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Do only computers scale? On the cognitive and social aspects of scalability

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Abstract

Scalability has been for long time presented as a desirable property of a networked computer system associated to measure of its performance. As information and communication technologies (ICT) become ubiquitous, a need of describing scalability also from a human perspective has emerged. Indeed, technical scalability only describes the performance of a computer system, but it does not explain anything about its impact on cognitive and social performance. Without acknowledging that technical scalability does not imply human scalability, there is the risk of not realizing the full potential of ICT in the everyday life. By adopting the Socionics approach, we extend the technical view of scalability with two additional concepts, namely cognitive and social scalability. These concepts describe the capacity to process individually or collectively growing volumes of work gracefully, and/or to adjust to their increasing complexity. The notion of social scalability is then evaluated in the activity-context of social coordination through mobile devices. We conclude that by improving our understanding of scalability issues, we may positively inform the design and use of ICT not only from the viewpoint of technical performance, but also for that of individual and collective performance.

Keywords: *Cognitive Scalability – Social Scalability – Conceptual Framework – Socionics*

La scalabilità è solo una proprietà dei computer? Sugli aspetti cognitivi e sociali della scalabilità
La scalabilità è una proprietà desiderabile di sistemi informatici associata a metriche di performance. Più precisamente, un sistema è definito scalabile quando riesce a gestire, senza calo di prestazioni, un numero crescente di elementi, processi, quantità di lavoro e/o quando può essere espanso a, piacimento. Progettare un sistema scalabile garantisce un'ottimizzazione dei costi, delle prestazioni e della produttività di un'azienda. Questi scopi sono stati perseguiti, dagli anni Ottanta, attraverso numerosi studi sulla scalabilità, che sono stati sviluppati in un ambito esclusivamente tecnologico. Tuttavia, negli ultimi anni è sorto il bisogno di estendere la tradizionale prospettiva tecnologica della scalabilità, perché troppo limitata, al di fuori delle organizzazioni e applicata alle

situazioni di uso quotidiano delle nuove tecnologie. Per esempio, le rubriche dei telefonini sono tecnicamente scalabili: grazie alla funzione di ricerca, essi offrono un accesso immediato alle informazioni indipendentemente dal numero dei contatti memorizzati. Inoltre, il supporto di memorie digitali esterne molto capienti permette di inserire un numero pressoché illimitato di contatti. Le versioni più avanzate delle rubriche degli smartphones sono integrate anche con i social network come Facebook. Dal punto di vista cognitivo, negli utenti si crea un'illusione di essere in grado di gestire efficacemente reti sociali sempre più estese e ricche di contenuti. In realtà, vari studi hanno dimostrato che esistono dei limiti alla gestione di relazioni sociali rilevanti, quali il famoso numero di Dunbar. Pertanto, la prospettiva tecnologica sulla scalabilità è limitata nel senso che essa riesce a descrivere solo la performance di un sistema informatico, ma non ne spiega l'impatto su performance cognitiva e sociale. Un approccio alternativo potrebbe essere basato sul presupposto che la scalabilità è una proprietà importante non solo per computer e reti informatiche, ma anche per esseri umani e reti sociali. La comprensione della correlazione fra scalabilità tecnologica e umana, renderebbe possibile migliorare il design delle tecnologie per uso quotidiano. Per esempio, le rubriche dei telefonini, come anche i siti di social network, potrebbero ottimizzare l'accesso ai contenuti in base al significato delle relazioni sociali e della situazione nella quale sono considerate. Si può ipotizzare che la comprensione della scalabilità, sia umana sia tecnologica, possa permettere di migliorare la performance dell'azione individuale e/o collettiva. Socionics, un programma interdisciplinare di ricerca che integra sociologia e informatica, offre la possibilità di estendere la definizione di scalabilità anche ai sistemi sociali. Al contrario della prospettiva tradizionale della scalabilità, che è incentrata sull'aspetto quantitativo, Socionics pone al centro dell'analisi il problema da risolvere, che è analizzato sia dal punto di vista quantitativo (i.e. il numero di sotto-problemi) sia da quello qualitativo (i.e. la loro complessità). Grazie a Socionics, nell'articolo sono introdotti i concetti di scalabilità cognitiva e scalabilità sociale, che descrivono la capacità di gestire elegantemente a livello individuale o collettivo quantità crescenti di lavoro, e/o adattarsi alla loro complessità crescente. Il processo di valutazione della scalabilità cognitiva e sociale di un problema si compone di tre fasi: la prima riguarda la definizione del contesto dell'attività a cui il problema è associato. Questo richiede di specificare gli attori coinvolti, le risorse disponibili e i compiti che essi stanno svolgendo, individualmente o in gruppo. La seconda fase si propone di identificare i bisogni legati al contesto, che servono a capire in che misura il sistema è riuscito a soddisfare il bisogno, ovvero a misurare la performance. Nella terza e ultima fase si considera la funzione delle ICT nella risoluzione del problema, al fine di capire se le ICT abbiano alleviato, accentuato o rimosso eventuali limitazioni cognitive e/o sociali. Lo stesso problema è scalabile da un punto di vista cognitivo e/o sociale se esso è risolto in modo efficace al variare dei suoi elementi quantitativi e qualitativi. Per una prima valutazione dell'approccio, è discusso il problema della coordinazione sociale tramite telefonini, che non è ridotto semplicemente al numero di persone che i telefonini riescono a mobiliz-

zare, ma anche alla qualità e impatto della loro performance. In conclusione, i concetti di scalabilità cognitiva e sociale offrono l'opportunità di informare la progettazione e favorire l'adozione di ICT grazie alla comprensione di come gli aspetti di scalabilità tecnologica influiscano sulla performance individuale e collettiva, e viceversa.

