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CHAPTER 1

What Is Collective Intelligence?

1.1 The Need for New Types of Collective Problem Solving

In the new era of digital communication, collective problem solving is increasingly important. With the Internet and digitalization of information, large groups can now solve problems together in completely different ways than are possible in offline settings (Lévy, 1999). These novel online technologies and practices challenge our conceptions of individualized human problem solving in various domains, including art, science, industry, business, education, technology, software design, and medicine. It is urgent that we rethink our understanding of intelligence in a profound way. Among scholars, collective intelligence (CI) is increasingly used as a broad, multidisciplinary term to describe new types of collective problem solving. This notion of intelligence is not about individual ability or computer algorithms; rather, it describes how collectives of people, both small and very large groups, solve problems. This book intends to give an overview of some of the most important basic problem-solving mechanisms that comprise CI.

Throughout our evolution, our most extraordinary ability as humans is, without doubt, our ability to collaborate with each other. Our story is very much about how we gradually learned to solve problems together in increasingly larger groups. First, we started living in caves solving issues in small numbers, from there we formed villages, and, with time, the villages grew into kingdoms and nations. Today, many of us spend most of our time in a global online setting. In this new setting of billions of people, fresh ways of solving problems in large distributed groups are constantly being invented in a wide range of sectors. Open online innovation and citizen science are but a few examples of projects that center on open invitations, allowing anyone to join. In addition, various platforms and projects promote open online knowledge sharing, including the sharing of both knowledge products (e.g. online videos, Wikipedia) and knowledge

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construction processes (e.g. argument mapping). There is also a growing awareness that complex wicked problems, like climate change or COVID-19, require innovative problem-solving approaches that build on the combined scientific and political efforts of individuals and groups all over the globe.

The increasingly popular concept of CI attempts to encompass this development across various scientific fields. Concerning group size, studies of CI cover anything from small group cooperation in teams in the offline setting to large group cooperation in distributed online settings (Salminen, 2012). While some CI researchers still primarily examine the Internet and development of a broad macro level (Heylighen, 2017; Lévy, 2010), others focus on collaboration in small groups (Woolley, Aggarwal, & Malone, 2015; Woolley, Chabris, Pentland, Hashmi, & Malone, 2010).

However, the invention of the Internet undoubtedly renewed interest in CI. Pierre Lévy coined the modern version of CI in 1994 with the book *Collective intelligence: Mankind's emerging world in cyberspace.* Inspired by the recent invention of the Internet, Lévy (1999) defines collective intelligence as a new universally distributed intelligence that constantly improves and coordinates itself in real time. For the first time in human history, the Internet made it possible for members of a decentralized community to interact with each other within the same virtual universe of knowledge. This made possible a new knowledge-producing culture that built on rapid and open exchange of data and ideas. Lévy predicted that this would lead to a fundamental change in how we think about ourselves. Knowledge will no longer be about established facts, but rather the essential part of an ongoing knowledge construction project that includes all humans. The fundamental premise is that nobody knows everything, everyone knows something, and all knowledge resides in humanity. Inspired by Verdansky's notion of "noosphere," Lévy predicts the emergence of a new collective intelligence at a global level (Lévy, 1999).

Since the World Wide Web was created in 1990, it has grown enormously from under 40 million users in 1995 to about 1.5 billion in 2009 (Castells, 2010). In 2020, an estimated 4.5 billion people are active Internet users, encompassing 59% of the global population (source: statista.com). The Internet makes it possible for most people on the earth to interact, create, and exchange information in new ways that extend previous space and time limitations (Castells, 2010). It builds on the instant storage and transmission of information with no loss. The speed of message transmission removes the problem of time delay and transport time. In principle, the outreach is global to all people who have access to the Internet. This permits flexible and easy communication between persons who are located in very different places (Brabham, 2013: 12–13).

