Collaborative information seeking environments benefiting from holistic ergonomics

Anika Meyer and Ina Fourie
Information Science, University of Pretoria, Pretoria, South Africa

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Abstract

Purpose – The purpose of this paper is to explore the value of utilising a holistic ergonomic approach, covering engineering, cognitive and social perspectives, to cultivate beneficial and productive collaborative information seeking (CIS) systems and environments, specifically with regard to three main CIS pillars (control, communication and awareness).

Design/methodology/approach – A qualitative research approach, based on a selective corpus of CIS literature, was utilised to perform a content analysis to note if terms and concepts normally associated with engineering, cognitive and social ergonomics can be used to eliminate terms reflecting issues related to three CIS pillars (control, communication and awareness) that can benefit from a holistic ergonomic approach.

Findings – The content analysis revealed that a fairly extensive amount of holistic ergonomic terminology is prominent within the CIS literature, therefore establishing a connection between the two disciplines: CIS and ergonomics. This suggests that CIS system issues could benefit from the insights of a holistic ergonomic approach.

Research limitations/implications – Since this is an exploratory study the scope of CIS literature utilised in the content analysis was limited to a selection considered most important by the authors; this should be supplemented by further research.

Practical implications – Intended to instigate interest in further exploration of the beneficial and productive implications and practical application of holistic ergonomics in designing CIS systems and environments.

Originality/value – This is the first research paper in the Library and Information Science literature that explores the potential of utilising holistic ergonomics to cultivate CIS systems and environments.

Keywords Design, Information science, Analysis, Literature review

Paper type Research paper

1. Introduction

There has been a growing interest in acknowledging the importance of collaborative information seeking (CIS) in performing complex tasks (Foster, 2006, p. 333; Shah, 2009, p. 1). According to Luccock (1961, sp.) "No one can whistle a symphony: it takes a whole orchestra to play it". CIS is an interdisciplinary field that has been shaped by several domains such as human-computer interaction, information retrieval (IR) and computer-supported cooperative work (Foster, 2006, p. 329). Shah (2013a, p. 1) notes that CIS is facing a very exciting intersection in the sense of generating new fields of opportunity to identifying research gaps. This may require input from a wider spectrum of disciplines, e.g. ergonomics and acknowledging all dimensions of a CIS environment.

According to Shah (2013a, p. 3), the predominant focus in the IR and Library and Information Science (LIS) fields used to be on single-user environments. The focus however has shifted to accommodate multiple participants. Due to this change issues have appeared such as changing user requirements and a need for evolving group dynamics within a specific domain (e.g. office environments) (Grudin, 1994, p. 97; Hyldegård, 2006, p. 277; Shah, 2009, p. 2, 2013a, pp. 3-4). A CIS environment has become

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very important due to the complex nature of work tasks and interaction (Boehm *et al.*, 2014, p. 33; Hertzum, 2008, p. 3; Shah, 2013a, p. 1).

Shah (2012, p. 24) clarifies that a CIS environment encapsulates a range of interactions, processes, users and systems – amongst others, a CIS system with its three main pillars, namely: control, communication and awareness. Within a CIS environment individuals can interact in a shared workplace (Case, 2007; Foster, 2006; Perkop, 2002; Shah, 2009, 2012, 2013a, b). The three pillars feature strongly in Shah's work, for example: CIS: the art and science of making the whole greater than the sum of all (Shah, 2012, pp. 44-50), collaborative information behavior: user engagement and communication sharing (Shah, 2010, pp. 141-158) and CIS (Shah, 2012, pp. 41-59).

Ergonomics is a field of study that attempts to provide a perfect fit between individuals and their work environments (Parsons, 2000, p. 581). It can be applied to nearly every type of environment imaginable (Institution of Ergonomics and Human Factors, 2014, sp.; O'Neill, 2011, p. 1; Rayner, 2008, pp. 36-39). O'Neill (2011, p. 1) points out that the nature of office work has evolved into a highly collaborative and social activity requiring an integrated work environment, therefore moving from a traditional "office ergonomic" approach (i.e. engineering and cognitive ergonomics) to a "holistic" approach. The "holistic" approach incorporates the physical (engineering ergonomics), mental (cognitive ergonomics) dimensions of a work environment, and formal and informal collaboration and interaction (social ergonomics) between individuals and their shared workspace (Boff, 2006; Carayon and Smith, 2000; Manuaba, 2007; Wilson, 2000). Knoll, a design firm, which aims at using "modern design to connect people to their work, their lives and their world", propagated the concept holistic ergonomics (Knoll Inc., 2010, p. 1).

Ergonomics is not explicitly mentioned in the literature of CIS, but through searches in relevant databases such as Library and Information Science Abstracts (LISA), Library and Information Science Source, Emerald, ISI Web of Science and ScienceDirect on "CIS", it appears as if issues discussed can benefit from insights from ergonomics and especially a holistic ergonomics approach as propagated by O'Neill (2011). The authors are aware that there are synonyms for "CIS" such as social searching, collaborative exploratory search, collaborative information behaviour and co-browsing, but as part of an exploratory study aimed for a manageable collection of documents to use for a first round of analysis. Only search terms closely associated to "CIS" were utilised: CIS, collaborative IR, collaborative search and collaborative retrieval. Although Fidel *et al.* (2000, p. 241, 2004, p. 943) mention the usage of ergonomic analysis which takes into consideration human interactions and perception-action capabilities for designing information systems, they do not elaborate.