Parole chiave: *Scalabilità Cognitiva – Scalabilità Sociale – Modello Concettuale – Socionics*

Introduction

The same term often has different meanings and applications in distinct disciplines. For instance, the idea of human multi-tasking resembles that of computer multi-tasking, a strategy that allows the operating system to concurrently manage multiple system processes. While computer multi-tasking is about computer processes and computational resources, human-multi-tasking is about cognitive tasks and cognitive resources (Pashler, 1994). Another term that conveys multiple meanings is network: a mathematician is likely to associate it to the mental model of a graph, a software engineer to a computer network, a sociologist to a social network and an economist to global markets. Typically, studies on human multi-tasking and computer multi-tasking do not mutually support each other; instead, the various perspectives on networks supported the emergence of social network analysis (SNA) (Scott, 2000). Therefore, the existence of specialized disciplinary vocabularies does not impede to successfully apply the same concept in related research fields or even to develop a new multidisciplinary research domain.

There are several benefits in conceptualizing a keyword from different angles and in exploring potential applications of its multiple meanings. For instance, SNA does not only offer an insight on evolving social structures, but it also contributes to enhance the design and use of information and communication technologies (ICT). Barry Wellman, one of the leading contributors to the theory of SNA, underlined the importance of recognizing the wide range of connections and implications of the network paradigm by observing that "computer networks are inherently social networks, linking people, organizations, and knowledge" (Wellman, 2001, p. 2031). Without SNA, many advances in design would not have been possible. For instance, the whole idea of online and mobile social networking services can be regarded as a technological application of the network paradigm

(Lugano, 2008). Despite the growing efforts in connecting more tightly the human and technological dimensions through interdisciplinary research (Saariluoma, 2005), much work is needed. In particular, little attention has been given to the development of a shared vocabulary consisting of keywords, such as multi-tasking and network, which are relevant from both a human and a technological viewpoint. This vocabulary can emerge for instance from the investigations on the connections between the varieties of meanings of a single concept. From the technological viewpoint, not acknowledging the importance of this research challenge may prevent realizing the full potential of existing and future technologies.

The sophisticated shapes and amazing features of smartphones, tablet computers and ebook readers suggest that a new phase of technological development has recently reached maturity. This trend is often referred to as technological convergence, which De Sola Pool (1983) described as "a process called the convergence of modes is blurring the line between media, even between point-to-point communications, such as the post, telephone, and telegraph, and mass communications, such as press, radio and television" (p. 23). Technological convergence is therefore associated to the idea that different types of communication networks, both digital and non digital, become part of an integrated infrastructure of converged digital networks. The theme of convergence has been recently developed from various perspectives (Jenkins, 2001; Fortunati, 2007; Lugano, 2010), making clear that converging technologies also imply several other forms of convergence encompassing culture, society, and the economy. In particular, Fortunati (2007) discussed convergence as a "strategy to rationalize the physical and technological space or, to put it more adequately, to overcome the distribution of technologies in space, and to rationalize the time and convenience of their use" (p. 110). Therefore, convergence made the technological, business and social landscape more complex, raising as major challenge the need to explore its multifaceted meanings and foundational concepts.

The growing penetration of the products of technological convergence, such as smartphones (Quick, 2009), should not diminish our efforts for realizing the potential of converged digital networks because, as Fortunati (2007) reminds us, convergence implies also new models of control, which apply to devices, information and, ultimately, on our lives. This challenge cannot be simply tackled by considering the statistics in ICT access. To understand the real added value, and potential risks, that converged digital networks entail, we need to follow the same path of SNA and develop an adequate vocabulary, as well as new methods and tools, which could positively contribute to enhance both the design and the use of ICT. The most popular products of technological convergence, such as the Web 2.0 (O'Reilly, 2005), often value, implicitly or explicitly, the keyword *social*. One of their key characteristics consists in the ability to function at different *scales*, ranging from individual use to interpersonal and mass communication. Hence, a key property to develop is scalability.

In the Eighties and Nineties, computer scientists and software engineers developed the notion of scalability, a property of a computer system associated to measures of its performance (Hill, 1990; Hwang, 1992; Bondi, 2000). Although it does not exist a generally accepted universal definition (Hill, 1990; Luke, 1993), scalability is usually referred to as a "desirable attribute of a network, system or process" that is able to "accommodate an increasing number of elements or objects, to process growing volumes of work gracefully, and/or to be susceptible to enlargement" (Bondi, 2000, p. 195). In this view, scalability is the ability for a computer system to function gracefully (i.e. with no delays or unproductive resource consumption) while making good use of the available computational resources such as processing power and memory. Hill (1990) underlined the theoretical and practical significance of the concept, which helps gaining insight about mathematical models of large networked systems and allows designing and implementing better computer architectures. A third benefit concerns the opportunity to improve the design of a computer system in a way that facilitates the interaction with the user (Neuman, 1994). Finally, designing scalable systems is particularly appealing to companies because it supports cost optimization. Indeed, systems that not scale do not cause only performance losses, but especially monetary losses (Bondi, 2000) because it brings in additional costs related to extra labor or improvement of the quality of service. Therefore, the traditional view of scalability, to which we refer as to the *technical view*, describes this property as a key design requirement for a computer system, which supports cost optimization, task efficiency and overall productivity.

