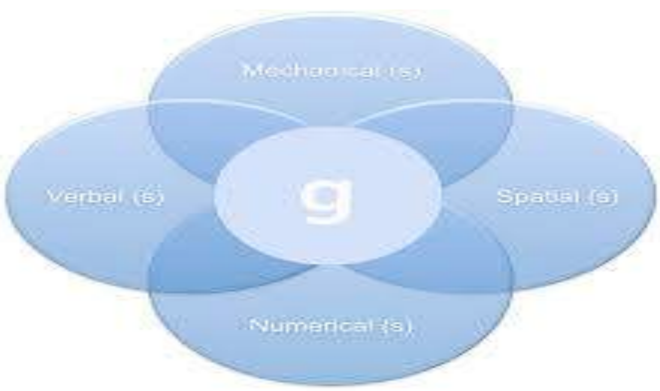
The tasks included

1. ***brainstorming***,

2. ***making collective moral judgements***,

3. ***negotiation over limited resources***

4. and ***solving visual puzzles amongst others***.



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Collective Intelligence

Theoretical Constructs and Models

The C Factor of Collective Intelligence

- In the first study ***an average correlation of r = .28 was observed between group scores on different tasks***,
- and exploratory factor analysis revealed that ***the first factor accounted for over 43% of the variance.***
- Interestingly, it was also found that ***the average and maximum intelligence scores of individual group members were not significantly correlated with C.***
- The second study increased the size and number of groups along with the diversity of group tasks, and substantively replicated the findings of the first study. (Luo, 2009)

Luo, S., Xia, H., Yoshida, T., & Wang, Z. (2009). Toward collective intelligence of online communities: A primitive conceptual model. *Journal of Systems Science and Systems Engineering, 18*(2), 203-221.

Collective Intelligence

Theoretical Constructs and Models

The C Factor of Collective Intelligence

By combining the findings of both studies, the researchers found that:

- ***the average intelligence of individual group members was in fact modestly correlated with C*** (r=.15, p.<.05),
- as was ***the intelligence of the highest-scoring team member*** (r = .19, p.<.01).

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Collective Intelligence

Theoretical Constructs and Models

The C Factor of Collective Intelligence

By combining the findings of both studies, the researchers found that:

- Three other unrelated factors appeared to be much more strongly correlated with **C** however:
    - average ***social sensitivity of group members***, measured using the ‘Reading the Mind in the Eyes Test’ (Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001), r=.26, p.<.01;
    - the ***variance in the number of speaking turns*** taken by group members, a measure of the degree to which individuals dominated conversations, (r = −.41, p.<.01);
    - ***the proportion of females in the group*** (r = .23, p.<.01). (Luo , 2009)

Luo, S., Xia, H., Yoshida, T., & Wang, Z. (2009). Toward collective intelligence of online communities: A primitive conceptual model. *Journal of Systems Science and Systems Engineering, 18*(2), 203-221.

Collective Intelligence

Theoretical Constructs and Models

The Wisdom of Crowds

Surowiecki's book *The Wisdom of Crowds* (2004) vividly describes the phenomenon and highlights some of the potentially underlying mechanisms.

- ***A group of average people can – under certain conditions – achieve better results than any individual of the group***. This seems to hold even if one member of the group is more intelligent than the rest of the group.

Leimeister, J. M. (2010). Collective intelligence. *Business & Information Systems Engineering*, 2(4), 245-248.

Collective Intelligence

Theoretical Constructs and Models

The Wisdom of Crowds

Surowiecki defines various conditions for the successful application of the "Wisdom of Crowds", such as:

- ***diversity in opinions***,
- ***independence***,
- and ***decentrality of group members*** or within a group.

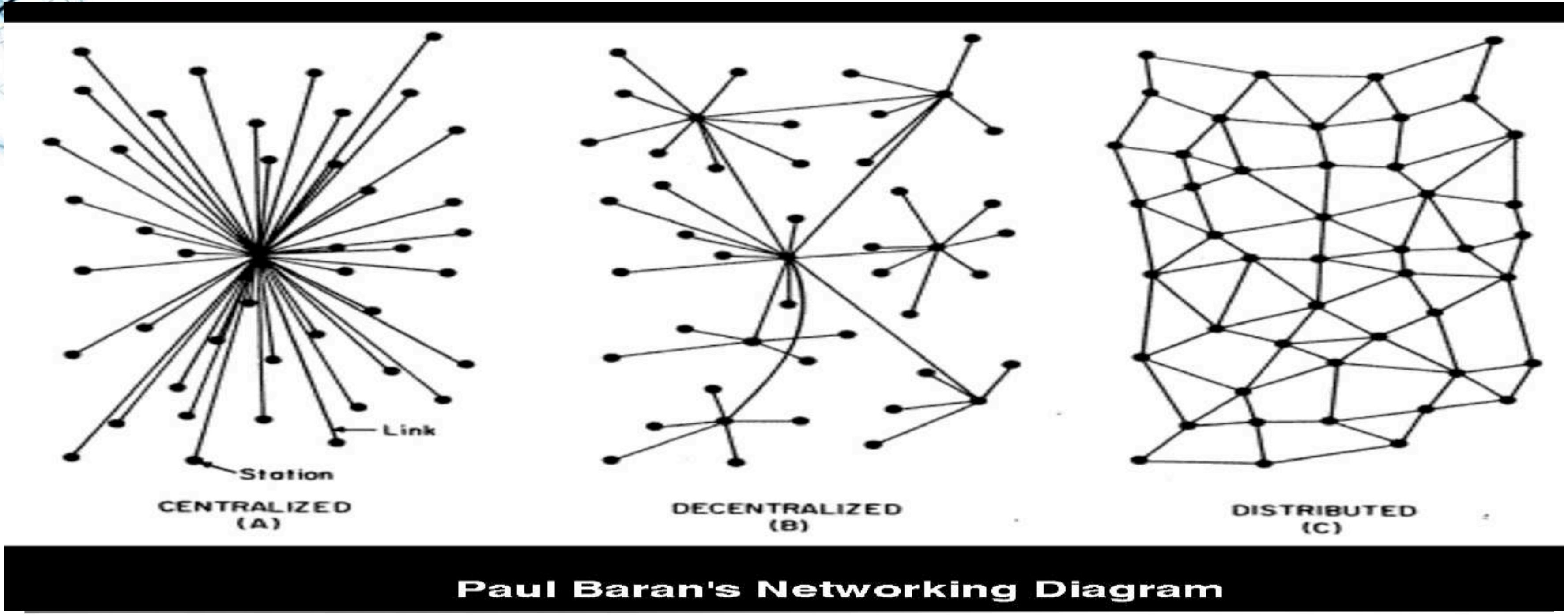
Thus, ***best collective decisions are not made by consensus building and compromises***, but through a ***competition of heterogeneous independent opinions***, i.e. through the usage of collective intelligence (Surowiecki 2004).