CIS faces issues such as system design, development and deployment that are interweaved with environmental issues such as group dynamics, personal and social interactions, and the successful integration of work practices into shared collaborative information spaces and environments (Fidel *et al.*, 2004; Foster, 2006; Shah, 2009). The purpose of this paper is to explore how a holistic ergonomic approach, covering engineering, cognitive and social perspectives, can help cultivate beneficial and productive CIS systems and environments, specifically with regard to the three main CIS pillars (control, communication and awareness), and to instigate interest in further research. The research question was:

RQ1. How can terminology from holistic ergonomics be used to eliminate issues in CIS systems that can benefit from a holistic ergonomic approach to cultivating beneficial and productive CIS systems and environments? Sub-questions included:

- Which categories of terminology from a holistic ergonomics approach can be used in a content analysis of CIS publications?
- Which categories of terminology that can be related to holistic ergonomic terminology are noted from a content analysis of CIS literature with specific reference to the three main CIS pillars (i.e. control, communication and awareness)?
- How can these categories be interpreted as issues to be addressed in strengthening the CIS pillars?
- How can the three main CIS pillars and their respective issues benefit from a holistic ergonomic approach?

2. Conceptualisation and contextualisation of CIS and ergonomics

Shah (2012, p. 25) notes that the CIS literature is filled with many seemingly related terms that in return generate a challenge for practitioners and researchers to agree on a general definition. This can also be seen in the work of Blackwell *et al.* (2004), Foster (2006) and Hertzum (2008). Foster (2006, p. 330) defines CIS as: "the study of the systems and practices that enable individuals to collaborate during seeking, searching, and retrieval of information". Thus, emphasising that CIS concerns how individuals retrieve, search, handle and interact while performing collaborative work tasks. Poltrock *et al.* (2003, p. 239) on the contrary focus on CIS as a collective action and propose that CIS should be defined as: "activities that a group or team of people undertakes to identify and resolve a shared information need". This definition highlights the significance of individuals working together to resolve a shared information need to achieve a positive outcome. For the purpose of this study CIS (a sub-discipline in LIS) will refer to a combination of the definitions provided by Foster (2006, p. 330) and Poltrock *et al.* (2003, p. 239), namely: the study of systems, practices and activities that enable a group of individuals to collaborate and interact through identifying and resolving a shared information need by means of seeking, searching and retrieving information. A CIS environment involves three main components: "a way to connect remote participants (i.e. awareness regarding the focused collaboration among individuals to accomplish a shared activity); a shared space for exchanging information (i.e. control within a specific environment); and a communication channel (i.e. communication as an interactive platform to stimulate engagement) to provide real-time message passing among the participants" (Shah and Gonzalez-Ibanez, 2012, pp. 334-335). There is a very close relationship between these components and the three main pillars (see Figure 1).

Ergonomics is defined by the official International Ergonomics Association (2014) as: "the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance". It is often applied to work/office environments due to the evolving and growing collaborative nature of work (O'Neill, 2011, p. 1). Various researchers such as Boff (2006), Carayon and Smith (2000), Manuaba (2007) and Wilson (2000) all support the concept of a total/holistic ergonomic approach to establish an effective and productive work environment. Holistic ergonomics (O'Neill, 2011, p. 2) include engineering ergonomics, cognitive ergonomics and social ergonomics.

O'Neill (2011, p. 1) defines engineering ergonomics as the fit between people and their office workspace (i.e. the work domain or physical context) by concentrating on,

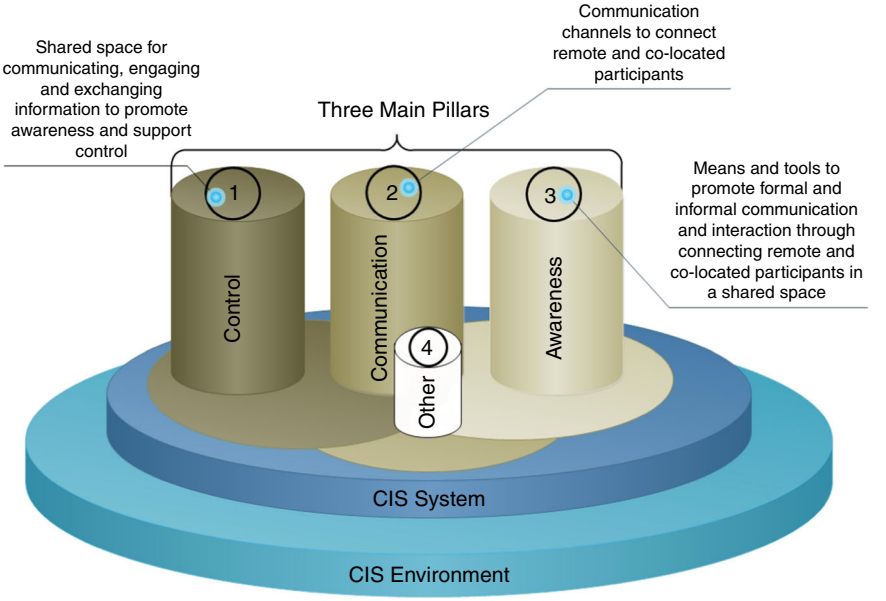

Figure 1.
Three main pillars of a CIS system in a CIS environment

e.g. body size and physical capabilities (also known as "anthropometrics") to study human anatomy (body size and proportions) relative to physical activities, comfort design and workstation layout, as well as creating a wholesome work environment for effective human performance and productivity. This interpretation is supported by Lee (2005, p. 549) and Wilson (2000, p. 558). Cognitive ergonomics refer to solutions to communication issues by optimising the fit between technology, job design and individuals' mental capabilities (Boff, 2006, p. 392; Carayon and Smith, 2000, p. 656; O'Neill, 2011, p. 1; Wilson, 2000, p. 562). Social ergonomics focuses on the social and collaborative contexts of work, and thus on improving the fit between the social aspects of work, learning, mentoring, formal and informal interaction, and group participation (Badham and Ehn, 2000, p. 67; O'Neill, 2011, p. 2).