These capabilities make it possible to scale up activities and increase human collective capability in a range of different ways. As a result, people share information and communicate with each other in a huge range of online environments. During the last decade, participatory technologies, originally coined by Tim O'Reilly as Web 2.0 (Alexander, 2006), have connected a large amount of people and become increasingly important. As the first generation of web software in the 1990s provided easy access to a vast amount of information, it was still technically difficult to publish information and produce web pages. The major change came with the second generation of Internet technologies, which made it easy for anyone to publish information and communicate with others. The Internet opened up a range of horizontal communication networks within social media, multiplayer online games and fan discussion communities. While the traditional mass media (television, radio, newspapers) had unidirectional links, the architecture in the networked information environment has multidirectional connections among all nodes (Benkler, 2006).

These networks are built around peoples' initiatives, interests, and desires and are used to share all kinds of digital information such as texts, photos, and videos. In social media, individuals constantly produce short texts (e.g. Twitter), images (e.g. Facebook), or videos (e.g. YouTube). These short messages are part of an ongoing online social dialogue, and they are viewed by others immediately afterwards. Online cultural expressions and personal experiences have become a fundamental part of our daily life in the last decade (Castells, 2010). In addition, these new networks integrate local and global media and transcend traditional space limitations.

A fundamental premise behind this development is the radical reduction of the cost of becoming a speaker. Because the cost is so low and it takes very short time to reach others over the Internet, more people can find each other and create something together. Before the age of the Internet, there were only a few people who published their knowledge and opinions to a wider audience, and the publishing channels were usually under editorial control. Now anyone that can afford a digital device (like a cell phone or laptop) can access the Internet and produce and publish digital information. One consequence is that the traditional expert model of knowledge production, which has been taken for granted for centuries, is now being challenged. Increasingly, experts today not only compete for attention with each other, but with a large number of influencers and other amateurs who create, publish, and share their own content. In this networked information economy, knowledge production is much more broadly distributed in society.

Some of these large, loosely organized groups of people have also been surprisingly successful in building new knowledge products of societal value. The rise of effective, large-scale cooperative efforts like Wikipedia, which build on peer production of information, knowledge, and culture, was considered to be the most radical new innovation in the network society (Benkler, 2006). In the early 2000s, these new global online communities gave promise of a bright new future which would bring people from all over the world together. This development spurred a new era for CI research. A decade ago, the research report "Harnessing Crowds: Mapping the Genome of Collective Intelligence", Malone, Laubacher, and Dellarocas (2009) helped form a preliminary overview of what could be regarded as a new research field. Inspired by global online networks and communities like Wikipedia, the report proposes a relatively detailed typology, specific "building blocks," that can guide the design of CI communities. The researchers also claim that CI has existed throughout history. Therefore, the basic mechanisms are not new, but the main difference is that the Internet has created a new type of web-enabled CI that have resulted in new practices in fields like business and science. However, the link between our present and previous history is not clarified, and leaves the question open on how these new online practices are similar or different from previous ways of solving problems.

Today, CI has become a multidisciplinary notion within a range of different areas. The concept is used within disciplines such as psychology (Woolley & Aggarwal, 2017), political science (Landemore, 2013), business (Täuscher, 2017), complexity sciences (Heylighen, 2017; Stefanelli et al., 2019), biology (Bonabeau, 2009; Ioannou, 2017; Vercammen & Burgman, 2019), computer sciences and semantics (Alag, 2009; Lévy, 2010; Lollini, Farley, & Levy, 2019), and social media research (Schoder, Gloor, & Metaxas, 2013). The recommended list of topics at the annual conference on CI in 2020 illustrated the rich variety of topics: human computation, social computing, crowdsourcing, wisdom of crowds (e.g. prediction markets), group cognition, collective decision-making and problem solving, participatory and deliberative democracy, animal collective behavior, organizational design, public policy design, ethics of collective intelligence, computational models of group search and optimization, emergence and evolution of intelligence in biological systems, new technologies for making groups smarter, collective creativity and innovation, citizen engagement and participation, citizen science, artificial intelligence and collaboration, open source intelligence, collective computation, swarming, voting mechanism design, and collective forecasting (Intelligence, 2020). This overview shows that many different disciplines address separate aspects of collective intelligence. CI encompasses a wide range of practices that move beyond the individual level to include groups of peoples of various sizes who use different types of technology (Mulgan, 2014, 2018).