Leimeister, J. M. (2010). Collective intelligence. *Business & Information Systems Engineering*, 2(4), 245-248.

Collective Intelligence

Theoretical Constructs and Models

The Wisdom of Crowds



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Collective Intelligence

Theoretical Constructs and Models

Social Problem Solving: The Critical Thinking

To study groups dynamics of social problem solving many reaserchers employ a classification of the levels of observable intellectual behaviors based on a five-stage critical thinking and problem-solving model proposed by Garrison (1991). This particular classification system could be better understood and put into the context of analyzing individual intellectual behaviors if paralleled with earlier models developed by Bloom (1956) and Henri (1991). (Kim, 2001)

Kim, P., Lee, D., Lee, Y., Huang, C., & Makany, T. (2011). Collective intelligence ratio: Measurement of real-time multimodal interactions in team projects. *Team Performance Management: An International Journal*, *17*(1/2), 41-62.

Collective Intelligence

Theoretical Constructs and Models

Social Problem Solving: The Critical Thinking

Garrison's stages	Bloom's categories	Henri's cognitive skills	Description
Identification	Knowledge	Elementary clarification	Observe, recall and identify information
Definition	Comprehension	In-depth clarification	Understand underlying meanings, values, assumptions
	Application		Use of a learnt concept in a novel situation
Exploration	Analysis	Inferencing	Concepts are separated and understood by their propositional structure
Evaluation	Evaluation	Judgment	Decision-making, evaluation, criticism
Integration	Synthesis	Application of strategies	Build from diverse elements to create a new structure

Table I. Comparison of the five-stage model of critical thinking by Garrison (1991) with the cognitive learning categories of Bloom (1956) and the cognitive skills in problem-solving by Henri (1991)

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Collective Intelligence

Theoretical Constructs and Models

Collective Intelligence

Smith (1994) stated the reasons that people normally form collaborative groups – ***the task is too large to be completed by an individual*** within limited time and no one possesses all of the skills and knowledge required.

- Through collective intelligence, groups of individuals often ***work collectively so as to acquire new knowledge on a just-in-time basis*** (Jenkins, 2009).
- Levy (2000) described the potential of "collective intelligence" as ***"everyone knows something, nobody knows everything and what any one person knows can be tapped by the group as a whole."***
- In regards to the motivation of collaborative behaviors, Brown and Lauder (2001) defined ***collective intelligence as*** a basis for an empowerment opportunity: "***pooling of team intelligence to attain common goals or resolve common problems***"

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Theoretical Constructs and Models

Collective Intelligence

- ***Teams often create novel and unexpected combinations of knowledge*** in ways that individuals could not (Hargadon, 1999).

Such ***opportunistic team cognition becomes more possible when there is a collective critical thinking process***. In other words, outcomes (e.g. ***augmented intelligence, new knowledge, innovative solution***) led by ***iterative team reflections and cognitions*** qualify to be the result of collective intelligence because such critical thinking processes involve the analysis of premises, arguments, and evidence arising from team interactions (Kamin et al., 2001).

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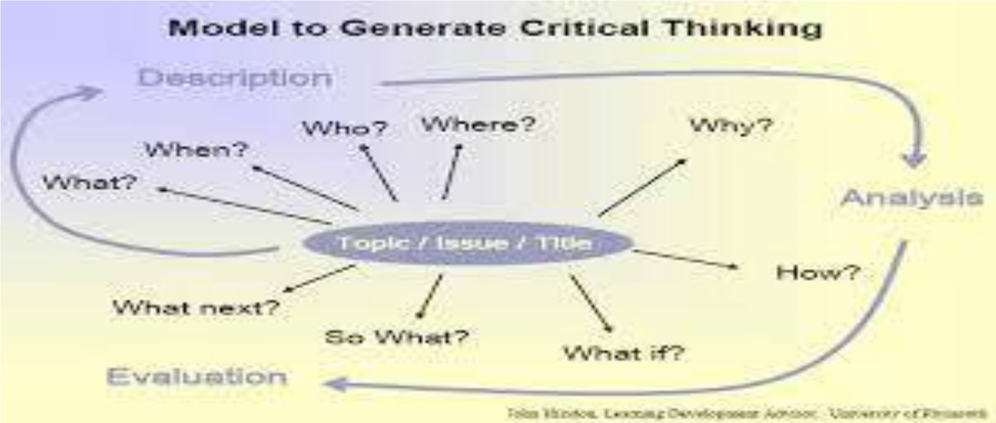
Collective Intelligence

Theoretical Constructs and Models

Critical Thinking: The model of Norris & Ennis

A widely used definition of critical thinking is proposed by Norris and Ennis (1989) who asserted that critical thinking is reflective thinking that is focused on deciding what to believe or do.