The intention with this paper is to explore how these types of ergonomics are implicitly featuring in the literature on CIS systems and CIS environments and how the key pillars of CIS (control, communication and awareness) can be strengthened and issues related to these pillars be resolved from a holistic ergonomic approach (Manuaba, 2007, p. 29; O'Neill, 2011, p. 2).

3. CIS system pillars and issues to be addressed by an ergonomic approach

CIS systems centre around three main pillars – control, communication and awareness (Shah, 2010, p. 1971, 2013b, p. 1123). Each faces a number of issues that need to be addressed (Shah, 2009, 2010, 2013a, b; Shah *et al.*, 2014; Shah and Marchionini, 2010). The pillars are depicted in Figure 1. There may be more, e.g. a coordination pillar (Shah, 2013b, p. 1123); these are indicated as "other".

The awareness pillar concerns the means of connecting remote and co-located individuals (also referred to as connecting) through providing socialising tools and connection support to promote interaction. The communication pillar concerns a channel(s) or other means for sending, exchanging and sharing information as well

as providing support (e.g. transmission support) for synchronously (i.e. in real-time) or asynchronously (i.e. non-real-time) manifestations. The control pillar refers to the provision of control support for engagement and communication, and establishing and raising awareness in a shared space.

The pillars are not mutually exclusive and can overlap. This is depicted by the overlapping circles. They each face issues that need to be addressed in developing beneficial and productive CIS systems and CIS environments. A holistic ergonomic approach might be able to address some of these issues. Table I explains each pillar and its possible relation to ergonomics in more detail. Table I also note terminology from holistic ergonomics that could guide the content analysis.

4. Research design

A research design refers to a structured plan, proposal or procedure that involves any particular method of data collection and analysis (Creswell, 2013). Three main methodologies are identified in the literature on research design, namely: a qualitative approach, quantitative approach and a mixed method approach (Creswell, 2013). This particular study focuses on an interpretative text analysis (qualitative approach) for a content analysis based on a literature search.

4.1 Content analysis as research method

Krippendorff (1989, p. 18) defines content analysis as "a research technique for making replicable and valid inference from text (or other meaningful matter) to the contexts of their use". A content analysis can also be described as a scientific tool that can systematically analyse text, in a qualitative or quantitative method, to provide new insight to researchers about a specific phenomenon (Krippendorff, 1989, 2004; Wilson, 2011). Content analysis is a well-established research method in LIS (Julien, 1996; Julien *et al.*, 2005).

For purposes of this paper content analysis will be applied to a selection of publications from the CIS literature to note terms and concepts normally associated with engineering, cognitive and social ergonomics. The list of ergonomic terms compiled from an article by O'Neill (2011) "Holistic ergonomics for the evolving nature of work" is depicted in Table II. The list was supplemented from the work of Boff (2006), Carayon and Smith (2000), Manuaba (2007) and Wilson (2000) who are also considered prominent researchers in holistic ergonomics.

4.2 Literature searching and selection for content analysis

Literature searches were performed in various databases such as Library and Information Science Abstracts (LISA), Library and Information Source, Emerald, ISI Web of Science and ScienceDirect. Searches were done in the period May 2014. Search terms had to appear within the title field (to find articles dealing with CIS in some detail), and furthermore the search results were filtered by the following specifications: literature published from 1995 till present (the cut-off date was 1995 to take into consideration literature from the previous century, which formed the foundations of CIS), literature published in English due to the authors being most familiar with this language; document types such as articles, book chapters and conference papers.

A total of 444 documents were retrieved; after removing duplicates 175 documents remained for further analysis. These were manually examined. Documents were excluded if focusing on hard-core IT systems (e.g. algorithms, artificial intelligence and query systems); collaboration with a focus on retrieval, recall, research, filtering,

Pillars	Description of pillars and alignment with potential to follow a holistic ergonomic approach
Control	A shared space for engaging and exchanging information need to be controlled – specifically the roles and rules applying. According to Yfantis *et al.* (2012, p. 1), control refers to the "rules for the group's processes and the adoption of roles (supervisor, analyst) by the participants". In order for a team to succeed in seeking, communicating and sharing information across multiple domains, the team needs to have a shared understanding and context (Foster, 2006, p. 337). Control is domain specific, thus referring to control and command across multiple domains and resources for the evolving and dynamic nature of work situations (Shah, 2013a, p. 3; Sonnenwald and Pierce, 2000, p. 462). Typical issues that need to be addressed is the nature of collaboration (e.g. synchronous vs asynchronous, co-located vs remote), and the context and domain in which collaboration occurs (Shah, 2010, pp. 23-26, 2013a, p. 2). To some extent these are also addressed by the other two pillars
Interpretation of control for purposes of content analysis	Control will refer to the roles, rules, mechanisms and shared spaces that individuals require to share understanding and context and to collaborate successfully across a specific domain or multiple domains in specific situations (e.g. an office environment)
Ergonomic terminology to consider in CIS literature	From a holistic ergonomic approach the terminology related to engineering ergonomics seems most relevant to control in a CIS system, e.g. workspace, physical effort, physical proximity and spatial context. Control might also be supported from cognitive and social ergonomics
Communication	According to Shah (2009, p. 4) communication can be defined as: "a channel to provide real-time message passing among the participants". Channels are used in a CIS system to connect participants who may be remote participants. Communication is one of the most important components for collaboration (Shah, 2010, p. 17; Sonnenwald, 1996, p. 279) e.g. an interactive platform (i.e. interactive environment) that motivates individuals to engage and connect collaboratively (Shah and Marchionini, 2010, p. 1971; Shah, 2011, p. 74). Issues to address include the design and implementation of CIS tools in relation to its processes, content, and devices, user' behaviour and motivation, cost and benefits of CIS systems, and developing interfaces to view personal and shared information (awareness) without increasing an individual's cognitive load (Shah, 2010, pp. 23-26, 2013a, p. 2).
Interpretation of communication for purposes of this paper	Communication will refer to one or more systems (e.g. communication channels, communication platforms and social networks and channels) that enable the sharing of information and knowledge, tasks, workloads and the solving of complex problems
Ergonomic terminology to consider in CIS literature	From a holistic ergonomic approach the terminology related to cognitive and social aspects overlap, thus signifying that some mental activities require additional human involvement (socialising) to make sense of gathered information and solve