In this contribution, we argue that it is time for moving beyond the technical view of scalability because it is not sufficient for expressing the richness of meaning that this concept embeds in the age of convergence. The scalability of networked digital systems cannot be described only through measures of technical performance, because they alone do not explain human and social performance.

The under-use of contacts in mobile phone-books (Lugano, 2008) well explains the limitations of technical scalability. Indeed, mobile phone-books are technically scalable because they offer quick access to phone numbers and contact details independently of the amount of stored contacts. In this respect, the search feature plays a key role in making mobile phone address-books technically scalable. A related aspect consists in the possibility to store almost an unlimited number of contacts thanks to external memories, which can be used when the phone memory is full. The most recent versions of the mobile phone-book do much more than the traditional ones: they enhance social awareness by allowing the disclosure of contextual cues (Oulasvirta et al., 2005) and act as *social aggregators* by displaying multiple online social networks (Bhatt et al., 2008).

From a cognitive perspective, the traditional model of mobile-book creates in the users the illusion that we are able to efficiently manage very large social networks. In reality, it has been argued that humans cannot efficiently manage more than 150 concurrent significant social relationships because of the structure of their neocortex size (Dunbar, 1998). This threshold, known also as the *Dunbar number*, has apparently been increased by online social networking sites (SNS), in which users have often large social networks counting hundreds or even thousands of contacts. In a recent study, Dunbar (2010) investigated whether Facebook, the most popular SNS, had effectively increased such threshold. For Dunbar (2010), the existence of a virtual social tie is not sufficient to denote a significant relationship, but it is necessary to consider also the more complex qualitative aspects of a Facebook relationship, such as the actual interactions. By considering this aspect as well, the number of active and significant contacts decreased to about 150 persons, confirming the stability of the Dunbar number.

The dissonancy between human limited social capacity and the almost unlimited technical storing capacity of mobile address-books suggests that technical scalability does not imply human scalability. As suggested by Lugano (2006), the mobile phone-book is currently poorly designed because it considers a mobile social network just as a technical network and without acknowledging that it is also a social network (Wellman, 2001). Therefore, the design of the mobile phone-book could be greatly enhanced by including the cognitive and social dimensions of interaction.

Similar considerations can be moved in relation to the support of multi-tasking in mobile operating systems. Recently, the Apple iPhone 4 was launched advertising multi-tasking as one of its main enhancements: according to Moren (2010), "Apple contends that multi-tasking on most mobile devices can hamper performance of the application running in the foreground while draining battery life". He also added how Apple improved the situation, by quoting Steve Jobs: "We've figured out how to do it and avoid those things". Surprisingly, the discussion on multi-tasking is still anchored only to a technical perspective. From a user perspective, it would be much more useful to be informed on whether and under which conditions this form of technical multi-tasking improves, interferes or is neutral to human multi-tasking. Recent research on human multi-tasking (Gonzalez & Mark, 2004; Kirn, 2007; Baron, 2008; Stephens & Davis, 2009) and media multi-tasking (Ophir et al., 2009) may suggest feasible approaches to this problem. For instance, Baron (2008) suggested using the metaphor of *volume control*, which can be turned up or down according to the conversational needs. In relation to the management of social information streams through mobile social software (MoSoSo), Lugano (2010) maintained that MoSoSo is likely to have a limited practical usefulness if designed only to *amplify* and not also to *attenuate* social network information, for instance through contextual filtering.

The examples of the mobile phone-book and mobile multi-tasking suggest that there is a practical need in understanding how scalability issues influence the individual and collective capacity to successfully attain action goals through ICT. The classic literature on scalability does not provide much help in expanding the notion of scalability beyond its technological domain. Indeed, scalability research needs to acknowledge that not only computer systems scale, but also humans and social networks do. Although we are not able to provide a full answer to this ambitious challenge, our aim is to contribute in this direction by introducing two major sides of human scalability, namely cognitive and social scalability. To this purpose, we adopt the perspective of Socionics, an interdisciplinary research program combining sociology and computer science, which has recently discussed scalability in the context of complex social systems (Fischer et al., 2005). The conceptual framework is then evaluated in relation to existing research on social coordination via mobile devices. We conclude the study by discussing the significance and challenges of our contribution, as well as pointers for future research.

The Socionics approach: scalability in complex social systems

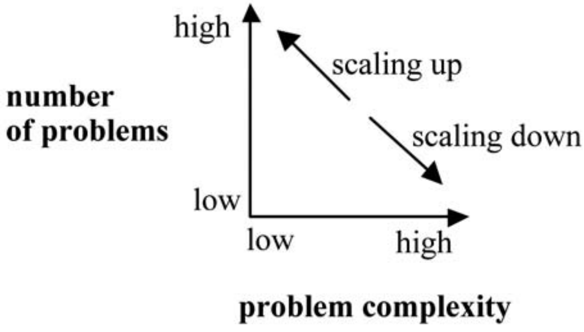
Scalability research has recently extended its scope beyond technical networks, attracting scholars from several disciplines with the goal of explaining the correlation that exists between the performance of computer systems and complex social systems like organizations and communities (Fischer et al., 2005). Much of the merit goes to the approach suggested by Socionics, a multidisciplinary research program established in the end of the Nineties with the goal of "developing intelligent computer technologies by picking up paradigms of our social world. And vice versa. Socionics uses computer technology in order to verify and to develop sociological models of societies and organizations" (Müller et al., 1998). As explained by the founders of the Socionics program, "computer science might learn from the adaptability, robustness, scalability and reflexivity of social systems and use their building blocks to come up with more powerful technologies" (Müller et al., 1998). Hence, Socionics suggests investigating the meaning of scalability in social systems and applying this knowledge to ICT design. In particular, scalability has been discussed in the context of multi-agent systems (MAS), multiple intelligent computer programs – software agents – designed for collectively solving complex problems (Wooldridge, 2002).