However, since CI is a relatively new academic concept, there are only a couple of books that aim to provide a broad overview of the concept, the field, and the different CI practices (Malone, 2018; Malone & Bernstein, 2015; Mulgan, 2018), including a few review articles (Peters & Heraud, 2015; Suran, Pattanaik, & Draheim, 2020). Although these publications represent important steps toward unifying the field, they also show how hard it is to summarize the field, primarily because of the lack of shared concepts. Separate disciplines use their own terminology within their own silo and there are few multidisciplinary studies. Although each discipline provides useful research, there is still no general framework that all disciplines can draw on which can provide a shared understanding of the basic mechanisms behind CI (Mulgan, 2018: 229–230).

According to Mulgan (2018: 229–230), the CI literature ranges from the limitlessly broad to the highly specific. The narrow variants describe collaboration in small groups, while the broader variants describe the whole of human civilization and culture (Mulgan, 2018: 1). For example, there is disagreement on whether collaboration in teams or smaller groups in an offline setting should be included in a definition of collective intelligence. Aulinger and Miller (2014) claim some definitions of CI imply that almost any collective action can be labeled as "collective intelligence." With this lack of precision, the concept may end up meaning nothing. They suggest the exclusion of small groups or team intelligence from a definition of CI. Instead, they propose that CI should focus on how individuals follow identical rules. This emphasis on a narrow variant of CI illustrates the conceptual struggle in this multidisciplinary field. Here, the basic question is whether CI studies of small group collaboration have anything in common with collective work in large global online communities. If this is the case, this connection needs to be further explained within a shared conceptual framework.

Because CI is a new research area, a range of other terms are obviously also used to describe the same or similar practices. One example is crowdsourcing (Brabham, 2013) or swarm intelligence (Corne, Reynolds, & Bonabeau, 2012). CI is also used to discuss nonhuman intelligence in some research areas, both animal intelligence and machine intelligence. In one review, Salminen (2012) found that only 25% of the papers on CI discuss human intelligence. A majority of the papers discuss collective behavior of cognitively simple agents such as insects, robots, and simulation algorithms. One area addresses new programming techniques used to analyze large amounts of quantitative data, which people leave behind when they use the Internet (e.g. Alag, 2009).

Although the focus of human CI research varies substantially, the shared assumption is that intelligence builds on some type of collective interaction or problem solving. It is something more than a psychological ability residing inside the head of an individual. For example, Jenkins (2009) challenges the view of intelligence as an attribute of individuals, and instead describes CI as being a new type of intelligence distributed across an extended technological and sociocultural online environment. In line with perspectives from distributed cognition, CI practices "offload" information into the environment.

1.2 Theoretical Perspectives on CI

As a scientific field, CI is still largely undeveloped and untheorized. There are relatively small research communities within areas such as computer science, psychology, economics, and biology. Some research studies also examine the interplay between human collective behavior and machine learning, but it is still not clear how CI differs from machine learning. There are few usable theories and a lack of analysis of CI at a large scale – in organizations, cities, nations, and networks (Mulgan, 2014, 2018). Typologies are practice-centered, often aiming to categorize and synthesize different online CI practices without any use of a dedicated theoretical framework (Malone et al., 2009; Suran et al., 2020).

Despite the lack of coherence, the scientific community has still identified some important mechanisms across different disciplines. First, at a micro level, empirical studies have identified a general group intelligence factor that explains problem solving in small groups. Second, many large-scale studies of collective work are explained through different self-organization mechanisms. Third, a vast number of CI studies, covering both a micro and macro level, address the role of informational diversity or cognitive diversity in different ways.