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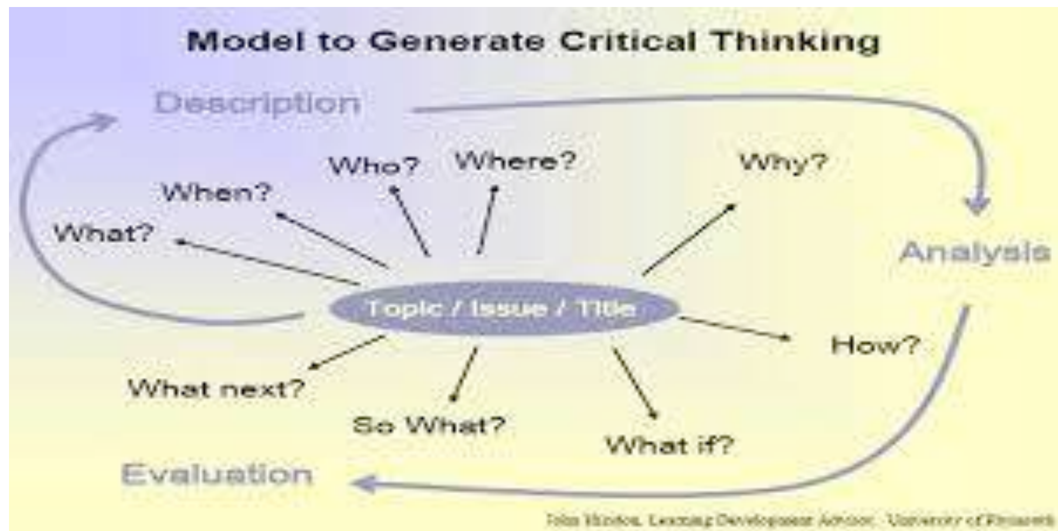
Collective Intelligence

Theoretical Constructs and Models

Critical Thinking: The model of Norris & Ennis



1. ***clarifying information***,
2. ***assessing evidence***,
3. ***judging inferences***, and
4. ***applying appropriate strategies and tactics***.

Kim, P., Lee, D., Lee, Y., Huang, C., & Makany, T. (2011). Collective intelligence ratio: Measurement of real-time multimodal interactions in team projects. *Team Performance Management: An International Journal*, *17*(1/2), 41-62.

Collective Intelligence

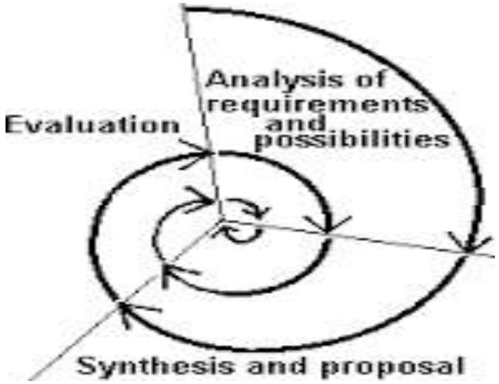
Theoretical Constructs and Models

Critical Thinking: From the model of Bloom to hyphothesys of Newman

A more historical source of critical thinking can be found in Bloom's cognitive taxonomy of educational objectives (Bloom, 1956).

The top three of Bloom's categories:

1. ***analysis***,
2. ***synthesis***
3. and ***evaluation***



are comparable to the definitions of critical thinking by Kennedy et al. (1991).

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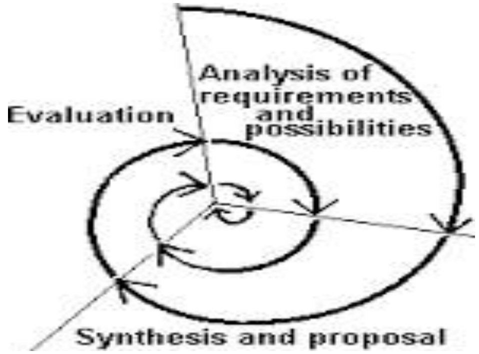
Collective Intelligence

Theoretical Constructs and Models

Critical Thinking: From the model of Bloom to hyphothesys of Newman



Note for the future

Newman et al. (1997) concluded that ***computer-mediated conferencing facilitates higher levels of critical thinking while face-to-face interactions encourage more creative and higher volumes of interaction.*** For this regard, Newman et al. (1997) also provided discrete evidence for each phase of Garrison's (1991) critical thinking model and a specific scenario in which teams tackled explicit problem-solving tasks.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

With the growing interest in complex adaptive systems, artificial life, swarms and simulated societies, the concept of "collective intelligence" is coming more and more to the fore.

The basic idea is that a group of individuals (e.g. people, insects, robots, or software agents) can be smart in a way that none of its members is. Complex, apparently intelligent behavior may emerge from the synergy created by simple interactions between individuals that follow simple rules.

Heylighen, F. (1999). Collective Intelligence and its Implementation on the Web: algorithms to develop a collective mental map. *Computational & Mathematical Organization Theory, 5*(3), 253-280.

Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

To be more accurate we can ***define intelligence as the ability to solve problems.***

A system is more intelligent than another system if:

in a given time interval it can solve more problems, or find better solutions to the same problems.

A group can then be said to exhibit collective intelligence if it can find more or better solutions than the whole of all solutions that would be found by its members working individually.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

All organizations, whether they be firms, institutions or sporting teams, are created on the assumption that their members can do more together than they could do alone.

- Yet, ***most organizations have a hierarchical structure***, with one individual at the top directing the activities of the other individuals at the levels below. Although no president, chief executive or general can oversee or control all the tasks performed by different individuals in a complex organization, one might still ***suspect that the intelligence of the organization is somehow merely a reflection or extension of the intelligence of its hierarchical head***.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

- ***This is no longer the case in small, closely interacting groups*** such as soccer or football teams, where the "captain" rarely gives orders to the other team members. *The movements and tactics that emerge during a soccer match are not controlled by a single individual, but result from complex sequences of interactions.* Still, they are simple enough for an individual to comprehend, and since soccer players are intrinsically intelligent individuals, it may appear that the team is not really more intelligent than its members.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Obstacles to collective intelligence

1. First, however competent the participants, their individual **intelligence is still limited**, and this imposes a fundamental restriction on their ability to cooperate.
2. Another recurrent problem is that people tend to **play power games**. Everybody would like to be recognized as the smartest or most important person in the group, and is therefore inclined to dismiss any opinion different from his or her own. Such power games often end up with the establishment of a "pecking order", where the one at the top can criticize everyone, while the one at the bottom can criticize no one. The result is that the people at the bottom are rarely ever paid attention to, however smart their suggestions.
3. ***coordination***. To tackle a problem collectively, the different subgroups must keep close contact. This implies a constant exchange of information so that the different groups would know what the others are doing, and can use each other's results. But this again creates a great information load, taxing both the communication channels and the individual cognitive systems that must process all this incoming information. Such load only becomes larger as the number of participants or groups increases.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Collective Problem-Solving

To better understand collective intelligence we must first analyse intelligence in general, that is, ***the ability to solve problems***.

