

Human reliability and ergonomics: a literature review from 1963 to 2011

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Abstract. This study reviews the academic literature on human reliability from the ergonomics perspective. The methodological approach used in this analysis combines several techniques, including bibliometric, content analysis, and social network analysis. The initial sample consisted of 304 articles, which totaled 1,872 citations, published in 94 journals, from the 47-year period between 1963 and 2011. From this initial sample, only 50 articles (16%), totaling 471 citations are classified as ergonomics area, published in 14 journals, which involve 108 authors, with 471 citations. This sample was expanded via the seminal studies of ergonomics. These articles were coded and tabulated according to their year of publication, the number of publications per journal, major areas of interest, and the relationship between the articles and the research methods discussed. Networks were prepared by keywords, co-citations, and cross-citations

Keywords: human reliability, bibliometric, content analysis, social networks.

1. Introduction

The human reliability research area tries to understand the interaction among human and high-risk systems, during the whole life cycle from the system design to operation. In consequence, it is a multidisciplinary area, mixing engineering, ergonomics and psychology among others distinctive approaches.

The literature emphasizes on the analysis of human error and its causes and tries to design mechanisms to avoid them. According to this view the causes of the human error related primarily to the design of the interface and co-ordination and communication problems previously unaddressed by the design process as suggested by Kirwan [1]. On the other hand, some authors criticize this perspective the highlights the proactive approach of the human in building system reliability [2-5].

This paper aims to provide a theoretical and conceptual framework that relates human reliability to ergonomics. An in-depth search of scientific data basis carries out followed by bibliometric and social network analysis [6]. An overview of the literature on

human reliability and its evolution over time was provided. It describes the main trends, gaps and research themes therein, identifying the works and authors of major influence.

This paper is organized as follows. First, will be present the research methods and detail the criteria that are used to select the sample and perform the analysis. Then, will be presented the results of the survey, followed by a discussion and conclusions.

2. Research Methods

A literature analysis can be conducted using different approaches such as bibliometric study [6], meta-analysis [7], and content analysis [8].

The interest in using bibliometric techniques has increased because of the availability of large scientific databases. It involves a series of techniques that are used to quantify the process of written communication and identify patterns [6, 9].

The methodological used approach mixes bibliometric, content analysis and social network techniques.

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2.1. Sample and Procedure

It has been decided to select a scientific database in order to create the initial sample. The ISI Web of Science database was selected because of the indexed and ranked journals with an impact factor calculated by the Journal Citation Reports (JCR), it could be reached through the search processes in despite of the fact that it belongs to other databases, such as Scopus, ProQuest, and Wiley. Furthermore, this database provides a set of meta-data, which are essential for the bibliometric analysis, such as abstracts, cited references, times cited, authors, institutions, countries, and the journal impact factor, which are not easily available in other databases.

The search was carried out without specifying a topic area, a specific journal, or temporal restrictions. The terms used in the search included "human reliability". It has been examined only articles in the initial sample because they go through the peer review process.

The search resulted in 304 articles, being the first dated in 1963. This general list of articles has been applied as background for the main analysis focusing on ergonomics perspective on the study area in human reliability. Thus, a new selection was applied by subject and ergonomics areas what resulted in 50 articles (16% of total) with 471 citations (25%). These articles covered the period between 1964 (first occurrence) and 2010 and encompass 108 authors from 21 countries and 14 journals.

Using the snowball method (Fink, 1995a; Fink, 1995b), the initial sample has been expanded with the references cited therein, adding 1835 references to the initial sample of 54 articles. At this moment, other document types such as books and proceedings paper have been included. Figure 1 illustrates the flow of the research activities.

A similar approach was conducted in the Scielo database, in which are some of the major national periodicals. Search with the keywords "human reliability" in both English and Portuguese has resulted in only 2 articles by [10, 11], both published in the journal production. The term "reliability" found 111 articles.

