A SHORT HISTORY OF HCI RESEARCH AND TRENDS PUBLISHED IN THE JOURNAL HUMAN FACTORS FROM 1984 TO 2004

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This study was undertaken to explore the history of the use of the term human-computer-interaction (HCI) over two decades of the journal Human Factors. Results show that while some work may have been accomplished in the first ten years, the work wasn't identified as HCI, except at a rate of approximately two articles per year. After 1995 the incidence in the use of HCI as a topical reference increased, and from 2001 - 2004 there were significantly more articles on this topic. The articles were written by scientists around the world, employed in all areas of the field. This research attempts to show how HCI has evolved over these 20 years, to identify any trends in the research, and to provide suggestions for future research, including search methodologies. Specific information will be provided to use in planning future work, such as procedures, descriptions of apparatus, dependent variables and other methodological information

While human computer interaction (HCI) is a separately identified field of study, it justifiably remains a multidisciplinary endeavor. Hewett, Baecker, Card, Carey, Gasen, Mantei, Perlman, Strong, and Verplank (1996) noted that HCI arose from "intertwined roots in computer science, cognitive computer graphics, operating systems, human factors, ergonomics, industrial engineering, cognitive psychology, and the systems part of computer science", and to date, there is no single agreed upon defininition.

Human computer interaction as a formally identified field of study has a relatively short history in comparison to other areas within human factors. Pew (2003) noted that it was in the late 1970's and early 1980's that "specialists began to speak of a professional field of usability and HCI". He also noted that the first formal publication devoted solely to HCI was a landmark bibliography that was published by Ramsey and Attwood (1979) that abstracted existing publications. The first textbook in HCI was written by Shneiderman (1980).

Pew identified significant areas of research in the field of HCI over its short history, such as the effort from 1978 to 1988, which saw a paradigm shift from a system governed by "rigid format and coding contraints to the fundamental features of the graphical user interface" (GUI). Topic areas included interative system development, interface building, user-centered design, usability testing for computer applications and a new emphasis on naturalistic and ethnographic methods of understanding users. The period of 1989-1999 was identified as the era of the Internet, when major topic areas included web usability, cost-justifying usability, and computer-supported cooperative work, noting also

that it was during the years 1992-1994 that a flurry of new textbooks in HCI were published.

Finally, Pew identified the period of 1999 and beyond as the era of ubiquitous computing, with topic areas concerning the challenge of designing for user control and for context-sensitive transparency of systems in the anywhere, anytime model of computing, as well as challenges enherent in the design and evaluation of such systems.

Hewett, et al. (1996) have developed a taxonomy for classifying the current content of research results in the field of HCI. The taxonomy "derive(s) from a consideration of five interrelated aspects of human-computer interaction: (N) the nature of human-computer interaction, (U) the use and context of computers, (H) human characteristics, (C) computer system and interface architecture, and (D) the development process" and includes division of these five aspects into 16 subgroups. They note that the purpose of this taxonomy is to define the scope of HCI and specify its connections with other fields. Pew's observations above, and the taxonomy by Hewett, et al., are useful in classifying the current state of HCI research.

The goal of the present research was to systematically review and evaluate the content of the *Human Factors* journal in terms of HCI related topics and trends published from 1984 to 2004. The journal *Human Factors*, as the flagship journal of the Human Factors and Ergonomics Society (HFES), can be expected to contain articles on the leading edge of HCI research. We have identified HCI articles by lead author affiliation, countries of origin for lead authors, and count of articles by year, in a similar fashion as Zavod and Hitt (2000) in their study of all articles in the *Human Factors*

journal. In addition, we plan to report on historical trends in the literature as suggested by Pew, and to code the articles by topic areas as suggested by Hewett, et al.

METHODOLOGY

This project was initiated with a search of the literature in the *Human Factors* journal for the period 1984 through 2004 using the Human Factors and Ergonomics Society website. The string "human computer interaction" was used, which resulted in 6 articles, followed by a search using "human and computer and interaction" which returned the same 6 articles. With the HFES website limited to searches of author's name or title of the article only, the next search was conducted using the PsychInfo database, which was available to the authors through the University of Central Florida Library website.