- A ***problem*** can be defined as a difference between the present situation, as perceived by some agent, and the situation desired by that agent.
- ***Problem-solving*** then means finding a sequence of actions that will transform the present state via a number of intermediate states into a goal state.

Of course, ***there does not need to be a single, well-defined goal: the agent's "goal" might be simply to get into any situation that is more pleasant, interesting or amusing than the present one***. The only requirement is that the agent can *distinguish* between subjectively "better" (preferred) and "worse" situations (Heylighen 1988, 1990).

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Collective Problem-Solving

To generalize this definition of a problem for a collective consisting of several agents it suffices to aggregate the desires of the different agents into a collective preference and their perceptions of the present situation into a collective perception.

- In economic terms, t***he aggregate desire becomes the market "demand" and the aggregate perception of the present situation becomes the "supply"*** (Heylighen, 1997).
- It must be noted, though, that ***what is preferable for an individual member is not necessarily what is preferable for a collective*** (Heylighen & Campbell, 1995):
- in general, a ***collective has emergent properties that cannot be reduced to mere sums of individual properties***.

(Therefore, the aggregation mechanism will need to have a non-linear component.)

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Mental maps

The efficiency of mental problem-solving depends on the way the problem is *represented* inside the cognitive system (Heylighen 1988, 1990).

Representations typically consist of the following components:

1. ***a set of problem states***,
2. ***a set of possible actions***,
3. and ***a preference function or "fitness" criterion*** for selecting the most adequate actions.

The ***fitness criterion***, of course, ***will vary with the specific goals or preferences of the agent***. Even for a given preference, though, there are many ways to decompose a problem into states and actions.

Changing the way a problem is represented, by considering different distinctions between the different features of a problem situation, may make an unsolvable problem trivial, or the other way around (Heylighen 1988, 1990).

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Mental maps

- ***Actions*** can be represented as ***operators or transitions that map one state onto another one***.
- ***A state*** that can be reached from another state by a single action can be seen as a neighbor of that state.
- Thus, ***the set of actions induces a topological structure on the set of states, transforming it into a problem space***.
- The ***simplest model of such a space is a network, where the states correspond to the nodes of the network, and the actions to the edges or links that connect the nodes***.
- The ***selection criterion***, finally, can be represented by a ***preference function that attaches a particular weight to each link***.

This problem representation can be seen as the agent's *mental map* of its problem environment.

Heylighen, F. (1999). Collective Intelligence and its Implementation on the Web: algorithms to develop a collective mental map. *Computational & Mathematical Organization Theory, 5*(3), 253-280.

Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Mental maps

To solve a problem, you need a general heuristic or search algorithm, that is, a method for selecting a sequence of actions that is likely to lead as quickly as possible to the goal.

- If we assume that the ***agent has only a local awareness of the mental map***, that is, that the agent can only evaluate actions and states that are directly connected to the present state,
- then ***the most basic heuristic it can use is some form of "hill-climbing" with backtracking***. This heuristic works as follows:

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Mental maps

"hill-climbing" with backtracking. This heuristic works as follows:

- from the present state choose the link with the highest weight that has not been tried out yet to reach a new state;
- if all links have already been tried, backtrack to a state visited earlier which still has an untried link;
- repeat this procedure until a goal state has been reached or until all available links have been exhausted.

The efficiency of this method will obviously depend on how well the nodes, links and preference function reflect the actual possibilities and constraints in the environment.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Mental maps

The better the map, the more easily problems will be solved.

- ***Intelligent agents***, then, ***are characterized by the quality of their mental maps***, that is, by the knowledge and under- standing they have of:
  - *their environment*,
  - *their own capacities for action*,
  - and *their goals*.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Mental maps

Increasing problem-solving ability will generally require two complementary processes:

1. ***Enlarging the map with additional states and actions***, so that until now unimagined options become reachable;

2. ***Improving the preference function***, so that the increase in total options is counterbalanced by a greater selectivity in the options that need to be explored to solve a given problem.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Coordinating individual problem-solutions

Let us apply this conceptual framework to collective problem-solving. Imagine a group of individuals trying to solve a problem together.

Each individual can explore his or her own mental map in order to come up with a sequence of actions that constitutes part of the solution.

It would then seem sufficient to combine these partial solutions into an overall solution.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Coordinating individual problem-solutions

Assuming that the individuals are similar (e.g. all human beings or all ants), and that they live in the same environment, we may expect their mental maps to be similar as well. However, ***mental maps are not objective reflections of the real world "out there": they are individual constructions, based on subjective preferences and experiences*** (cf. Heylighen 1999).

Therefore, the maps will also be to an important degree different.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Coordinating individual problem-solutions: the maps

The mental maps' diversity is healthy, since it means that different individuals may complement each others' weaknesses.

- Imagine that each individual would have exactly the same mental map. In that case, they would all find the same solutions in the same way, and little could be gained by a collective effort. (In the best case, the problem could be factorized into independent subproblems, which would then be divided among the participating in- dividuals. This would merely speed up the problem-solving process, though; it would not produce any novel solutions).

As it is clear that a CMM cannot be developed by merely registering and editing individual contributions, we will need to study different methods to collectively develop a mental map.

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: The model of Heylinghen

Mechanisms of CMM Development

Probably the most basic method for reaching collective decisions and avoiding conflicts is ***voting***.