Although Socionics is not a widely known research program, it represents the most suitable framework to go beyond the technical view of scalability for two main reasons, the first more of general nature and the second related to the specific issue of scalability. First, Socionics is a multidisciplinary effort, which aims at enlarging the scope of computer science by integrating sociological knowledge. Second, the Socionics community has already elaborated on the concept of scalability in complex social systems (Fischer et al., 2005). This clearly represents a good starting point to consider for any other investigation on this topic. It is also worth noting that Socionics, being focused on the behavior of artificial software agents, does not allow a straightforward application of its principles outside its research domain. A sociologist may complain that Socionics oversimplifies some aspects of human behavior, and an engineer that this approach renders mere technical issues way too complicated. Despite its limitations, the Socionics approach has the merit of having overcome a major shortcoming of the technical view of scalability, namely the lack of an adequate definition and vocabulary describing the diverse properties of the concept of scalability. For instance, Socionics scholars emphasize the importance of investigating the scalability of organizations and social networks (Paetow et al., 2005). In spite of their different size, both contexts emphasize the need for maintaining an acceptable performance despite an increasingly complex environment. In this regard, the role of ICT is to overcome the traditional limits for the management of complexity and to support a more flexible and efficient performance in the executive of cognitive and social tasks, a set of actions executed to accomplish a job, problem or assignment. While performance measures may be not obvious to define in ordinary social interactions, in the organizational context they may be connected to the ultimate goals of survival and growth in a highly competitive environment.

The main contribution of Socionics consists in having replaced the system-oriented view with a problem-oriented perspective to scalability in which the problems to solve in an activity-context become the focus of the analysis. As Albrecht (2005, p. 254) explains, "in any case, the important independent variable is not the number of agents, but the problems that are solved". Although the concept of problem is not extensively elaborated in the conceptual framework, we adopt the definition of Newell & Simon (1972, p. 72): "a person is confronted with a problem when he wants something and does not know immediately what series of actions he can perform to get it". As Frensch & Funke (1995, p. 8) observed, "explicitly, problems have been defined in terms of the interaction between task and individual; implicitly, however, problems frequently have been defined in terms of their task properties". The problem-oriented view of scalability involves two dimensions, a quantitative and a qualitative one, which respectively refer to the 'number of problems' and to the 'problem complexity' (Figure 1). The former variable includes, for example, the number of participating agents and the amount of exchanged messages, while the latter focuses on the types of agents that take part in the problem-solving task, and on the type of communication that is established.

In this way, scalability denotes the "*ability to react flexibly to changing environments*" (Albrecht, 2005, p. 243) by scaling up to cope with an increasing number of problems of low complexity and by scaling down to solve a limited number of problems of high complexity. By contrast, the technical view of scalability was conceived as a uni-dimensional quantitative concept grounded on the capacity of 'growing' by scaling up. In that perspective, to support the increasing demands of work, the performance of a technical

Figure 1. Quantitative and qualitative dimensions of scalability (Albrecht et al., 2005).



system was maintained acceptable by adding more computational resources (Bondi, 2000). Socionics adds to this view also the notion of scaling down, which "does not mean simply to reduce the capacity of a system, but rather to switch from a quantitative scale to a qualitative one" (Albrecht, 2005, p. 254). More specifically, scaling down refers to the "ability to adapt to a kind of problem solving behavior that is most suitable for a small number of highly complex problems" (Albrecht, 2005, p. 255).
In the Socionics approach, scalability draws from theoretical concepts of complexity science because "a complex system builds and reduces its internal complexity by scaling up and down" (p. 141). Paetow et al. (2005) propose using Luhmann's key concepts of 'element' and 'relation' (1995) to analyze how a complex system may scale up and scale down. These basic concepts can be used to describe the scaling processes from a qualitative and a quantitative dimension (Table 1).

Table 1. Scaling processes (Paetow et al., 2005).

	Elements	**Relations**
Quantitative dimension	Number of elements	Number of couplings
Qualitative dimension	Diversity	Multiplexity

In the quantitative dimension, scaling up and scaling down are associated to an increase or decrease of elements or couplings. In regard to the qualitative dimension, scaling processes rely on an increase or decrease in the diversity of its elements or couplings. Diversity is a key feature of scalability because, as Morin (1992) argued in relation to organizations, it is this property that supports a growing complexity. Paetow et al. (2005) go further with their description of scaling processes by including also the system/environment variable. Even if this aspect is theoretically relevant, this level of detail is out of the scope of this contribution.

In conclusion, the Socionics approach allows going beyond the technical view of scalability, which offers the opportunity to discuss scalability issues by bringing in human and social aspects of interacting with and through ICT. By describing scalability in terms of scaling processes, Socionics scholars answer to the need for decomposing scalability in several dimensions, which was also pointed out in earlier research on the traditional view of the concept (Bondi, 2000; Brown, 2004). In the next section, this insight is used to conceptualize cognitive and social scalability, the two main dimensions of human scalability.