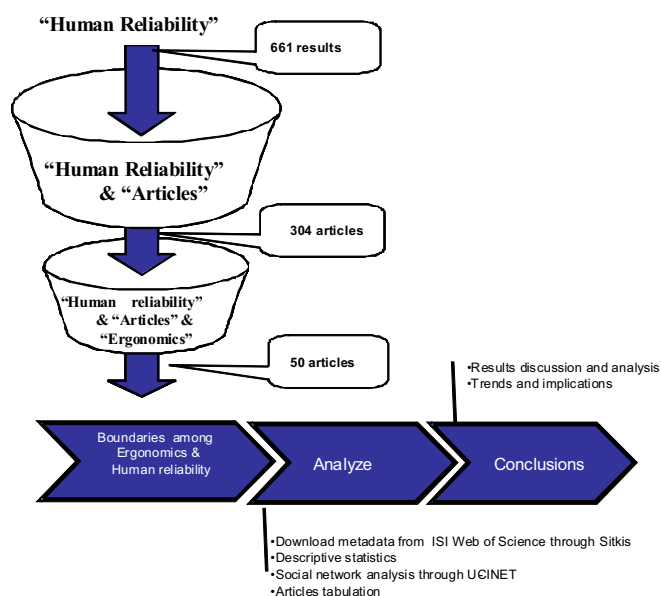


Figure 1 – Methodological research approach

2.2. Bibliometric analysis

The bibliometric analysis has been conducted using two software packages: Sitkis [12] and Ucinet [13]. The data were downloaded using the Sitkis, while the network analysis and index calculation were done using the Ucinet.

Based on the premise that authors cite the articles that most influence their research, and the journals with the highest impact factors are the most influential in a specific research field, it has been proposed an impact index [14-16]. Based on the resulting index, a rank of the most influential articles has been established, and the main authors identified.

Several social networks analyses were performed such as co-citation network, cross citation network, article to reference network and keyword network [17]. As a criterion for the development of the networks, it was included works that were cited in the range of 1% to 10% of the sample, as suggested in the Sitkis' user guide [12].

3. Research Results

3.1. Publication patterns by journal and year

The first work available in ISI Web of Science was published in the American Journal of Psychiatry in

1963 and discussed the implications of human reliability in the selection and screening procedures in the U.S. Navy [18]. The pioneering work focused on ergonomics was published in Human Factors journal the following year, by Meister [19], and is the 5th most cited area, whose goal was to discuss methods for predicting human reliability in man-machine systems. It can be seen in Figure 2 that for nearly two decades the publication was very shy no more than three articles per year, with several periods without any publication. The second paper focusing on ergonomics only occurs after almost two decades with the paper by Adams [20]. Only from the second half of the 1980s the volume of publications has gained a larger scale. The years of publication were higher in 2004 and 2006.

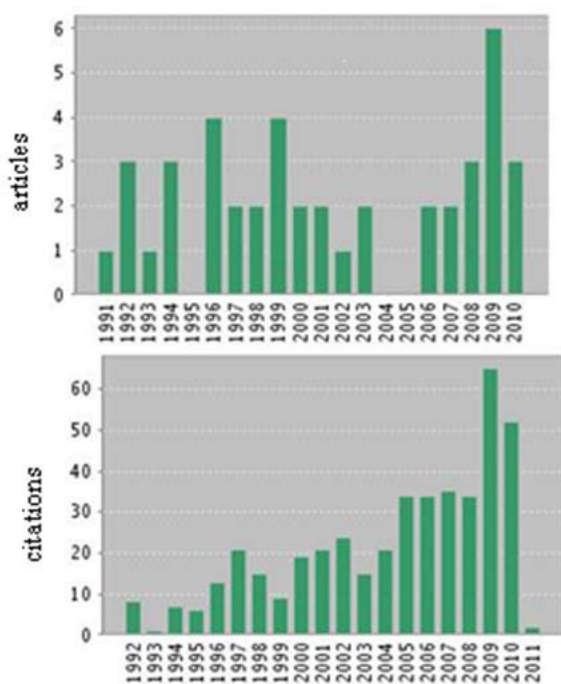


Figure 2 – Yearly publication and citation

The journals of ergonomics area that had at least two publications on the topic of human reliability is listed in Table 1. Remarkably, by the number of articles published in Applied Ergonomics, 16 items (~32% of the area of ergonomics) and Ergonomics, with 11 items (~21%). However, considering the number of citations of relevance of the Applied Ergonomics for the discussion of human reliability is amplified as 6 of the 10 most cited articles were published in the magazine, totaling 220 (73% of citations G10) citations refer the articles in this journal.