This method assumes that all options are known by all individuals, and that the remaining question is to determine their aggregate preference. In the simplest case, every individual has one vote, which is given to the options that this individual prefers above all others. Adding all the votes together determines the relative preferences of the different alternatives for actions.

Heylighen, F. (1999). Collective Intelligence and its Implementation on the Web: algorithms to develop a collective mental map. *Computational & Mathematical Organization Theory, 5*(3), 253-280.

Collective Intelligence

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Mechanisms of CMM Development

The three basic mechanisms of

- ***averaging***,
- ***feedback*** and
- ***division of labor***

gave us a first idea of a how a CMM can be developed in the most efficient way, that is, ***how a given number of individuals can achieve a maximum of collective problem-solving competence.***

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Mechanisms of CMM Development

A ***collective mental map is developed basically by superposing a number of individual mental maps***.

- There must be ***sufficient diversity*** among these individual maps to cover an as large as possible domain,
- yet ***sufficient redundancy*** so that the overlap between maps is large enough to make the resulting graph fully connected, and so that each preference in the map is the superposition of a number of individual preferences that is large enough to cancel out individual fluctuations.
- The best way to quickly expand and improve the map and fill in gaps is to ***use a positive feedback that encourages individuals to use high preference paths discovered by others, yet is not so strong that it discourages the exploration of new paths***.

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In the work at MIT's Center for Collective Intelligence, the Malone's team have gathered nearly 250 examples of Web enabled collective intelligence (for more, see "About the Research").

At first glance, what strikes one most about this collection of examples is its diversity, with the systems exhibiting a wildly varying array of purposes and methods. But after examining these examples in depth, they identified a relatively small set of building blocks that are combined and recombined in various ways in different collective intelligence systems. To classify these building blocks, they use two pairs of related questions.

- ***Who is performing the task? Why are they doing it?***
- ***What is being accomplished? How is it being done?***

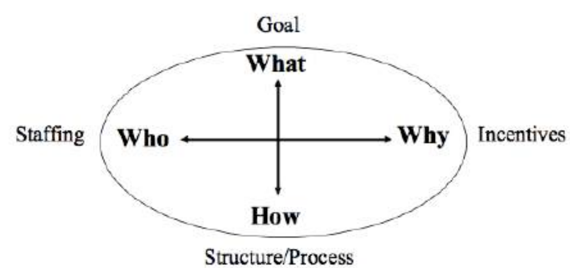

Figure 1: Elements of collective intelligence building blocks or "genes"

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Collective Intelligence

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Collective intelligence: The model of Malone

The genes of collective intelligence

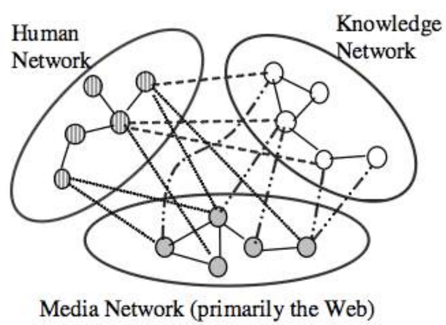

Figure 2 Illustration of the supernetowrk of community intelligence

Malone's team calls these ***building blocks the "genes" of collective intelligence systems***. And they define a ***gene as a particular answer to one of the key questions*** (Who, Why, What, or How) ***associated with a single task in a collective intelligence system.*** (Malone, 2009)

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Who? and Why?

The first question to be answered is, ***Who undertakes the activity***? Here there are two basic genes.

Hierarchy. In traditional hierarchical organizations, this question is typically answered when ***someone in authority assigns a particular person or group of people to perform the task***. The task may be assigned to personnel inside the firm or to people outside it, through the hiring of a subcontractor.

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Who? and Why?

Crowd. In the Crowd gene, ***activities can be undertaken by anyone in a large group who chooses to do so***, without being assigned by someone in a position of authority.

For example, *anyone who wants to can submit a module for possible inclusion in Linux. While crowds have done certain things, like voting in elections, for a long time, low cost electronic communication enabled by the Internet now makes it feasible for crowds to do many more things than ever before*. (Malone, 2009)

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Closely related to the Who question is Why? ***Why do people take part in the activity?*** What motivates them to participate? What incentives are at work?

As a simplified overview of the possibilities, however, ***three basic Why genes can cover the high level motivations that lead people to participate in collective intelligence systems***.

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Even if Maslow rules …. we can suggesting a trivial three factors model:

- ***Money***. The promise of financial gain is an important motivator for most actors in markets and traditional organizations.
- ***Love***. Love is also an important motivator in many situations, even when there is no prospect of monetary gain. The Love gene can take several forms: people can be motivated by their intrinsic *enjoyment* of an activity, by the opportunities it provides to *socialize with others,* or because it makes them feel they are *contributing to a cause* larger than themselves. Studies of Wikipedia have shown that its participants are motivated by all three of these variants of the Love gene.
- ***Glory***. Glory or recognition is another important motivator. The programmers in many open source software communities, for example, are motivated by the desire to be recognized by peers for their contributions.

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Why?

What is novel about many of the collective intelligence systems that have emerged in recent years is their reliance on the Love and Glory genes, in contrast to traditional organizations, which have relied more heavily on Money as a motivating force.

- For instance, **collective intelligence systems often explicitly engineer opportunities for recognition by compiling and publishing "top contributor" lists** *or by institutionalizing performance-based classes of membership that confer various degrees of status, such as "power seller" on eBay and "top reviewer" on Amazon.*

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What? and How?

The third question to be answered for any activity is: ***What is being done***? In traditional organizations, the answer to this question is often spoken of as *the **mission** or **goal**.*

For What, the many organizational goals encountered in collective intelligence systems can be boiled down into two basic genes.

Create. In this gene, the actors in the system generate something new—a piece of software code, a blog entry, a T-shirt design.

Decide. In this gene, the actors evaluate and select alternatives—deciding whether a new module should be included in the next release of Linux, selecting which T-shirt design to manufacture, deciding whether to delete a Wikipedia article.

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What? and How?