Conceptualizing cognitive and social scalability

The conceptual framework of Socionics can be applied to Bondi's original definition of scalability (2000) to introduce the notions of cognitive scalability and social scalability. Before illustrating these concepts, it is worth observing that Socionics tackles scalability from the viewpoint of multiple interacting computer agents, which collaboratively work to solve a well defined problem. On the contrary, human beings do not always behave cooperatively. In fact, the majority of daily problems, including learning, work and family life, are typically solved autonomously, while larger and more complex problems related to broader social, political and economic systems are approached through large-scale collaboration. In practice, problems often involve a set of smaller tasks, which are solved using a mix of individual and collective problem-solving. There exist an endless variety of problems and approaches to solve them, both individually and socially. For instance, the individual problem of job searches is often solved thanks to information provided by personal social networks (Granovetter, 1974). Maintaining and improving the well-being of a community requires a collective effort, which has been explained through the concept of social capital (Putnam, 2000). Innovative solutions to complex problems, especially in the business context, are increasingly sought through crowdsourcing (Tapscott & Williams, 2006). This approach, which aims at exploiting the *wisdom of the crowds* (Surowiecki, 2004), has been recently employed to quickly obtain creative ideas to solve the recent natural disaster of the British Petroleum oil spill (De Castella, 2010).

Although very different in nature, all the above problems can be more efficiently addressed through ICT. Intuitively, technically scalable ICT facilitate the solution of such problems by supporting larger participation. However, technical scalability does not fit to common metrics of human performance, such as timeliness, usefulness, pleasantness or stress. In other words, technically scalable systems are designed to optimize companies' business opportunity and the performance of computer architectures rather than to meet real human needs. Hence, to be able to measure performance variations of a social system in relation to available resources and problem complexity, it is necessary to introduce two new concepts, namely cognitive and social scalability, which respectively refer to the individual and collaborative efforts in problem-solving.

Cognitive scalability refers to the capacity to cognitively process growing volumes of work gracefully, and/or to adjust to their increasing complexity. The first part of the definition acknowledges the quantitative element of scalability, i.e. the number of concurrent activities or processes, is related to human multi-tasking (Pashler, 1994; Kirn, 2007). Instead, the qualitative aspect of the definition, i.e. the complexity of its activity or process, is linked to factors like the level of expertise (Chi et al., 1982) or to the ability to apply appropriate cognitive filters (Neisser, 1967). While the possibility to scale-up through human multi-tasking seems to be limited by hard biological constraints (Miller, 1956; Nicolis & Tsuda, 1985; Marois & Ivanoff, 2005), scaling-down via synergic use of human strategies and technological support seems much more promising. This point is demonstrated for instance by the usefulness of the search function in mobile phone-books, as well in online information repositories: once the user interface has been learnt, searching a particular document, or the occurrences of a term in a set of documents, is a problem that can be easily solved in a matter of seconds.

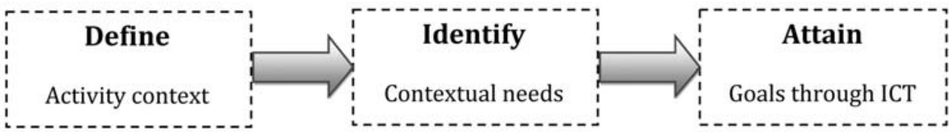
Similarly, social scalability is defined as the capacity to collectively process growing volumes of work gracefully, and/or to adjust to their increasing complexity. Unlike cognitive scalability, social scalability supports both scaling-up and scaling-down. As Shirky (2008) pointed out, the new forms of digital technologies empower individuals to organize without organizations. Several other studies on the social aspects of ICT (Rheingold, 2002;

Tapscott & Williams, 2006) maintain, from different angles, that complex problems can be more efficiently solved in a distributed manner through digital technologies. In this case, the main limitation consists in the ability to coordinate a cooperative process of problem-solving. According to Lugano (2010), this problem needs to be addressed at the same time from the technological perspective of design and from the policy perspective of educational plans and strategies supporting the desired goals of ICT use.

The two definitions of cognitive and social scalability can be synthesized by a unified definition of scalability, which concerns the capacity to process individually or collectively growing volumes of work gracefully, and/or to adjust to their increasing complexity. Even if the dynamics of the scaling processes associated to cognitive and social scalability greatly differ, the two concepts are both connected to measures of individual and collective performance.

After illustrating the definitions of cognitive and social scalability, the next step is to describe how to observe, evaluate and enhance them in a particular activity context. To achieve this purpose, Socionics' problem-oriented approach can be applied as a series of three main steps (Figure 2).

Figure 2. Evaluating cognitive and social scalability.



First, we need to define the activity context by means of its actors, resources and tasks that are associated to the specific problem. An actor is typically a single individual, but it could also refer to a social group, an organization or institution. By resource we refer to as symbolic or material goods such as information, tools, or money, which have functional value in that specific action context. Finally, a task is regarded as the activity, on which to engage one or more actors. The solution of the main problem of the activity context typically involves the successful completion of various tasks by means of actors' individual and/or collective engagement around available resources. Next, we have to identify the individual and/or collective contextual needs, which are used to adopt viable performance measures. A contextual need, as the term suggests, is an individual or collective need that emerges in the action context. Finally, we need to analyze how ICT support the attainment of the individual or collective goals in the action context by recognizing the existing cognitive and social constraints to remove or optimize.