Table 1
Main journals

Journal	# articles
Applied Ergonomics	16
Ergonomics	11
International Journal of Industrial Ergonomics	5
Human Factors	3
Human Factors and Ergonomics In Manufacturing	2
Interacting with Computers	2
International Journal of Human-Computer Studies	2
International Journal of Occupational Safety and Ergonomics	2
Travail Humain	2

However, overall (304 articles), there is the journal Reliability Engineering & System Safety, with 95 articles (31% of total), whose scope emphasizes the reliability of the broad scope. However, it is noteworthy that in the general list of the 10 most cited, 4 are of Applied Ergonomics, including the most cited article Joice et al. (1998), against 3 of Reliability Engineering & System Safety.

3.2. Main research themes

Trying to trace a panorama of topics and areas of interface we chose to analyze the network of keywords and classification of articles on areas and sub-areas of knowledge according to ISI. The most common pattern of keywords and citation of articles in the network is represented in Figure 4, developed using the software UCINET [13].

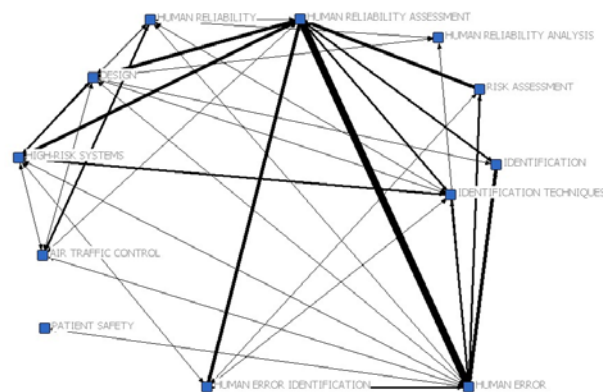


Figure 4 - Keyword Network

Considering the network of most cited and interrelated keywords, one can see that in fact the instruments of analysis, identification and diagnostic reli-

bility (human reliability analysis, assessment) and human error (human error identification) dominate the discussion among the 50 studied articles. In terms of application area there is the emphasis on air traffic control, complex systems at high risk, and patient safety.

As a sort of thematic stands out for these 304 articles, the area of industrial engineering (engineering, industrial), with 157 articles, and the area of operations and administration (Operations Research & Management Science), with 122 items, area of ergonomics holds the third position within 50 articles. Note, however, that an article may be related to more than one subject area.

Based on the grouping and sub-areas of knowledge presented in Appendix 1, it is noteworthy that the 50 articles on the topic of human reliability that are classified in the field of ergonomics have a strong interface with the engineering and Psychology & Behavioral Sciences. Figure 5 summarizes the relationship of articles by area.