Table I.
Three CIS system pillars aligned with terminology from holistic ergonomics

(*continued*)

Pillars	Description of pillars and alignment with potential to follow a holistic ergonomic approach
	complex problems. Engineering and social ergonomics seems relevant to communication in a CIS system. Terms include workspace, physical effort, physical proximity, spatial context, cognitive load, mental/mind, and communication channels and processes
Awareness	The promotion of formal and informal interaction through a connection between physically close as well as remote participants in a shared space. According to Dourish and Bellotti (1992, p. 107), awareness in CIS is: "an understanding of the activities of others, which provides a context for your own activity". Awareness manifests between co-located and remote participants. Both Shah and Marchionini (2010, p. 1971) state that awareness is the most significant issue in a CIS system. More specifically, Gaver (1991, p. 293) claims that casual awareness can lead to better collaboration through stimulating serendipitous communication. Typical issues to address include distribution of responsibilities and roles among collaborators, need for privacy vs sharing among the collaborators, converting social connections to collaborative connections and providing awareness for individual and group benefits (Shah, 2010, p. 27, 2013a, p. 3)
Interpretation of awareness for purposes of this paper	Awareness will refer to the informal and formal interactions, spontaneous conversations, teamwork, group learning, and the participation and engagement of individuals to accomplish a shared goal and to ensure that all are informed about progress and other issues
Ergonomic terminology to consider in CIS literature	From a holistic ergonomic approach the terminology related to social ergonomics seems most relevant, e.g. social efforts, social experience, interrelations, interconnection or interconnectedness, social interaction and social networks. Engineering and cognitive ergonomics might also be able to contribute

Table I.

learning and teaching; and documents being irrelevant based on their content (e.g. knowledge seeking, content dissemination, individual searching and information problem solving). For documents considered appropriate, the full text was obtained, leaving 49 documents for the content analysis. Since this is an exploratory study to show the potential of utilising a holistic ergonomics approach to assist in eliminating CIS system issues the 49 articles were considered adequate.

4.3 Content analysis and identification of holistic ergonomic terminology in the CIS literature

The objective of the content analysis was to determine how terminology from the three perspectives of ergonomics features in CIS literature and to indicate the correlation between the three perspectives of ergonomics and the three CIS pillars. The terms in Table II guided the textual analysis. Terms similar to the terms in Table II and related terms were highlighted in the documents. All highlighted terms were captured and organised into categories representing engineering ergonomics, cognitive ergonomics

Holistic ergonomics	Engineering ergonomics	Cognitive ergonomics	Social ergonomics
Description	Fit between people and their physical space (including situation and context)	Optimisation of the fit between technology, task design and people's mental capabilities	Improving of the fit between social and collaborative aspects of work, learning, mentoring, interaction and participation
Ergonomic terms selected from O'Neill (2011)	Physical spaces, places, environments, settings, contexts, locations, domains, dimensions, layout, physical aspects and physical capabilities (e.g. comfort and functionality design of workspace, layout and equipment)	Mental capabilities, mental dimensions, mental aspects, mental workload, work tasks, decision making, work process, cognitive, knowledge and behaviour	Social and collaborative aspects, social dimension, group work, social interaction, social exchanges, collaborative work and collaborative interaction
Additional ergonomic terms selected from Boff (2006), Carayon and Smith (2000), Manuaba (2007) and Wilson (2000)	Human factors, engineering human factors, physical fit, biological fit and workspace awareness	Cognitive fit, cognitive capabilities, cognitive engineering, biological fit (i.e. physical, people perceive and think), psychology, cognitive limits, capacity to process information, choices, decision making, fit minds, cognitive state, sensing, motivation, judgement, knowledge, mental demand, work tasks, experiences, problem solving, mind-set, understanding, human behaviour and affective (this can also be associated with social ergonomics)	Social culture, interpersonal, networking, intricate relationships, interactions, collaboration, social, participation, teamwork, cooperation, sharing, psychosocial work factors, information exchange, social groups and social influences

Table II.
Terms from holistic ergonomics guiding the content analysis

and social ergonomics. Where applicable sub-categories with a few example terms were identified; these are discussed in Sections 4.3.1-4.3.3. The focus was on issues of CIS pillars (see Figure 1) that can benefit from taking a holistic ergonomics perspective. The cognitive point of view is discussed in more detail since it seems least obvious to be of benefit to CIS. The contrary is demonstrated through the discussion. To proof the argument that CIS systems and environments can benefit from a holistic ergonomic approach a few relevant applications are noted in the discussion.

4.3.1 Content analysis from an engineering ergonomics perspective. The broad categories of issues identified from the CIS literature are applicable to physical and virtual spaces. Engineering ergonomics aim at providing the perfect fit between individuals and their workspaces by taking into consideration spatial components, different environments, impacting factors, human components and support within

physical spaces. Physical spaces connect individuals, thus focusing on proximity, for example, remote, co-located, distant, geographically distributed, as well as temporal, technological and spatial distributions. Examples of categories of issues to address for CIS – from an engineering ergonomics perspective – are discussed below.

4.3.1.1 Spatial issues and physical spaces. CIS physical spaces focus on a variety of factors, e.g. contextualisation (including social contextualisation), addressing isolation, the impact of the environment and situation, space-adaptive features, and the constructing of shared spaces. The following are of special importance:

- Specific nature of physical spaces, e.g. 3D spaces, design spaces, shared workspaces, interconnected shared information spaces and shared social workspaces.
- Space boundaries, e.g. community and organisational boundaries. Sometimes CIS spaces are referred to as "constraint bound".
- Platforms supporting physical and virtual spaces, e.g. collaboration platforms, discussion and working platforms.