The final question to be answered concerning an activity is, ***How is it being done***? In traditional organizations, the How question is typically answered by describing the *organizational structures and processes*.

Many collective intelligence systems still use hierarchies for some of their tasks, but *what is novel is how they use crowds*. So we focus here on instances of the How gene where the crowd does the Create or Decide task.

A **key determinant of the answer to this question is whether the different members of the crowd make their contributions and decisions *independently* of each other or whether there are strong *dependencies* between their contributions.**

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What? and How?

This insight gives rise to four primary How genes for Crowds (see Table 1).

	Independent	Dependent
Create	Collection	Collaboration
Decide	Individual Decisions	Group Decision

Table 1: Variations of the How gene for Crowds

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Collection and Collaboration

The two How genes associated with the Create task are ***Collection*** and ***Collaboration***.

- ***Collection***. This gene occurs when the items contributed by members of the crowd are created independently of each other.

For example, YouTube videos are created mostly independently of each other, and this makes YouTube a collection. Other examples of this common gene include Digg, a collection of news stories, and Flickr, a collection of photographs.

- An important subtype of the Collection gene is the ***Contest* gene**. In contests, like Threadless, one or several items in the collection are designated as the best entries and receive a prize or other form of recognition.
- In another example of contests, ***InnoCentive***, companies offer cash rewards, typically totaling in the five or even six figures, to researchers anywhere in the world who can solve challenging scientific problems such as how to synthesize a particular chemical compound.

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Collection and Collaboration

Collaboration The Collaboration gene occurs when members of a Crowd work together to create something and important dependencies exist between their contributions.

For example, even though there is extensive hyper-linking between them, articles in Wikipedia are meant to stand on their own as independent entities. This means Wikipedia as a whole is a Collection of articles. But the additions and editorial changes that different contributors make within a single Wikipedia article are strongly interdependent. So each individual Wikipedia article is a Collaboration, comprised of contributions submitted by a number of users. Another important example of the Collaboration gene is Linux, and any other open source software project, where there are strong interdependencies among the modules submitted by different contributors.

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Decision

For Decide tasks, there are two possible genes: ***Group Decision*** and ***Individual Decisions***.

Group Decision. The Group Decision gene occurs when inputs from members of the crowd are assembled to generate a decision that holds for the group as a whole.

In some instances, such as Threadless, this decision determines the subset of contributed items that will be included into the final output. In other instances, such as Digg, the decision relates to generating a common rank-ordering of the contributed items. In yet other instances, such as prediction markets, the decision relates to aggregating individual inputs to form a publicly visible estimate of a quantity. (Malone, 2009)

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Decision

Important variants of the Group Evaluation gene are ***Voting***, ***Consensus***, ***Averaging***, and ***Prediction Markets.***

Voting. New technologies make the Voting gene feasible in many situations where it would not otherwise have been practical. For example:

- An important sub-variation of voting is ***implicit voting***, where actions like buying or viewing items are counted as implicit "votes." *For instance, iStockPhoto displays photos in order of the number of times each photo has been downloaded, and YouTube ranks videos by the number of times they have been viewed.*
- Another important sub-variation involves ***weighted voting***. *For example, Google ranks search results, in part, on the basis of how many other sites link to the sites in the list. But Google's algorithm gives more weight to links from sites that are, themselves, more popular.*

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Decision

Important variants of the Group Evaluation gene are ***Voting***, ***Consensus***, ***Averaging***, and ***Prediction Markets.***

- ***Consensus***. Consensus means that all, or essentially all, group members agree on the final decision.

For example in Wikipedia, the articles that remain unchanged are those for which everyone who cares is satisfied with the current version. Thus Wikipedia uses a kind of consensus to make editing decisions on individual articles.

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Decision

- Consensus is also used in an interesting way in *reCAPTCHA,* a Web security utility. *Two words are displayed on the screen, with users required to type both to gain access to a Web page. One of the words is a security key and the other a word previously scanned as part of a project to digitize old books. Words the optical character recognition software finds difficult to read are served up to multiple users as one half of each reCAPTCHA. Only after the transcriptions provided by multiple users reach a* **level of consensus, as determined by a statistical algorithm**, *is that word deemed to have been correctly transcribed.*

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Decision

Important variants of the Group Evaluation gene are ***Voting***, ***Consensus***, ***Averaging***, and ***Prediction Markets.***

Averaging. In cases where decisions involve picking a number, another common practices is to average the numbers contributed by the members of the Crowd. In some cases, such as guessing the weight of an oxiv, simple averaging works surprisingly well.

Averaging is commonly used in systems that rely on a point scale for quality rating. For example,

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Decision

- **users of *Amazon*** can rate books or CDs on a five star scale, and these ratings are averaged to provide an overall score for each item. Similar systems allow users of *Expedia* to rate hotels and users of *Internet Movie Database* to rate movies.
- ***NASA Clickworkers***. In 2001-02, NASA let anyone look at photos of the surface of Mars on the Internet and identify features they thought were craters. Crater locations were designated by sets of coordinates in two dimensional space. When the coordinates contributed by amateurs were averaged, they were found to be just as accurate as the classifications made by expert scientists.
- ***Marketocracy*** runs an investment portfolio that is selected by averaging the stocks and bonds chosen by the 100 most successful investors from over 55,000 who participate on the website.

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Decision

Important variants of the Group Evaluation gene are ***Voting***, ***Consensus***, ***Averaging***, and ***Prediction Markets.***

Prediction markets. A useful way of letting crowds estimate the probability of future events is with prediction markets. In prediction markets, people buy and sell "shares" of predictions about future events. If their predictions are correct, they are rewarded, either with real money or with points that can be redeemed for cash or prizes.

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- *Google, Microsoft, and Best Buy have all used prediction markets to tap the collective intelligence of people within their organizations.*
- *Microsoft used its prediction market to estimate completion dates for projects. When one of the first of these markets opened, the share prices for a project declined within minutes to a price indicating a 1 percent probability of on time completion. The managers in charge had thought everything was on schedule, but the prediction market's results led them to investigate further, and they found problems. The project was eventually completed three months late. Awareness of the problem was available in the organization, but the prediction market was required to bring this decentralized knowledge to the attention of people who could act on it. (Malone, 2009)*

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Individual Decisions.