1. A general group intelligence factor
2. Self-organization
3. The role of diversity

1.2.1 A General Group Intelligence Factor

Historically, the invention of the intelligence test establishes the intelligence concept. In 1905, Alfred Binet designed the first version of this test. It identified French schoolchildren with learning disabilities who needed more support than other children (Binet, Simon, & Kite, 1916). At the same time, Charles Spearman (1904) developed the theory of general intelligence (or "g") that proposed that a large part of a person's intelligence was built on a general problem-solving ability. It would persist for many years before more complex definitions of intelligence were accepted (Piaget, 1952). In recent time, there have also been attempts to extend the notion of intelligence beyond its focus on human cognition. For example, Howard Gardner (1983) described the existence of seven different types of intelligence in his book *Frames of Mind: The Theory of Multiple Intelligences*. Three types covered cognitive abilities (linguistic intelligence, logical-mathematical intelligence, and spatial intelligence), and the four others, musical intelligence, bodily-kinesthetic intelligence, interpersonal intelligence, and intrapersonal intelligence, were new types of intelligence. Intrapersonal intelligence focuses on the capacity to have knowledge about oneself and control personal emotions, while socially orientated interpersonal intelligence describes the ability to understand and collaborate with other people. Still, human intelligence today is primarily connected to cognitive abilities and skills.

In contrast, CI research by Woolley et al. (2010) have found evidence of a general group intelligence factor, labeled the "c factor," in different types of group work. This has even led to the development of a group intelligence test, which is different from the cognitive tasks that are typical in standardized individual intelligence tests. The test tasks cover four different dimensions in authentic settings. The first task is about generating something new, like brainstorming various uses for a brick. The second category involves the selection of a pre-specified alternative, making groups solve visual puzzles from a standardized test called Raven's Matrices. The third dimension includes negotiating tasks, challenging the group to pretend they live together and have to plan a shopping trip. The fourth dimension is about executing tasks, and letting the group type a long text passage through synchronous online writing. In addition, other tasks involve word-completion problems, spatial puzzles, and estimation problems (Malone, 2018: 31).

In the original study, 152 groups of two to five members were set to solve a wide range of different tasks. Factor analysis of team scores identified one factor accounting for 44 percent of the variance, while the second factor only explained 20 percent of the scores. Here, collective intelligence is the inference one draws when the ability of a group to perform one task is correlated with that group's ability to perform a wide range of other tasks. The first factor with significant explanatory power is interpreted as a property of the group itself, not just the individuals in it. Nor was this factor correlated with the average or maximum individual intelligence of group members (Woolley et al., 2010). Other follow-up studies have shown similar results in other settings across different languages, cultures, and activities (Malone, 2018: 32–42; Woolley et al., 2015). For example, in high-performing teams playing online video games, collective intelligence scores were significant predictors of their performance in the game (Kim et al., 2017). The "c factor" has also predicted performance for other more complex tasks such as playing checkers against a computer or solving architectural design problems. In addition, the highly collectively intelligent teams exhibited steady improvement in performance across the series of tests, indicating that these groups also learn faster (Malone, 2018: 32–42; Woolley et al., 2015).

According to Malone (2018: 41), the combination of all these studies indicate that human groups have a kind of collective intelligence that is directly analogous to what is measured by individual intelligence tests. He highlights the distinction between (1) specialized intelligence and (2) general intelligence in individual intelligence tests (Malone, 2018: 24). First, specialized intelligence refers to the ability to achieve specific goals effectively in a given environment. The equivalent of this type at a group level will then be "group effectiveness." However, intelligence tests have been designed to predict your general intelligence or your ability to do a wide range of other tasks beyond those in the test. People who have much of this general intelligence are better at adapting to new environments and learn more quickly. Likewise, general collective intelligence refers to the group's ability to adapt to new environments and perform well on a wide range of different group tasks (Malone, 2018: 24–25, 41).