4.3.1.2 Environments in which physical spaces manifests. The environment in which an individual or group's physical space manifests is marked by different contexts, settings, boundaries and conditions. It can even be collaboration-resistant. Environments noted in the CIS literature include corporate, library, military and hospital environments. These environments aim at connecting co-located as well as remote individuals through virtual or physical means. The following are important:

- specific nature of the context of the environment which can, e.g. be described as an IT, collaborative, educational, learning, cultural, research or multimedia context;
- specific settings within physical spaces which can be described as awareness-rich, information-intensive, experimental, professional, real-life or workplace; and
- boundaries as set by, e.g. a community, geographic demarcation, task or discipline.

4.3.1.3 Human components within physical spaces. Various individuals or groups are active in physical spaces. Individuals interact with their environment to successfully accomplish their work tasks and in CIS also to collaborate (the human components in a physical space will thus also apply when discussing cognitive and social ergonomic perspectives to CIS):

- People active in physical CIS spaces are referred to as groups, teams, searchers, members, partners, learners and also according to specific professions (e.g. engineers). They perform physical actions and activities such as asynchronous and synchronous collaborative IR and information seeking, information exchange and interactive design activities.

Awareness within physical spaces is very important (Boff, 2006, p. 392; Shah, 2013b, p. 1125; Sonnenwald and Pierce, 2000, p. 463). In CIS environments an engineering ergonomics perspective can contribute to raising awareness by, e.g. the use of context-adaptive and context-aware CIS systems. Types of awareness within physical spaces can include situation, interwoven situational, intragroup situational, intergroup situational, contextual and workspace awareness. As will be pointed out, awareness is also very important for a cognitive and social ergonomics perspective to CIS.

4.3.1.4 Factors impacting on physical spaces. Within physical spaces a range of constraints can occur such as environmental, design, organisational, physical and task constraints. There are many factors impacting on physical spaces; many of these also figure in cognitive and social spaces because engineering ergonomics applies to constructing the shared (collaborative) spaces in which cognitive and social activities as part of CIS occur. The following factors are important:

- environmental factors such as infrastructures, buildings, office spaces, locations;
- contextual factors such as awareness, conditions, work and workgroup activities;
- situational factors such as accessibility (group or individual access), awareness, spatial layout and engineering infrastructure; and
- physical factors such as physical activities, arrangements, processes and physical position.

4.3.1.5 Support within physical spaces. CIS support within physical spaces can be provided by means of CIS and retrieval systems, control systems, physical and digital libraries, knowledge repositories, document storage repositories, and online support groups.

4.3.2 Content analysis from a cognitive ergonomics point of view. Seven broad categories of terminology to be interpreted as issues of CIS pillars are briefly discussed: cognitive spaces, environments, human components, activities and processes, support, and system components.

4.3.2.1 Cognitive spaces. Specific needs arise within cognitive spaces. These include affective, emotional, communication, factual and awareness information needs; cognitive spaces should support the fulfilment of information needs. In a CIS system it should support formal, informal and effortless participation with mutual benefits for all participants. Specific cognitive space issues revealed in the CIS terminology include:

- Support for conceptualisation, e.g. cognitive construction of models, gaining clarity in the Anomalous State of Knowledge (with specific reference to the recognition of information needs), operating according to a Cognitive Work Analysis Framework (models complex sociotechnical work systems with specific recognition to users' cognitive and social activities (Fidel *et al.*, 2000, p. 241, 2004, p. 943)) and refining mental models.
- Support for emotional spaces manifesting within cognitive spaces, i.e. with regard to the affective state of an individual or group's cognitive processing capacity including affective, task and workloads in CIS. Terminology describing affective states includes motivation, desire for collaboration, negative emotions such as anxiety and doubt, positive emotions such as enthusiasm and happiness. Within emotional spaces individuals' behaviour influences their affective state and consequently their cognitive state. This again influences CIS activities such as browsing, exploration, and sharing, and the information seeking habits people develop. All require support in a CIS environment.
- Support for problem spaces where specific challenges need to be overcome to successfully accomplish CIS activities, e.g. dealing with administrative and awareness issues, argumentation, cognitive overload and challenges in sense making.

- Support for factors impacting on cognitive spaces, e.g. affective, communication, motivational, cultural, emotional, personal and perceptual factors.
- Support for issues of timing in cognitive spaces, e.g. asynchronous and synchronous IR, searching, seeking, communication, acknowledgement, and sharing.

4.3.2.2 Environments in which cognitive spaces manifests. The environment in which an individual or group's cognitive space manifest, can be considered in terms of:

- Types of work, e.g. ethnographic work, knowledge work and network reference work. Work can be loosely or tightly coupled.
- Environmental boundaries, e.g. communication, cultural and social boundaries.
- Sessions as short events in the environment, e.g. for brainstorming and browsing.

From a cognitive engineering perspective the environments can benefit by improving the biological fit, for example, modifying the physical environment according to work tasks, physical proximity and spatial context to lighten physical effort and as a result reducing cognitive overload.