The cognitive and social scalability of the final solution can be evaluated by assessing its performance by varying its quantitative and qualitative elements. In Table 2, the scaling processes described in Table 1 are modified by replacing elements and relations with actors and tasks.

Table 2. Scaling processes for cognitive and social scalability.

	Actors	**Tasks**
Quantitative dimension	Number of actors	Number of tasks
Qualitative dimension	Behavioral patterns	Complexity of tasks

The variables of Table 2 can be discussed to evaluate the social scalability of social coordination, one of the most important activity-contexts of mobile communication. Despite the significance of this function, Ling (2004) recognizes that scalability constitutes a major limitation for mobile devices because rescheduling meeting times or plans cannot be easily achieved beyond the threshold of 8-10 people. Although interpersonal and small group interactions represent the largest bulk of ordinary interactions, mobile phones are increasingly used for mass mobilizations. Already in 2001, the short messaging service (SMS) was used to mobilize the Filipino population towards a converging point, the Epifanio de los Santas Avenue, to protest against President Estrada, who had to resign after a few days of peaceful demonstrations. Mentioning this trend as an emerging form of mobile communication, Rheingold (2002) coined the term Smart Mobs well characterize the behavior of a community that acts together to achieve goals, which would be impossible by acting as individuals. Thanks to converged digital networks, Internet and mobiles are used together to enable new forms of mobilization, such as Flashmobs (Mc Fedries, 2003; Marchbank, 2004; Kluitenberg, 2006). These social practices, which bring together many people, but only for a short time, are typically connected to political protests or entertainment.

These examples do not allow understanding whether mobile devices are socially scalable. In Ling's view (2004), Smart Mobs, which typically rely on the SMS, are not entirely scalable because they cannot be fully interactive.

Indeed, they usually rely on the mere forwarding of SMS to a group of personal contacts. Evidently, Ling (2004) assumes interactivity as a key aspect of scalability. On the contrary, Rheingold (2002) underlines that the performance of the collective group is what really matters in large-scale social interactions. Hence, in his view mobile devices are socially scalable.

The conceptual framework we introduced with Figure 2 and Table 2 allow moving some observations. First, social coordination represents the broad activity-context, which contains a variable number of actors, who have as main task to physically converge to the agreed meeting point. Mobile devices represent the key resource to use for managing the process of social coordination, for instance by renegotiating time and place of the meeting. At this level, the key difference between small group interactions and mass mobilizations just lies in the quantitative dimension of the number of actors. In addition, actors may have additional planned tasks, such as shopping on the way to the meeting, and unplanned ones, such as a work phone call or choose an alternative means of transport. Depending on their priority, both planned and unplanned tasks may have as main effect a delay, rescheduling or even a cancellation of the meeting. These quantitative factors influence the emerging contextual needs and behavioral patterns, which present some marked differences. Thanks to mobile devices, individuals have more flexibility in renegotiating times and places in small group interactions than in mass mobilizations. For some purposes, like political protest, it is not only a matter of coordinating a large group of individuals, but also of renegotiating the event permissions with the authorities, who are responsible for the public security.

From the viewpoint of the contextual need, large scale events require individuals to adhere more strictly to the values of the community, which are often dictated by the organizers. Performance metrics such as security or participation are therefore connected to the attainment of the collective goal of the event. On the contrary, in small group interactions individual and collective contextual needs are more balanced. This issue can be understood by considering a simple performance metric, such as that of arriving on time at a meeting. In some countries, such as Italy, a delay of five or ten minutes is widely accepted. Instead, in Nordic countries it would be polite to inform others of the delay. Even if delays are in some cases unpredictable, in many others they are caused by personal choices based on the assumption that individual needs have higher priority than collective needs. These behavioral aspects, which are partly related to cultural backgrounds, have an effect on the complexity of the tasks. Indeed, if there is no need of rescheduling a meeting, or informing others of the delay, the complexity of the task is related to the planning and execution of the physical convergence to the meeting place. In this regard, mobile devices can lower the complexity of such tasks, for instance by optimizing urban navigation through maps.

In conclusion, these observations suggest that it is somehow misleading to debate whether mobile devices are socially scalable, both in general terms and in specific contexts such as social coordination. It would be more appropriate to discuss to which extent human activities scale, cognitively and/or socially, and in which way ICT in general and mobiles in particular have the potential to lower the existing thresholds. In this respect, smartphones and mobile Internet services are very promising, but may also introduce new forms of complexity. For instance, the combined use of maps, social networks and additional tools, such as instant pools, provide new ways to small and large social groups for both enhancing the interactivity of mobile services and for reducing the complexity of their shared activities (Lugano, 2010).