The string "human computer interaction" was used to search *Human Factors* within the desired 20-year window. The "all text" index search field was selected and 40 articles were returned. (Note: "all text" searches the database for the specific string of words in all searchable index fields.) Further search of the database revealed that the index fields that returned the articles were "digital object identifier", "abstract", "title", "subject", and "keyword". The search was then modified to a Boolean method with the phrase "human and computer and interaction" entered in the "all text" index field. This resulted in 55 articles. The list of 40 articles was compared to the list of 55 and all 40 were included, with the additional 15 identified and retained.

Curious about what appeared to be a low number of articles, another database that lists articles from *Human Factors* was chosen for comparison: the Expanded Academic ASAP database. The same two forms of the phrase "human computer interaction" were used to search index fields "abstract", "keyword", "subject", and "title" as a way to force the equivalent of the "all text" search that was conducted in PsychInfo, but not available in Expanded Academic ASAP. The two search terms returned the same list of 49 articles for the "keyword" index search. In addition, searches by "abstract", "subject", and "title" included 9, 43, and 6 articles, respectively. The latter searches were all included in the "keyword" search of 49 articles. Therefore, the list of 49 articles was retained for further analysis.

A comparison was made between the 49 articles from Expanded Academic ASAP and the 55 articles returned from PsychInfo and 14 (16%) articles were found in both databases. The PsychInfo database contained 42 (48%) articles not found in Expanded Academic ASAP, while Expanded Academic ASAP contained 32 (37%) articles not found in PsychInfo; therefore, 88 articles were identified for inclusion in this study.

RESULTS

Preliminary statistics were determined regarding the affiliation of the lead author (i.e. university, industry, or government), the originating country of the lead author, and a count of articles by year. Subsequent analysis included an examination of other subject area classifications for the articles, coding and classification of the articles' content focus areas, counts of the types of dependent variables used, and counts of the apparatus used in the studies. In addition, prior editors of the journal *Human Factors* as well as past presidents of HFES were contacted regarding their observations of the emergence of the term HCI in the field, as well as any directed efforts they may have initiated to expand the articles on HCI in the journal.

Lead Author statistics

The articles were written by scientists around the world, employed in all areas of the field. There were 62 lead authors (70%) affiliated with a university, 17 (19%) with industry, and 9 (10%) were with government agencies. There were 14 countries represented by the lead authors with the United States the originating country for 60 (68%) of the authors. The next most frequent country of origination was the Netherlands with 6 (7%) followed by Canada and the United Kingdom as the originating country for 4 authors (5%), Israel with 3 authors (3%) and Japan and Australia each with 2 authors (2%). The remaining seven countries, Austria, Korea, Finland, Hong Cong, Taiwan, Germany, and Lebanon, were represented by one article (1%) each.

Articles by year

In order to identify trends by year, an initial count of articles was made for each year. In the first decade, (1984-1993) there were 16 articles published, or 18% of the total HCI articles identified. All years had at least one article published, except for 1985 which had no articles published under the term human-computer-interaction. In 1993, there were five articles published, however, in 1994 there were none.

Between 1995 and 2000, there was at least one article published each year concerning HCI. In 1998, there were 10 articles published, twice as many as in any year previously, but then no articles published as HCI in 1999. Over 50% of the articles identified as HCI have been published since 2001, with between 10 and 13 articles published each year.

Identification as a subject in databases

The first occurrence of the term "human computer interaction" as a key concept search term occurred in the PsychInfo database in 1993, and the first occurrence of the term as a searchable subject in PsychInfo was in 1996. Prior to that, the subject areas under which the research was classified included human machine systems and computers. In Expanded Academic ASAP, the first occurrence of the use of human computer interaction as a searchable subject area was in 1992, which was also the first year the journal *Human Factors* was included in the database.

Given the similar period covered by the two databases, we wanted to better understand why only 16% of the articles overlapped between them. We investigated the differences, and summarized the information below.

Several search fields can be used when searching for topics in the databases. The search field "all text" (PsychINFO) or "keyword" (ASAP) are referred to as uncontrolled search terms because the search that results looks within the specified search field for any occurrences of any of the words that are typed into the search window. While the PsychINFO and the Expanded Academic ASAP databases are structured differently, these two search fields were determined to be the most closely matched choices. In PsychINFO, an "all text" search looks for the search term in all of its searchable fields. However, full articles of *Human Factors* are not available. In ASAP, the "keyword" search looks for the search terms in the title, citation, abstract, and the entire article when full-text is available (as it is for *Human Factors*) (Thompson/Gale, 2005).