Although some researchers claim there is insufficient support for the existence of a collective intelligence construct (e.g. Bates & Gupta, 2017; Credé & Howardson, 2017; Woolley, Kim, & Malone, 2018), there is increased interest in the more general problem-solving abilities in groups in both offline and online settings. However, we still know little about which group processes or group qualities influence the "c factor." There are affiliated concepts such as group cognition and group mind. Within sociology, both Durkheim's concept of collective consciousness and

Gabriel Tarde's notion of group mind move beyond the individual self in their examination of societal beliefs in larger groups. In psychology, new theories of learning also highlight the qualities of group discourse and joint meaning making to a greater degree (Sawyer, 2006; Stahl, 2006). Knowledge does not reside inside the heads of individuals, but in the practice itself (Flick, 1998; Gergen, 1985). Likewise, this book analyzes CI as a group phenomenon.

1.2.2 Self-Organization

Another strand of CI research examines different types of self-organization. The first type of self-organization is at a macro level, describing the Internet as a self-organizing super-intelligence that unites all human intelligence into a worldwide network of information and communication. For example, Heylighen (2011) uses the metaphor of a global brain to describe the Internet as an intelligent, organism-like system, a brain of brains. CI emerges from the collective interactions between humans and machine in a global online communication network. This global brain is immensely complex and self-organizing without any centralized control, and emerges as an adaptive complex system. In an interview (Lollini et al., 2019), Levy claims this type of self-organization can best be described as stigmergic communication. Throughout our human history, improvements in CI has followed from inventions that augmented the power of human language. The invention of writing created a new collective memory that was further developed with the invention of the printing press. Moreover, the invention of the Internet completely removes the constraints of physical space and memory when knowledge becomes accessible from anywhere in the world. This is not only communication from many to many, but also a new way of connecting knowledge when it is stored in an online setting. The stigmergic element refers to the intermediary of a common shared environment that everyone uses. Almost the entirety of humanity can add knowledge to this shared memory, which anyone can access. In addition, every new trace of action on the Internet will continuously change the relationship between the stored digitized data. In this sense, everybody contributes to the transformation of the common memory at the same time. Although CI is facing huge challenges today, Levy proposes that the way forward is to design practices that can promote reflective communication between people in the online setting (Lollini et al., 2019).

The second type of self-organization describes the emergence of global online communities. One example is Wikipedia, which has more than six

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million articles in the English version alone (Rijshouwer, 2019). Another example is the development of open source software where many individuals contribute at different points of time (Raymond, 1999). Mulgan (2018: 76) also describes how stigmergy is important in self-organizing systems like Wikipedia, or among open source software development programmers who pass around tasks in the form of challenges until they find a volunteer. Human stigmergic problem solving is an important part of the analysis in this book (see Chapter 6).

Third, self-organization can build on market mechanisms, like the “invisible hand” that self-regulates the market economy by letting everyone pursue their own interests (Hayek, 2013). Widely dispersed markets use price signals efficiently to coordinate large-scale activities. Markets can adjust prices with little horizontal communication between the participants, but they are limited to the binary decision of whether or not to buy something (Mulgan, 2018: 111, 115). In CI research, this type of self-organization has been examined in studies of prediction markets (Buckley & O’Brien, 2017; Malone, 2018) which is also a topic addressed in this book (see Section 6.3).

A fourth type of self-organization studies swarm problem solving in animals. Peters and Heraud (2015) claim biological studies of “swarm intelligence” is one of six major areas within CI. It refers to the collective behavior of social insects and flocking behavior (Mulgan, 2018: 232). For example, Sumpter (2010) claims human collective behavior can be explained through self-organization and different behavioral algorithms. These principles, such as positive feedback, response thresholds, and independent decision-making, are also present in different animal groups and can inform our understanding of human societies. However, Willcox, Rosenberg, and Domnauer (2020), claim there is no good theory that explains how human swarms operate. Few studies examine large-scale human collective work in the offline setting. This area of investigation is labeled as human swarm problem solving in this book (see Chapter 4).

1.2.3 The Role of Diversity

In general, CI expects that new technologies will make groups better at solving problems than ever before (Malone, 2018). The predominant strategy is to scale up the size of the group and hope this can create more diversity benefits. A prominent example is the book *The Wisdom of Crowds* by Surowiecki (2005), which describes four qualities that make a crowd intelligent. First, the group should be diverse, so different individuals can