Conclusions

The realization of the potential of the new forms of ICT, which are based on the convergence of computer networks, mobile networks and the media, also depends on our understanding of both their technological and human meanings. The products of the age of convergence, such as smartphones, tablet computers and ebook readers, are characterized by increasing computational capabilities, versatility, and complexity. Until now, their usefulness has been mostly marketed through measures of their technical performance, such as larger memories and screens, sensors, support of 3-D graphics and innovative input modalities such as touch interfaces. However, such features do not explain how they actually enhance human performance. The existing gap between the potential and the realized benefits of a technology is caused, among others, by the inadequate vocabulary that is used to conceive, design and use *human technology* (Saariluoma, 2005). For decades, software engineers and computer scientists have developed a thorough understanding of technical scalability, which is regarded as a positive property of computer systems. As computers became an integral part of the everyday life, this approach to scalability needs to be updated with a broader one, which acknowledges that not only computers scale, but also human societies do. By adopting the Socionics approach (Fischer et al., 2005), we presented an initial effort towards an understanding of human scalability, both in its cognitive and social dimensions. This approach underlines that scalability does not only involve a quantitative dimension, but also a qualitative one. In addition, it shifts the attention from a system-oriented to a problem-oriented view, in which the activity-context becomes the focus of the analysis. Through this approach, the technical definition of scalability was complemented by two new concepts, namely cognitive and social scalability. In the unified definition, these concepts were presented as the capacity to process individually or collectively growing volumes of work gracefully, and/or adjust to their increasing complexity. The conceptual framework was then considered in relation to debate on the social scalability of mobile devices in social coordination. In this regard, it was pointed out that mobile devices can efficiently support social coordination at different scales, but in different manners. As mobile devices can both lower existing thresholds and introduce new ones, it is essential to study their scalability issues in well defined activity contexts, rather than discussing whether they are socially scalable devices. An empirical exploration of human scalability in different situations represents therefore the natural extension of this study, which only provides an initial effort towards a conceptualization of cognitive and social scalability. The study offers a new perspective to scalability, a term that is equally important and useful in technical and human networks. It may be debated whether other approaches than Socionics may better ways to conceptualize human scalability, especially from a design perspective. The investigation of viable alternatives to Socionics is another important direction of future research.

In conclusion, in networked information societies scalability can no longer be associated only to technical networks, but it has to be analyzed also in the context of human networks as well. Without this effort, human and social factors may reduce the potential usefulness of a technically scalable system because technical scalability does not imply also cognitive and social scalability. For this reason, design research needs to acknowledge cognitive and social scalability in the conception, implementation and deployment of new forms of ICT.

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References

Albrecht, S., Lubcke, M., Malsch, T. & Schlieder, C. (2005). Scalability and the Social Dynamics of Communication. On Comparing Social Network Analysis and Communication-Oriented Modelling as Models of Communication Networks. *Lecture notes in computer science*, *3413*, Berlin/Heidelberg: Springer, 242-262.

Bakardjieva, M. (2005). *Internet Society: The Internet in Everyday Life*. London, UK: Sage.

Baron, N. (2008). Adjusting the volume: Technology and multitasking in discourse control. In J. E. Katz (Ed.) *Mobile communication and social change in a global context*. Cambridge, MA: The MIT Press, 117-19.

Bhatt, J., Denick, D. & Chandra, S. 2008. Using Web 2.0 applications as information awareness tools for science and engineering faculty and students in academic institutions. In: *Proceedings of the International Conference of Asian Special Libraries*. http://hdl.handle.net/1860/2973

Bondi, A.B. (2000). *Characteristics of scalability and their impact on performance*. Paper presented at the 2nd international workshop on Software and performance, Ottawa, Canada, 195-203. doi: doi.acm.org/10.1145/350391.350432

Brown, D.H. (2004). *Vertical and horizontal scalability. A study of representative UNIX, Linux and Windows Customer environments*. Retrieved from http://www.sun.com/servers/wp/docs/vertical_horizontal_scalability.pdf

Chi, M.T.H., Glaser & R. Rees, E. (1982). Expertise in problem solving. In R.J.Sternberg (Ed.) *Advances in the psychology of human intelligence* (Vol. 1). Hillsdale, NJ: Erlbaum.

De Castella, T. (2010) *Should we trust the wisdom of crowds?* BBC News online. Retrieved from http://news.bbc.co.uk/2/hi/uk_news/magazine/8788780.stm

De Sola Pool, I. (1983). *Technologies of freedom*. Cambridge, USA: Harvard University Press.

Dunbar, R. I. M. (1998). The social brain hyphotesis. *Evolutionary anthropology*, *6*(5), 178-190.

Dunbar, R. I. M. (2010). *How many friends does one person need?*. London: Faber and Faber.

Fischer, K., Florian, M. & Malsch, T. (2005). *Socionics: scalability of complex social systems*. Lecture Notes in Artificial Intelligence LNAI 3413. Berlin: Springer.

Fortunati, L. (2007). Discussing a possible research agenda for the convergence of the mobile and the Internet. In: *Towards a Philosophy of Telecommunications Convergence, Communications in the 21st Century*, Budapest, Hungary, 109-114.

Frensch, P.A. & Funke, J. (1995) *Complex problem solving. The European perspective*. Hillsdale, NJ, US: Lawrence Erlbaum.

Gonzalez, V.M. & Mark, G. (2004) Constant, constant, multi-tasking craziness: managing multiple working spheres. In: *Proceedings of the CHI 2004*, Vienna, Austria, 113-120.

Granovetter, M.S. (1974). *Getting A Job: A Study of Contacts and Careers*. Chicago: University of Chicago Press.

Hill, M.D. (1990). What is scalability? *ACM SIGARCH Computer Architecture News*, *18*(4), 18-21.

Hwang, K. (1992). *Advanced computer architecture: parallelism, scalability, programmability*. New York, USA: McGraw-Hill Higher Education.

Jenkins, H. (2001). Convergence? I diverge. *Technology review, 104*(5), 93.