The Individual Decision gene occurs when members of a Crowd make decisions that, though informed by crowd input, do not need to be identical for all. For instance, individual YouTube users decide for themselves which videos to watch. They may be influenced by recommendations or rankings from others, but they are not required to watch the same videos as others.

Two important variations of the Individual Decisions gene are: ***Markets*** and ***Social Networks***.

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Individual Decisions.

Two important variations of the Individual Decisions gene are: ***Markets*** and ***Social Networks***.

Markets. In Markets, there is some kind of formal exchange (like money) involved in the decisions.

1. Each member of the crowd makes an individual decision about what products to buy or sell.
2. Purchasing decisions by buyers in the crowd determine collective demand, which, for its part affects the availability of products and their prices.
3. And in turn, the quantities and prices of the goods put up for sale by sellers in the crowd influence, but do not bind, purchasing decisions.

Markets for many kinds of goods and services have existed for millennia, but new technologies will enable new electronic forms of markets.

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Individual Decisions.

Two important variations of the Individual Decisions gene are: ***Markets*** and ***Social Networks****.*

Social Networks. In Social Networks, members of a crowd form a network of relationships that, depending on the context, might translate into levels of trust, similarity of taste and viewpoints, or other common characteristics that might cause individuals to feel an affinity for one another. Crowd members assign different weights to individual inputs on the basis of their relationship with the people who provided them and then make individual decisions. For example:

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Collective Decisions: few examples

In the ***blogosphere**,* authors have the habit of placing links to content they like, including entries by other bloggers, notable news articles, or interesting videos. Readers, in turn, have favorite blogs that act as personalized entry points to the blogosphere. By reading these blogs and their links every reader makes an individual decision about what content to consume. But these individual decisions are shaped by the structure of the social network of the crowd. For example, bloggers often cluster in cliques that link frequently to one another. Clicking on a blog entry by one member of such a clique can quickly give a reader access to an interlinked web of related content.

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Collective Decisions: few examples

In ***YouTube****,* every user is associated with a "channel." On these channels, users can upload their own videos and/or link to selections of other users' videos, via a favorites option. Users can subscribe to other users' channels and receive notifications when their favorite channels have been updated. Users thus form social networks that affect their choices of what videos to watch.

In ***Epinions.com****,* a product review site, users form trust networks with other reviewers. Empirical evidence suggests that users weigh reviews written by members of their trust network more heavily than other reviews, leading to personalized assessments of individual product quality.

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Collective Decisions: few examples

Amazon.com provides personalized recommendations to users. Amazon does this by automatically constructing an implied social network that relates each user to other users who have purchased or rated similar products in the past. The system then recommends products that many "similar" users have liked but which the target user has not yet purchased. This is an example of the broader class of systems that are referred to by (Malone, 2009)

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Collective intelligence: The model of Malone

Question	*Gene*	*When useful*
Who	**Crowd**	• Resources useful in doing activities are distributed widely or in places not known in advance • Activities can be divided into pieces satisfactorily (necessary information can be shared; gaming and sabotage can be managed)
	Hierarchy	• Conditions for crowd aren't met
Why	**Money** **Love** **Glory**	• Many factors, too complex to list here, are relevant, with two rules of thumb – Appealing to Love and Glory, rather than Money, can often (but not always) reduce costs – Providing Money and Glory can often (but not always) influence a group's direction and speed.
How—Create	**Collection**	Conditions for Crowd, *plus*… • Activity can be divided into small pieces that can be done (mostly) independently of each other.
	Contest	Conditions for Collection, *plus*… • Only one (or a few) good solutions are needed.
	Collaboration	• Activity *cannot* be divided into small independent pieces (otherwise Collection would be better) • There are satisfactory ways of managing the dependencies among the pieces
How—Decide	**Group Decision**	Conditions for Crowd, *plus* . . . • Everyone in the group needs to abide by the same decision, *plus* …
	Voting	• It is important for the Crowd to be committed to the decision
	Averaging	Conditions for Voting, *plus*... • Decision consists of estimating a number • Crowd has no systematic bias about estimating the number
	Consensus	Conditions for Voting, *plus*… • Achieving consensus in reasonable time is feasible (group is small enough or has similar enough views)
	Prediction market	• Decision consists of estimating a number • Crowd has some information about estimating the number (biases and non-independent information are okay) • Some people may have (or obtain) much better information than others • Continuously updated estimates are useful
	Individual Decisions	Conditions for Crowd, *plus*... • Different people can make their own decision, *plus* …
	Market	• Money is needed to motivate people to provide the necessary effort or other resources
	Social network	• Non-monetary motivations are sufficient for people to provide the necessary effort or other resources • Individuals find information about other's opinions useful in making their own choices.

Table 5. Conditions for when collective intelligence genes are useful

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Collective Intelligence

Theoretical Constructs and Models

Collective intelligence: Some recent examples

In the last few years we've seen some very interesting examples of new kinds of collective intelligence:

Google, for instance, takes the collective knowledge created by millions of people making websites for other purposes and harnesses that collective knowledge—using some very clever algorithms and sophisticated technology—to produce amazingly intelligent answers to the questions we type in.

Wikipedia, at another extreme, uses much less sophisticated technology, but some very clever organizational principles and motivational techniques, to get thousands of people all over the world to volunteer their time to create an amazing on-line collection of knowledge.

Collective Intelligence

Theoretical Constructs and Models

WEB Based Collective intelligence

With advancing ***information and communication technologies*** (ICT) coupled with ***synchronous conferencing applications*** and ***social network services***, various innovative team interaction and collaboration environments have emerged in recent years.