In contrast, when a researcher chooses to search by subject, the search becomes a controlled search because indexers for each database have classified and coded the content of the articles according to their own subject classification system. For PsychINFO that classification system is Thesaurus of Psychological Index Terms (APA, 2005) and it is discussed further on the database information website (PsychINFO, 2005). For Expanded Academic ASAP, the subject field is based on the Library of Congress Subject Headings (Thompson/Gale, 2005).

In both databases, a search by subject returned fewer article (32 articles in PsychINFO and 43 in ASAP) than a broader "all text" and "keyword" search (55 for PsychINFO and 49 for ASAP). We reasoned that for a young field such as HCI the broader term would return a more inclusive list of articles in the field, and in reviewing the articles; found that the additional articles not included in subject searches were relevant to HCI.

We also listed and examined the other subject search terms that occurred for the articles in each of the databases. Our purpose in this was two-fold. We wanted to look for other terms that may have identified the field prior to the formal classification of "human computer interaction" as a separate subject field. In addition, indexers for each database code subjects by primary and secondary focus area. We were looking for any trends in secondary focus area.

We found numerous other subject area classification terms in both databases, but the most frequent occurred only three or four times. The most frequent other subject terms in PsychINFO were "human systems design", "human machine systems", "computers", "visual displays", "computer applications", "attention", and "human factors engineering". In Expanded Academic ASAP the most frequently used additional subject terms were "Ergonomics Research", "Research", and "Psychological Aspects".

Classification of content focus

The taxonomy introduced by Hewett, et al. (1996) was used to classify the focus areas of the 88 articles from the two databases. The five broad content areas of (N) the nature of human-computer interaction, (U) the use and context of computers, (H) human characteristics, (C) computer system and interface architecture, and (D) the development process and their subareas were examined, and each article classified as to primary and a secondary focus. Based on the classification, the primary focus of articles was in use and context (28%), human characteristics (35%), and computer systems and interface architecture (25%). The nature of HCI, and the development process, were classified as the primary focus in 5% and 7% of articles, respectively. A similar pattern was seen in classifying the secondary focus. Use and context, human characteristics, and computer systems, were applicable to the majority of the articles with 26%, 36%, and 25% in each classification respectively. The nature of HCI, and the development process accounted for 1% and 11% of articles, respectively.

Dependent variables used

Of the 88 articles, 15 were theoretical, and or literature reviews. As might be expected the dependent variables used among the 73 experimental articles were measures of human performance. The 159 unique variables were grouped into 10 categories with the largest categories being time measures and 'positioning', with 31 and 30 different variables respectively. Time measures included response time, but also time off target

and the latency of the participant's request for information. Positioning included such measures as the position of a steering wheel measured using standard deviations, or the position of the participant's own aircraft on an approach path while flying a simulator. User's actions (16) were captured in the participants braking behavior in a driving simulator, or a choice made in whether or not to use an autopilot in a flight simulator. Physiological factors were captured using 25 different types of measures, from EEG to ECG to blood oxygen saturation levels. Eighteen different scales were used; from the well known, such as the NASA TLX and SWAT, to the participants' rating of their own confidence level as they performed a task. The 10 object characteristics included signal frequency and the length of a file, while counting variables, also 10 separate variables, showed up as the number of trials, the number of errors and the number of correct input. Accuracy measures only appeared in 10 different forms, and included accuracy of facts as had been presented in the experiment, diagnostic accuracy and grammatical accuracy. The two least frequently used variable categories are percentages (5) and rates (2). These included hit rate and false alarm rate percentages, and response rate and error rate

Experimental apparati

Experimental apparati were sorted into 50 different categories with the most frequently listed pieces of equipment being a personal computer (42) and the next most frequent the monitor (40) used with the computer. Input devices such as keyboards (15), mice (16), and joysticks (9), help round out the most frequently used and related to personal computer use.

Flight simulators were used in 16 separate studies, and variations of computer software were used in 8 studies. Five head mounted displays with head trackers were used in the 4 virtual and 1 augmented reality environments. Several items that were used only once, such as active noise reduction ear cups, a visual display terminal near point tester, and an infusion pump. Other items that were used infrequently included physiological measurement devices such as EEG machines and galvanic skin response measurement devices. Methods of recording events were used such as video cameras as well as developing technologies such as a dataglove and a space mouse.