Kirn, W. (2007). The autumn of the multitaskers. *The Atlantic Monthly*. Retrieved from http://www.theatlantic.com/magazine/archive/2007/11/the-autumn-of-the-multitaskers/6342.

Kluitenberg, E. (2006). The network of waves: Living and acting in a hybrid space. *Open 11 Hybrid Space*, 6-16. Retrieved from http://www.skor.nl/download.php?id=3231

Ling, R. (2004). *The mobile connection: The cell phone's impact on society* (1st ed.). San Francisco, USA: Morgan Kaufmann Pub.

Lugano G. (2006). Understanding Mobile Relationships. In J. Multisilta & H. Haaparanta (Eds.): *Proceedings of the Workshop on Human-Centred Technology (HCT 2006)*, Pori, Finland, 152-161.

Lugano, G. (2008). Mobile social networking in theory and practice. *FirstMonday*, *13*. Retrieved from http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/2232/2050

Lugano, G. (2010) *Digital community design: exploring the role of mobile social software in the process of digital convergence*. Doctoral thesis. Jyväskylä Studies in Computing 114, University of Jyväskylä, Finland.

Luhmann, N. (1995). *Social systems*. Stanford, CA: Stanford University Press.

Luke, E. A. (1993). *Defining and measuring scalability*. Paper presented at the Scalable Parallel Libraries Conference, Mississippi, USA, 183-186.

Marchbank, T. (2004). Intense Flows: Flashmobbing, Rush Capital and the Swarming of Space. *Philament: An Online Journal of Arts and Culture, 4*. Retrieved from http://www.arts.usyd.edu.au/publications/philament/issue4_Critique_Marchbank.htm.

Mc Fedries, P. (2003). Mobs R Us. *IEEE Spectrum*, *10*, 56.

Miller, G.A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological review*, 63(2), 81-97.

Morin, E. (1992). From the concept of system to the paradigm of complexity. *Journal of Social and Evolutionary Systems*, *15*(4), 371-385.

Nicolis, J.S. & Tsuda, I. (1985) Chaotic dynamics of information processing: The "magic number seven plus-minus two" revisited. *Bulletin of Mathematical Biology*, *47*(3), 343-365.

Marois, R. & Ivanoff, J. (2005) Capacity limits of information processing in the brain. *Trends in Cognitive Sciences*, *9*(6), 296-305.

Müller, H.J., Malsch, T. & Schulz-Schaeffer, I. (1998). Socionics: introduction and potential. *Journal of artificial societies and social simulation, 1*(3), 2001-2007.

Neisser, U. (1967). *Cognitive psychology* (1st ed.). Prentice-Hall. Appleton-Century-Crofts New York.

Neuman, B.C. (1994). Scale in distributed systems. *Readings in Distributed Computing Systems*, 463-489.

Newell, A., & H. A. Simon (1972). *Human problem solving.* Englewood Cliffs, NJ: Prentice Hall.

O'Reilly, T. (2005). *What is Web 2.0: Design patterns and business models for the next generation of software*. Retrieved from www.oreillynet.com/pub/a/oreilly/tim/news/2005/09/30/what-is-web-20.html.

Ophir, E., Nass, C. & Wagner, A.D. (2009). Cognitive control in media multitaskers. In: *Proceedings of the National Academy of Sciences (PNAS)*, *106*(37), 15583-15587.

Oulasvirta, A., Raento, M. & Tiitta, S. (2005). ContextContacts: re-designing SmartPhone's contact book to support mobile awareness and collaboration. In: *Proceedings of Mobile HCI 2005*, Salzburg, Austria, 167-174. http://doi.acm.org/10.1145/1085777.1085805

Paetow, K., Schmitt, M. & Malsch, T. (2005). Scalability, Scaling Processes, and the Management of Complexity. A System Theoretical Approach. *Lecture notes in computer science, 3413*, Berlin/Heidelberg: Springer, 132-154.

Pashler, H. (1994). Dual-task interference in simple tasks: Data and theory. *Psychological bulletin, 116*(2), 220-244.

Putnam, R.D. (2000). *Bowling alone: the collapse and revival of American community*. New York, USA: Simon & Schuster.

Quick, C. (2009). *With smartphones on the rise, opportunity for marketers is calling.*

Retrieved from http://blog.nielsen.com/nielsenwire/online_mobile/with-smartphone-adoption-on-the-rise-opportunity-for-marketers-is-calling

Rheingold, H. (2002). *Smartmobs: The next social revolution* (1st ed.). Perseus books.

Saariluoma, P.(2005). The challenges and opportunities of human technology. *Human Technology, 1*(1), 1-4.

Scott, J. (2000). *Social network analysis: a handboo*k (2nd ed), London, UK: Sage.

Shirky, C. (2008). *Here comes everybody: the power of organizing without organizations*. Penguin Press.

Stephens, K.K. & Davis, J.D. (2009) The social influences on electronic multitasking in organizational meetings. *Management Communication Quarterly, 23*, 63-83.

Surowiecki, J. (2004). *The wisdom of the crowds: Why the many are smarter than the few and how collective wisdom shapes business, economies, societies and nations*. New York, US: Anchor books.

Tapscott, D. & Williams, A. (2006). *Wikinomics: How mass collaboration changes everything*. London: Penguin Press.

Wellman, B. (2001). Computer networks as social networks. *Science*, *293*(5537), 2031-2034.

Wooldridge, M. (2002). *An Introduction to Multiagent Systems*. John Wiley & Sons.

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