4.3.2.3 Human components within cognitive spaces. Various people (i.e. individuals, group members) are active in cognitive spaces in CIS contributing their expertise, experiences, knowledge, capabilities, skills and work efforts. They affect the relationships required to perform CIS cognitive activities. The following are important:

- People who are active in CIS cognitive spaces need to be acknowledged, e.g. communication partners, domain, search and subject experts. They can also operate in groups (e.g. online communities and IR communities), and in teams. Different types of relationships are required for individuals to complete their CIS activities successfully, e.g. interpersonal, system-mediated, work, organisational and professional relationships. Trust is very important in these relationships. Cognitive ergonomics can add value by means of identifying human behaviours, motivation and cognitive processing through studying their mental functions and capabilities (psychology) and then practically applying it within the design of CIS systems. There is also a close relationship to a social ergonomic perspective as explained in Section 4.3.3.
- People are driven by different work efforts, e.g. cognitive, communication, coordination, problem solving, research and sense-making efforts.
- Different types of searchers participate in CIS, e.g. externally motivated searchers, individual searchers and self-motivated searchers.
- A spectrum of expertise, knowledge and experience is required to successfully complete CIS activities, e.g. authority, and domain, search, IR, job, and professional expertise. Knowledge required includes contextual, domain, cultural, human, internal/external, perceived, procedural search, sense making and tacit/explicit knowledge. Experiences required include information seeking, browsing, cognitive and work experience. Cognitive ergonomics is system-focused, and thus can add value through interface design to promote the assembly and creation of knowledge and expertise for improving cognitive capabilities, communication and collaboration.

4.3.2.4 Activities and processes within cognitive spaces. Activities within cognitive spaces can be conducted individually, in pairs, or in groups or teams through synchronous

or asynchronous means to support goals such as personal search goals, recall-orientated and information seeking goals. Activities can be planned and focused or unfocused, active or passive and explicit or implicit. The following are important for CIS and can be addressed from an ergonomics perspective to evaluate individuals' cognitive capabilities:

- Work task activities occurring within cognitive spaces, e.g. information seeking, decision making, design, evaluation, exploratory searching, IR and learning tasks.
- Tasks can be influenced by the task allocation, task content, task coordination, task division, task labour, task performance, task repertoire, task responsibility and task situation. Tasks can be simple or complex.
- Activities as part of CIS include conveying information, allocation (e.g. of work tasks and roles), browsing, classification, communication (directly, serendipitously or spontaneously), coordination (e.g. of actions, interactions), dissemination, filtering (content), formulation (e.g. of queries), management (resources), monitoring, seeking (e.g. for information, new resources) and sense making. There is thus extensive scope for a cognitive ergonomic approach to support cognitive capabilities, for example, dividing workload or work tasks to decrease a person's cognitive load.
- Some activities can be approached as processes, e.g. browsing, consultation and decision making. Processes can include protocols such as for conversational practice, data collection, synchronisation, interviews and evaluation.
- Some activities can also be approached as functions, e.g. chat, communication and search functions.
- Search activities are very specific to CIS and can include exploratory searching, extended in-depth searching and searching for specific media. Search activities can be influenced by the search scenario, search requirements and search tools. Various types of queries are noted such as exploratory queries, self-motivated queries and externally motivated queries. Cognitive ergonomics can add value through identifying individuals' decision making, understanding and cognitive sense-making capabilities to construct CIS tools that can view both personal and shared information, thus reducing cognitive- and workload.
- Communication activities are very important within cognitive spaces. Communication can be user driven or system driven including the exchange of chat messages, after-meeting discussions, creating annotations, follow-up interviews, social feedback, problem-solving meetings, spontaneous and informal discussion, verbal and contextual cues. Various channels can be used, e.g. chat messaging, e-mail, conference calls and audio-video communication, or face-to-face interaction. Communication can be influenced by the nature of the communication, communication dynamics, communication preferences and communication roles.
- Monitoring activities (e.g. using chat logs, individual search logs and users' profiles) are necessary to monitor awareness levels, degree of collaboration, productivity, research progress, retrieval performance, retrieval effectiveness and individual search efficiency.
- Strategies and tactics are often required for the successful completion of activities and processes, e.g. analytical strategies, coordination strategies, search tactics, monitoring tactics and social tactics.

4.3.2.5 Support within cognitive spaces. Within CIS cognitive space support can apply to search interfaces, knowledge communities, intelligent filters, awareness support, cognitive aids, communication facilities, communication mediation, recommendation and social bookmarking services. It can include support by means of:

- information sources such as: document collections, knowledge repositories, human resources, informal resources, institutional resources, library resources and web resources;
- mediation such as mediated information seeking and mediated communication by means of a human intermediary or computer-mediation; and
- system support (asynchronous or synchronous) applied to the communication structure, design, interaction and sense making.

Awareness support is especially important in CIS cognitive spaces (Boff, 2006, p. 392; Shah and Marchionini, 2010, p. 1971). It includes awareness of information, cues, actions, design choices, task status, workspaces and intragroup situational awareness. According to Boff (2006, p. 392), human factors play a key part in effective human system integration through the support of situational awareness, decision making and collaboration.

4.3.2.6 System components in CIS cognitive spaces. A variety of tools (i.e. systems) is noted in the CIS literature such as communication tools, analytical tools, current awareness services, discussion boards, IR tools, search tools, sense-making enhancing tools, web search tools and horizontal computing surfaces. Technology and systems such as awareness systems, automated filtering systems, collaborative footprinting systems, collaborative filtering and recommendation systems, shared workspace technologies, co-browsing systems, multimedia searching systems and tools for information sharing are important. The tools often utilise awareness widgets, browsing applications, chat applications, communication mediation software and collaborative browsing applications. Cognitive fit in ergonomics integrate humans, technology and work to enable effective systems and decrease cognitive load. This can be applicable to any system or tool that require cognitive processing to perform daily work tasks by means of developing interfaces for personal and shared views to decrease an individual's cognitive load.

4.3.3 Content analysis from a social ergonomics point of view. The broad categories of issues noted here are very similar to the categories noted for a cognitive ergonomic perspective.