Encouragement from leadership

During this twenty-year span of journal publication, there were 20 different presidents of HFES and 5 editors of Human Factors. Presidents of the

society challenge the membership to pursue new areas where the infusion of human factors principles would be beneficial, and often those areas are those in which the presidents themselves are involved. This was true of Thomas B. Sheridan's address to the membership in 1991, when he pointed out that the increased use of automation and other technology increased the demand for three human factors activities. These included the inference of people's mental models, measurement of costs and benefits, and monitoring what people really do throughout their day, not what they say they do (Sheridan, 1991).

To capture other such observations, challenges or special interests, a short survey was emailed to each of the past presidents and editors. With a 30% response rate, we found that the use of the term human computer interaction was common and generally increasing in use during this 20-year period. Other terms that had been replaced by HCI included human machine interface, man machine interaction, and software psychology, while terms such as usability increased in reference to HCI issues. While there was already an observable interest among the membership, these leaders encouraged or emphasized work in HCI, along with the publication of HCI research in *Human Factors*, *Ergonomics in Design*, and the proceedings of annual meetings.

Summary and future research

This study shows how research in HCI has evolved over the two decades from 1984 through 2004, identifies some trends in the research, and provides suggestions for future research, including search methodologies.

One concern that arose from our database searches is that the same search terms do not yield the same results across databases. In our study the "hit" rate was only 16% between two databases for the journal *Human Factors* when searching with the broadest term "human and computer and interaction" and in the index fields that allowed the most comparable yet broadest searches of two differently structured databases. Further study to test for this phenomenon in other journals with HCI content is recommended. In the interim, researchers and students are advised to use more than one database when searching for material in the HCI field.

In addition, it was observed that the formal term "human computer interaction" did not appear under the "keyword" index search in PsychInfo until 1993, and in the "subjects" field until 1996. Prior to these years, HCI research was obtained only by searching abstracts or titles for either the term as a string or as individual word occurrences. PsychINFO is an abstract only database

that covers psychological literature since the 1800's. The Thesaurus of Psychological Index Terms, currently in it's 30th year of publication, catalogs controlled vocabulary, also known as index terms or descriptors, used by APA indexers to describe the content of a document. Subjects are indexed for every record using major and minor descriptors, which describe the primary and secondary focus of the document.

In the Expanded Academic ASAP database, both the "keyword" and the "subject" indexes returned results starting in 1992, the first year that the database was published, and the earliest year of *Human Factors* available through this database. While the database doesn't include earlier years, the years that are covered are provided in full text. The Gale Group, which is the parent corporation that operates Expanded Academic ASAP, has their own thesaurus, or keyword index which is based, in part, on the Library of Congress Subject Headings. This thesaurus is maintained by a staff of professionals who monitor word and subject usage in the publications available in their databases, building a keyword index using a proprietary methodology. This staff then uses another proprietary methodology for training their indexers, who learn how to "skim" articles to find those indexed keywords. (Personal communication, M.Diltz, Indexing Manager, Gale Group)

While the HCI field may have been formally established in the early 1980's, the research databases did not identify a separate subject field until more than 13 years later. Given that indexers at neither database provider organization were identified as being experts in human factors, or human computer interaction, the most expedient way for authors to be sure their articles are referenced in a database, using keywords specific to the area of interest, is to use those keywords clearly in the title and or abstract of the published article. For researchers looking for articles in the field, various searches may need to be completed specific to their interests (i.e. "visual displays", "computers", "attention", etc.).

In addition, based on the taxonomy introduced by Hewett, et al. (1996), more research in the conceptualization of the nature of HCI as a field may be useful. These would include points of view, objectives, history and intellectual roots, and HCI as an academic topic in comparison to other fields, as outlined by the authors in regard to research that has appeared in the journal *Human Factors.* Further research on the development process, including design approaches, implementation techniques and tools, evaluation techniques, and sample systems and case studies, according to the taxonomy, might prove productive.

Our results indicate an increase in HCI research in the *Human Factors* journal, especially over the past ten years. This trend was noted by Pew (2003) for textbooks during a roughly similar period, and our research mirrors that found in previous studies. Statistics for the top four countries of origination of the articles (the U.S., Canada, the Netherlands, and the UK) were found previously by Zavod and Hitt (2000). In addition, as was previously noted by Zavod and Hitt in their study of all subject areas in the *Human Factors* journal, much of the research (nearly three quarters of those reviewed for the current study) comes from the academic community, with two thirds of the remaining 25% of research coming from industry, and one third of from government agencies.

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