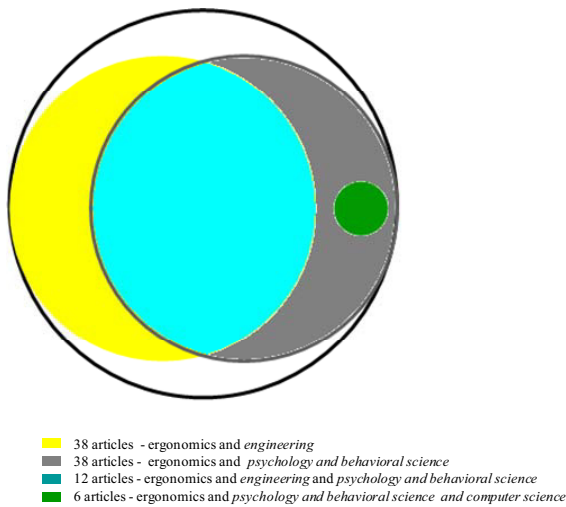


Figure 5 - Intersection of areas in addressing the issue of human reliability

It can be seen in Figure 5, that within the 50 articles, 38 are classified as engineering and 38 as psychology & behavior between these two groups there is an intersection of 14 articles. A smaller group of six articles dealing with issues related to human reliability field of computers, especially software, of which 50% is interfaced with the area of psychology & behavior.

The detailing of the 50 items, with the number of citations, and sub-areas of knowledge is found in Appendix 2.

3.3. Main articles and authors

It has been verified in 50 works of the border between HR and ergonomics (see Appendix 2), there is a predominance of Kirwan, University of Birmingham, which has four articles [21-24] among its 10 articles in the list of the most cited, and these two articles are also in the general classification of the ten most cited among the 304. Table 2 details the authors who contributed with more than one article in view of ergonomics, also highlighting the number of citations.

Table 2

List of authors with more than one item in the areas of Human Reliability & Ergonomics

Author	# papers	Citations
Kirwan	10	154
Stanton	3	40
Wilson	3	23
Baber	2	39
Shorrock	2	37
Kennedy	2	16
Karwowski	3	13

The most cited authors Joice, Hanna and Cuschieri [25] have other publications within the 304 articles on human reliability, especially Cuschieri and Hanna are in 2nd and 3rd places with the highest number of articles, with 8 and 7 articles, respectively, after Kirwan with 16 articles published. However, the article by Joice, Hanna and Cuschieri [25] is the only one of these authors classified in the field of ergonomics. No entanto, o artigo é o único desses autores classificados na área de ergonomia.

Out of the 50 articles, only one is by Brazilian authors: Carvalho, Vidal and De Carvalho [26], which highlights the communication between operators as a relevant factor in the study of reliability in the context of study of the control rooms at a nuclear plant

One can see that among the 10 most cited articles, most (6 items) is classified in ISI Web of Knowledge as belonging to both the ergonomics and engineering area (sub-area engineering, industrial), as Appendix 1. Since the articles [19,20] border the ergonomics of

the psychology and behavioral sciences. Only the article by Baber and Stanton [27] ranks in the areas of ergonomics, engineering and psychology, seeking a more plural analysis

3.4. The relationships among the studies surveyed

It can be seen in Figure 6 the centrality of work to Kirwan [21] that is a strong reference to the work that followed. They also observed that the work of Joice, Hanna and Cuschieri [25] and Catchpole et al [28] in surgery are a group isolated from others. The pattern of citation of articles was done by considering those with a citation as the above five cited articles should be cited at least three times. The line thickness indicates the frequency with which connected the two articles were co-cited.

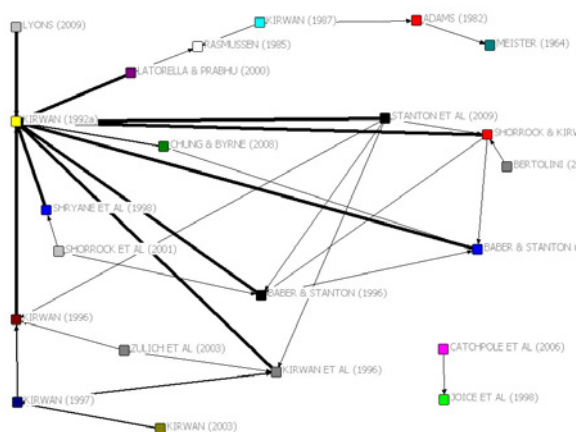


Figure 6 – Co-citation network

4. Discussion and Conclusions

Without venturing to describe a theoretical final panel in this field, if it really were possible, this work has outlined an overview of research in human reliability in the perspective of ergonomics, a complex issue, which constitutes a kaleidoscope, in which different approaches coexist.