4.3.3.1 Social spaces. In CIS specific needs arise within social spaces, such as information needs regarding collaboration, information seeking, social interaction and sense making. Social spaces should support the fulfilment of such information needs with mutual benefits for collaborating participants. The following is of special importance:

- support for shared spaces including spaces for learning and socialisation; the use of interactive multimedia is noted;
- support for specific actions impacting on social spaces, e.g. collaboration, cooperation, explicit socialisation, and information seeking and sharing (as well as other issues noted for cognitive spaces);

- support for challenges faced within social spaces, e.g. regarding collaboration, social and affective issues arising, and dealing with conflict; and
- timing in social spaces, e.g. for asynchronous and synchronous actions such as collaborative task completion and work.

4.3.3.2 Environments in which social spaces manifests. The environment in which an individual or group's social space(s) manifest, can be considered in terms of:

- Types of tasks, e.g. collaborative information handling, information seeking and learning as well as group-based problem solving and social tasks (e.g. social information search activities). Tasks can be performed synchronously or asynchronously.
- Environmental boundaries, e.g. group (ingroup/outgroup), cultural, social and team boundaries.
- Meetings as short events in the environment, e.g. meetings with team or group members, or business colleagues, face-to-face or virtual meetings.
- Social conditions for CIS, e.g. communication means allowing for shared-gaze-only, shared-gaze-plus-voice, shared-voice-only and dealing with non-social and non-communicative behaviour.
- Situations occurring in social spaces, e.g. social, collaborative IR and CIS situations.

4.3.3.3 Human components within social spaces. Various participants are active in social spaces to form a team that offers different experiences and efforts and taking on different roles (task related and social). Different relationships develop, e.g. interrelations, interpersonal, online social relations, organisational, productive and trust based; such relationships need to be supported from a social ergonomics point of view. Tasks to fulfil in the CIS literature are very similar to what has been noted for cognitive ergonomics. This reflects a gap in the CIS literature; more attention needs to be paid to the social components of CIS from an ergonomics point of view. The following specifics were noted:

- People who are active in CIS social spaces are referred to as actors, collaborators, colleagues, searchers, collectivist societies, groups of experts, groups of seekers and work colleague(s). Communities of interest can also develop, e.g. knowledge and social Q&A communities. Different interactions are required between individuals to complete CIS activities successfully as a team, e.g. content sharing and distribution. These can be conducted face-to-face or virtually.
- Groups and teams in social spaces can be described as cohesive, formal/informal, intercultural, interdisciplinary or multifunctional. From a social ergonomics perspective the nature of a group or team need to be supported.
- The types of collaboration in social spaces can be labelled as user- or system driven, mediated, peer collaboration, etc. Collaboration can be active or passive through synchronous or asynchronous means to cultivate mutually beneficial and meaningful collaboration.

4.3.3.4 Activities and process within social spaces. Activities within social spaces can be conducted in pairs, or in groups or teams through synchronous or asynchronous means to support goals such as common or shared goals or social goals. Social

activities and actions can occur serendipitously or spontaneously. The following are important for CIS and can be addressed from a social ergonomics perspective to evaluate individuals' social and collaboration capabilities (again there is much overlap with activities noted from a cognitive ergonomic perspective):

- Key CIS activities and actions from a social perspective include social activities, connecting collaborators, coupling, cross-cultural coordination, online social support and personal connecting. The emphasis is on interaction, the team or other collaborators and the collective nature of seeking and sharing. The later can include group brainstorming, learning, sense making and problem solving. Social activities manifesting in social spaces include social answering, augmentation, networking, question and answering, social recommendations, and socialising. From a social ergonomics perspective the emphasis will be on improving the interactions and strengthening the relationships between individuals to cultivate a social awareness for CIS activities.
- Factors impacting on CIS and especially collaboration from a social point of view include collaboration genres, levels, mediation, surroundings and requirements (this also applies to cognitive spaces). Regarding socialising the social actor as person, social and contextual cues, social and cultural conflicts, social capital, social cognition, social connections, social dynamics, social intelligence, and social norms, rules, values and skills are especially important, as well as sharing judgements, ideas and expertise.
- Some activities can be approached as processes, e.g. collaboration, collaborative learning, collaborative sense making, group communication and collaborative filtering. Again there is a very close relation with issues noted for cognitive spaces. Shared practices, interaction and social protocols are important in such activities if seen from a social ergonomics perspective.
- Some activities can also be approached as functions, e.g. collaborative, group or social functions.
- Strategies play an important role, e.g. collaboration strategies, strategies for jointly constructing search strategies and pairing strategies.

From a social perspective activities and processes in social spaces are influenced by diversity in collaboration, relational, social, and cultural factors, connections, dynamics, group size, synergy and network diversity.

4.3.3.5 Support within social spaces. Within CIS social spaces support for real-time sharing, social answering, collaboration, group decision making and group-related activities are needed. It can include support by means of:

- information sources within social spaces, e.g. communal resources, human resources, group repositories, social information media and a community's collective knowledge; and
- system support (asynchronously or synchronously) applying to the collaboration and interactive structure, design, and sense making of socialising platforms.

Awareness in social spaces includes awareness of other's activity, of one another's actions and equal partnership. Types of awareness include casual, intergroup situational, group, general, group peripheral, group progress and structured social awareness (many of these also apply to a cognitive perspective).

4.3.3.6 System components in CIS social spaces. A variety of collaboration tools are noted in the CIS literature such as collaborative multimedia search tools, collaborative spreadsheets, support tools for collaborative sense making, data exchange tools, interactive walls, interactive playback tools, social navigation and social media tools, and group discussion boards. Such tools can be utilised in social systems and platforms such as blogs, collaborative search systems, interactive video search systems, collaborative portals, information sharing social network, group wiki's, question-answer sites and collaborative bookmarking web sites.