- In this era of digitally afforded multimodality and highly networked society, ***people "integrate words with images, sound, music, and movement to create digital artifacts that do not necessarily privilege linguistic forms of signification but rather draw on a variety of modalities – speech, writing, image, gesture and sound – to create different forms of meaning"*** (Hull and Nelson, 2005, pp. 224-225).
- In the context of multimodal interaction analyses, ***these communicative intents are the building blocks of the individual's intelligence, defined as "the aggregate or global capacity of the individual to act purposefully, to think rationally and to deal effectively with his environment"*** (Wechsler, 1944, p. 3). (Kim, 2011)

Collective Intelligence

Theoretical Constructs and Models

WEB Based Collective intelligence

Inspired by the ideas of *Swarm Intelligence* and the *"global brain",* a concept of ***"community intelligence"*** is suggested, reflecting that ***some "intelligent" features may emerge in a Web-mediated online community from interactions and knowledge-transmissions between the community members.***

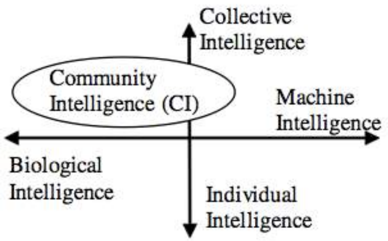

Figure 1 Community intelligence in the two-dimension-space of intelligence research

The collective intelligence of human groups is the idea that a human group may manifest higher capabilities of information-processing and problem-solving than any individual participant of that group does, especially when the participants densely interact with each other through the computerized communication channels such as the Internet and the World Wide Web. (Luo, 2009)

Collective Intelligence

Theoretical Constructs and Models

WEB Based Collective intelligence

Accompany with the explosion of the World Wide Web is the ***rapid growth of the different categories of online communities or virtual communities*** (Rheingold 2000), and the ***collective activities of those virtual communities often manifest high problem-solving capabilities***.

For example,

- in the *Open Source Software movement*, a loosely-connected community of programmers who don't even know each other can collectively develop very complex software products like the Linux operating system. With the support of the information and communication technologies (ICT), the online communities may exhibit higher intelligent features than a traditional community does since ICT firstly provides an effective communication channel for massive exchange of data, information and knowledge and secondly the computation capabilities of the modern ICT may be of great help for the information processing tasks within the entire community. (Luo, 2009)

Collective Intelligence

Theoretical Constructs and Models

WEB Based Collective intelligence

"**Emergence**" aspect of intelligence - In a virtual community, the participants exchange their opinions and expertise during the collaborative learning and problem-solving processes.

The collective-level intelligence may then emerge from such knowledge exchange activities, analogous to the emergence of the collective intelligence of the biological swarms.

The rapid development of the Internet and the Web may greatly facilitate the inter-personal knowledge exchange within a community; consequently, the virtual and online communities are of particular importance. (Luo, 2009)

Google. Wikipedia. Threadless. All are well-known examples of large, loosely organized groups of people working together electronically in surprisingly effective ways. These new modes of organizing work have been described with a variety of terms—radical decentralization, crowd-sourcing, wisdom of crowds, peer production, and wikinomics.i The phrase we find most useful is *collective intelligence,* defined very broadly as *groups of individuals doing things collectively that seem intelligent. (Malone, 2009)*

Collective Intelligence

Theoretical Constructs and Models

WEB Based Collective intelligence

From genes to genomes

(Malone, 2009)

Using the individual genes, let's now consider how sequences of these genes can be combined into genomes of complete collective intelligence systems.

Linux

As described above and summarized below, the Linux community performs two key tasks. First, anyone who wants to can Create new software modules. Then a miniature Hierarchy, consisting of Linus Torvalds and a small group of colleagues, Decides which of the submitted modules to include in the next release. Most who contribute do so for enjoyment or peer recognition, though some are also paid to contribute by companies like IBM.

Example	What		Who	Why	How
Linux	Create	New software modules	Crowd	Money Love Glory	Collaboration
	Decide	Which modules warrant inclusion in next release	Torvalds and lieutenants	Love Glory	Hierarchy

Table 2: Mapping the collective intelligence genome for Linux

Collective Intelligence

Theoretical Constructs and Models

WEB Based Collective intelligence

From genes to genomes

(Malone, 2009)

Using the individual genes, let's now consider how sequences of these genes can be combined into genomes of complete collective intelligence systems.

Wikipedia

As described above and summarized in Table, editing individual Wikipedia articles is a form of Collaboration in which decisions are made by a rough consensus: anyone who wants to can make a change in almost any article, and articles remain unchanged only if everyone who cares is satisfied with the current version.

Collective Intelligence

Theoretical Constructs and Models

WEB Based Collective intelligence

From genes to genomes

(Malone, 2009)

Wikipedia

Example	What		Who	Why	How
Edit existing Wikipedia articles	Create	New version of article	Crowd	Love, Glory	Collaboration
	Decide	Whether to keep current version	Crowd	Love, Glory	Consensus
Decide what Wikipedia articles to include	Create	New article	Crowd	Love, Glory	Collection
	Decide	Whether to delete (preliminary)	Crowd	Love, Glory	Voting
	Decide	Whether to delete (final)	Wikipedia administrator	Love, Glory	Hierarchy

Table 3: Mapping the collective intelligence genome for Wikipedia

Collective Intelligence

Theoretical Constructs and Models

WEB Based Collective intelligence

From genes to genomes

(Malone, 2009)

Using the individual genes, let's now consider how sequences of these genes can be combined into genomes of complete collective intelligence systems.

Wikipedia

A different set of mechanisms is used to decide which articles should be included at all.

- Anyone who wants to can create a new article. For instance, no one would stop someone from creating an article about his or her own cat (What = Create article; Who = Crowd).
- But if someone else thinks the article isn't important enough, they can nominate it for deletion.
- Then anyone can give comments about why the article should or should not be deleted and cast a vote (What = Decide whether to delete article; Who = Crowd; How = Voting).
- Eventually, a Wikipedia administrator looks at the votes, reads the comments, and makes a final decision about whether to delete the article (What = Decide whether to delete article; Who = Wikipedia administrator; How = Hierarchy). (Malone, 2009)