The mapping process identified 304 publications of articles on human reliability in the scientific basis ISI Web of Knowledge. The predominant area of human reliability discussions on this basis is the industrial engineering, then the area of operations. In this universe, only 50 items are classified in the field

of ergonomics (16%), with 471 citations (25%). To this literature were added the texts of ergonomics.

It has been observed the influence of Kirwan's researches [1, 21-24], once his researches represent 20% of the total articles on human reliability classified on ergonomics area and 33% of the citations, using the ISI Web of Science as a reference. The influence of Kirwan, whose contribution is strongly related to human reliability analysis methods, supported by questionnaires and simulation software. It has been noted that the major part the literature focus on nominal scenarios, quantification techniques and reliability assessments, and therefore, strongly aligned industrial engineering perspective on human reliability, exemplified by Kirwan approach. Thus, in ergonomics point of view these researches focus on the task in the prescribed work [29, 30].

A minor stream of human reliability researches were focused on real work and in their social, psychological and cognitive aspects. These works seek a change in both; mentality and the concept of human reliability, favoring a model of understanding and mastery of insurance situations, considering the error as an ancillary variable [2, 31]. Corroborates to this approach some articles, stressing the role of the operator as an agent of reliability [3, 4] and the recovery of deformation and minimizing the consequences [5], not vice versa, as the industrial engineering literature, which highlights the human error as the main variable, i.e., error identification and construction of barriers to prevent them

By analyzing the evolution of the number of studies over time, it was observed that the consolidation occurs on the last two decades, with peaks in recent years 2004, 2006 and 2008. The most recent articles discuss human reliability in the computer science field, which are strong influenced by psychology and behavioral sciences areas [32-34]. Another trend is the connection between human reliability and resilience engineering [35, 36].

In Brazil it has been observed that the human reliability is still in an embryonic step once only two article in Brazilian journal were identified [10,11], both published in the Production journal. It has also been identified only one article of Brazilian researchers among the 50 articles in ISI Web of Knowledge sample, ISI Web of Science sample [26].

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Appendix 2:
Top ten articles

Title	Year	Authors	Journal	Subject areas	Citations	Ergonomics Rank	Overall Rank
Errors enacted during endoscopic surgery - a human reliability analysis	1998	Joice, Hanna, and Cuschieri	Applied Ergonomics	Ergonomics and engineering	77	1°	1°
Development and application of a human error identification tool for air traffic control	2002	Shorrock and Kirwan	Applied Ergonomics	Ergonomics	34	2°	5°
Human error identification in human reliability assessment.2. detailed comparison of techniques	1992	Kirwan	Applied Ergonomics	Ergonomics and engineering	34	3°	6°
Human error identification in human reliability assessment.1. overview of approaches	1992	Kirwan	Applied Ergonomics	Ergonomics and engineering	34	4°	7°
Methods of predicting human reliability in man-machine systems	1964	Meister	Human Factors	Ergonomics, <i>psychology and behavioral science</i>	22	5°	14°
The validation of three human reliability quantification techniques THERP, HEART and JHEDI.1. technique descriptions and validation issues	1996	Kirwan	Applied Ergonomics	Ergonomics and engineering	21	6°	15°
Human error identification techniques applied to public technology: predictions compared with observed use	1996	Baber and Stanton	Applied Ergonomics	Ergonomics and engineering	20	7°	16°
Task-analysis for error identification – a methodology for designing error-tolerant consumer products	1994	Baber and Stanton	Ergonomics	Ergonomics, <i>psychology and engineering</i>	19	8°	19°
Issues in human reliability	1982	Adams	Human Factors	Ergonomics, <i>psychology and behavioral science</i>	19	9°	20°
Identification of systems failures in successful paediatric cardiac surgery. 567-588..	2006.	Catchpole, Giddings, De Leval, Peek, Godden, Utley, Gallivan, Hirst, Dale.	Ergonomics	Ergonomics, <i>psychology and engineering</i>	15	10°	21°