5. Value for CIS pillars if taking an holistic ergonomic approach

Table III presents an example of how a holistic ergonomics approach can be applied to add value and insight when addressing issues experienced in CIS work environments and CIS systems including the main pillars (control, communication and awareness). This is by utilising engineering ergonomics to construct the most desirable physical fit by way of adapting equipment, workplace and tasks to human capabilities and limits; to promote communication through utilising cognitive ergonomics to construct the most desirable cognitive fit by way of integrating humans (i.e. co-located and remote), technology (i.e. synchronously and asynchronously) and systems that can support task completion with acknowledgement of the need to decrease mental and workload capacity; and lastly to promote awareness through utilising social ergonomics to construct the most desirable neutral fit by way of strengthening the physical and cognitive capabilities of humans to interact, collaborate and perform teamwork on interactive platforms. Although not demonstrated here in detail, these aspects can all be related to the categories (as issues) noted in the preceding Sections 4.3.1-4.3.3.

6. Conclusion

The application of holistic ergonomics to CIS environments and systems can offer benefits for individuals and groups in different workspaces, particularly in relation to supporting the three CIS pillars. As Shah (2010, p. 26) explicated, CIS systems need to provide support for control, communication and awareness, due to its intricate design, integrated systems and diversity of interactions in CIS environments. This paper explored the value of utilising a holistic ergonomics approach, covering engineering, cognitive and social perspectives, to eliminate issues arising for the three CIS pillars (i.e. control, communications and awareness) by a content analysis of a selection from the CIS literature. Findings suggest that a holistic ergonomics approach can add value when addressing issues regarding CIS environments and the CIS pillars through considering all dimensions of the work environment (e.g. organisation, technology, business processes and culture) to support people's physical (comfort and functionality design), cognitive (mental and workload capacity) and social (formal and informal interaction) capabilities to operate optimally.

A fairly extensive amount of holistic ergonomic terminology was noted in the CIS literature. This was categorised according to engineering, cognitive and social ergonomic perspectives. The categorisation showed the value of utilising ergonomic terminology to eliminate terms reflecting issues related to the three CIS pillars. The three CIS pillars, as well as the three ergonomic perspectives, are not mutually exclusive, overlap occurs and therefore these need to be considered in conjunction with each other to maximise support for the performance of CIS activities.

Although the paper points out some potential for aligning holistic ergonomics with CIS, this is only an exploratory study and further work needs to be done.

Control pillar Aim: to provide control support for engagement, communication and awareness through establishing a shared CIS space, e.g.: Workspace-focused: support roles (people) and rules (processes) for CIS activities Mechanisms supporting shared understanding: offer support for control within CIS systems for cognitive and social purposes Mechanisms, roles, rules: supporting work across multiple domains and resources	*Engineering ergonomics* Aim: to provide the perfect fit between people and their physical space (including situation and context) e.g.: Focus on workspace design: contribute to the construction of work environments to fit human components according to their spatial position Contributing to the construction of an environment which takes into consideration impacting factors such as different contexts, boundaries, conditions and situations to connect remote and co-located individuals collaborating in CIS Establishing a physical or virtual space that provides support, e.g. by means of information through libraries, repositories and online support groups
Communication pillar Aim: to provide interactive platforms to collaborate, engage and connect remote and co-located people through intentional or spontaneous communication, e.g.: Systems-focused: providing communication mechanisms for CIS activities Providing for shared spaces: to complete CIS activities Providing communication spaces: to exchange and share information, support, etc. Providing interactive platforms: to connect remote and co-located people (connection support) Providing communication channels, communication platforms and social networks: synchronous (real-time) and asynchronous (non-real-time) message passing for CIS activities	*Cognitive ergonomics* Aim: optimisation of the fit between technology, task design and people's mental capabilities, e.g.: System-focused: providing system components such as tools, technology and software applications Establishing an environment that takes into consideration different types of work, boundaries, sessions and timing Focusing on the human components when establishing systems such as roles of people, affective factors, expertise, experiences and work efforts Establishing cognitive spaces providing support for: information resources, mediation and most importantly implementing awareness support within systems Identifies a variety of cognitive activities, which can be planned and focused or unfocused, active or passive, and explicit or implicit, such as searching, monitoring and communication important for the completion of CIS tasks and decreasing cognitive overload
Awareness pillar Aim: to provide the means to connect remote and co-located individuals (also referred to as connecting) through providing socialising tools and connection support to promote interaction User- and system-focused: to provide for shared social experiences, learning and reaching goals for CIS activities	*Social ergonomics* Aim: to improve the fit between social and collaborative aspects of work, learning, mentoring, interaction and participation User- and system-focused: to provide system components that promote collaboration through social networking tools, technology and software applications

(*continued*)

Table III.
Illustration of how holistic ergonomics can assist the three CIS pillars

Shared collaboration space: to connect remote and co-located team members Collaboration mechanisms: to establish support for formal and informal communication and interactions Social and collaboration aspects: to promote collaboration and social engagement through socialising support	Establishing an environment that takes into consideration a variety of social spaces, types of work and social conditions for CIS activities, e.g. communication means allowing for shared-gaze-only, shared-gaze-plus-voice and shared-voice-only Identifying a variety of social activities, which can occur serendipitously or spontaneously, to evaluate individuals' social and collaboration capabilities. Can link the human component with the design of collaboration mechanisms to improve CIS awareness Establishing a social space that provides support to promote socialisation and engagement, e.g. social media tools

Table III.

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About the authors

Anika Meyer is an Assistant Lecturer at the Department of Information Science, University of Pretoria. She completed her Honours Degree with distinction in the Department of Information Science, University of Pretoria in 2014. During her undergraduate studies she has also been awarded several prizes. She is currently enroled for the Masters in Information Technology (Carnegie Programme) offered by the Department of Information Science (University of Pretoria).

Dr Ina Fourie is a Full Professor at the Department of Information Science, University of Pretoria. Her main research focus is on information behaviour in healthcare contexts (cancer, palliative care, affect and emotion), information literacy and current awareness services. Dr Ina Fourie is the corresponding author and can be contacted at: ina.fourie@up.ac.za