*German Medical Data Sciences: Shaping Change – Creative Solutions for Innovative Medicine*
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# Mental Workload Relating Health Information System – A Literature Review

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**Abstract.** *Background:* Assessing Mental Workload related to Health Information Systems can help to analyze weak points of the use of Health Information Systems and in health care work processes. Our objectives were to give an overview of current research and applied measurement methods as well as gaining insights into influencing factors of mental workload on the use of health information systems and vice versa. *Methods:* We applied a structured literature research by searching for "mental workload" on PubMed. Studies were included into our review if they assessed related to Health Information Systems. *Results:* The research in PubMed led to 124 articles, resulting in 17 papers taken into in-depth analyses. We identified three categories referring to different study design types. Additionally, articles showed that mental workload was influenced by using health information systems and vice versa. *Discussion:* The review was limited to only one database but revealed that future research with sociotechnical focus including mental workload is necessary. *Conclusion*: In contrast to the high relevance only a few articles address mental workload in Health Information systems. The quality of the studies in terms of evidence and external validity appears to be largely in need of development and should be improved in ongoing research.

**Keywords.** Systematic Review, Mental Workload, Health Information Systems.

## 1. Introduction

### *1.1. Scientific Background*

Digital transformation is one of the main challenges in today's society - especially in health care sector. While health economy generated more than 12 % of Germany's GDP in year 2016 and grew by more than 3,8 % than the economy as a whole [1], the level of digitalization remains quite low. Germany ranks nineteenth in the European eHealth Level Ranking. [2]. Even though digitalization level in German health care isn't adequate, it must be declined that Health Information Technology (HIT) has already become an important part in daily health care work in inpatient as well as in outpatient care. However, while HIT, especially Health Information Systems (HIS), are already frequently used, the tasks and demands placed on staff are becoming increasingly complex. A high intensity of personal interactions in health care sector results in a high amount of communication and tasks [3]. Reasons for this progressive process can also be found in digitalization process. HIS should be supportive for staff and patients: The main objectives of implementing health information systems are to

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achieve high-quality, economical and efficient medical care and to relieve the burden on medical personnel [4]. This seems particularly important in this context, as medical staff feel significantly more stressed than staff in other branches [5]. The share of medical information systems in this subjectively perceived stress remains largely unclear to this day.

Human Factors research including system design reached high efforts by assessing mental workload (MWL) in high risk as well as highly demanding and complex aviation field. The idea to optimize working processes and increase patient safety by implementing a growing number of HIS, must take human factors as MWL into account. High task demands and a complex working environment can lead to a high cognitive or MWL. Vidulich and Tsang define MWL as "very much a function of the supply and demands of attentional or processing resources [6]." MWL is the amount of available resources within a person to fulfill a task with a certain amount of demands. Vidulich and Tsang state that there are exogenous task demands like task difficulty, task priority and situational contingencies and endogenous supply specified as information processing resources [6]. If task demands from HIS exceed mental resources of medical staff, it can lead to high MWL which in clinical processes is associated to higher error rates [7]. One relevant issue referring to MWL is valid measurement. Eggemeier et al. proposed to address the lack of valid, objective measurement methods regarding psychophysiological correlates that can be applied in real working situations [8]. Kramer proposed a classification of psychophysiological measurement methods correlating with measures for MWL in *heart rate variability*, *measuring pupil width* and *visual scanning of eye movement* [9].

There's a lack of improvement that those listed methods are able to measure MWL, but there are more improvements that physiological strain correlates with psychological one [10]. Methodical approaches in health informatics research seem to be very limited to classical usability methods. Johnson et al. formulate a framework for guiding a design process of HIS including methods from different disciplines: informatics, cognitive science, psychology and human – computer interaction [11].

A recent review on cognitive informatics already showed a growing interest in human factor topics relating to health information systems [12]. They pointed out that research focuses on sole usability analyses. Additionally, methodical approaches were relatively restricted to classic usability methods conducted with small sample sizes. Patel and Kannampallil note critically that results of their reviewed studies are having difficulties concerning external validity [12].

### *1.2. Objectives of the study*

By analyzing a broad variety of paper, we'd like to gain an overview of current research to MWL related to HIS. Our main aim is to identify different methodical approaches to assess MWL relating to HIS. Another objective is to identify if there are first results that can show if currently used HIS cause high MWL to medical staff.

## 2. Methods

### *2.1. Constraints/ Inclusion and Exclusion criteria*

Only articles written in English or German were considered. In addition, we did not limit the selection of papers in terms of study design and study type due to the low number of search results. The term HIS in our analyses was constrained to (parts of) information systems with a direct impact to medical personnel. Relating to workload the analyses focused on the psychological construct of MWL. Therefore, other psychological constructs as stress weren't considered.

### *2.2. Literature collection*

A systematic literature search was performed to identify relevant methodical approaches. The main search was carried out on the Medline database via PubMed. The review process was conducted by two reviewers with previous research experience in Health Information Systems and Human Factors Engineering Topics. Decisions to include or exclude articles were made on the basis of consensus discussions..
We started our search by using the Mesh-Terms "mental workload AND Health information systems". Because of very low results, we decided to modify the search to "workload AND Health Information systems", although the Mesh-Term "workload" also includes physical workload. We extended our research strategy by searching for "cognitive workload AND Health information systems". Since our research interest relates to work processes and thus medical personnel, we excluded articles dealing with patients or non-health science perspectives after screening the abstracts. We also excluded papers that did not explicitly focus on the mental workload construct. We involved papers dealing with error detection when using HIS, since the measurement of errors is a legitimate measurement method for MWL. We also rejected paper that conducted a pretest or a pilot-study.

### *2.3. Analyses process*

The resulting relevant papers were reviewed according measurement methods that were applied. At the same time, first notes on the relationship between MWL and HIS were provided. We extracted information about the study design, sample size and data analysis to get an overview of the study quality. Additionally, we summarized the purpose and findings. Based on this process, we grouped them by study design, evidence grade and major finding categories regarding to their research approaches.

## 3. Results

### *3.1. Collection and analyses process*

We identified 124 paper in PubMed by searching for "cognitive workload AND health information system", "workload AND health information system" and "mental workload AND health information system". After removing duplicated articles we

ended having 112 papers in total. We included 37 paper into further analyses after applying inclusion criteria on the abstracts.

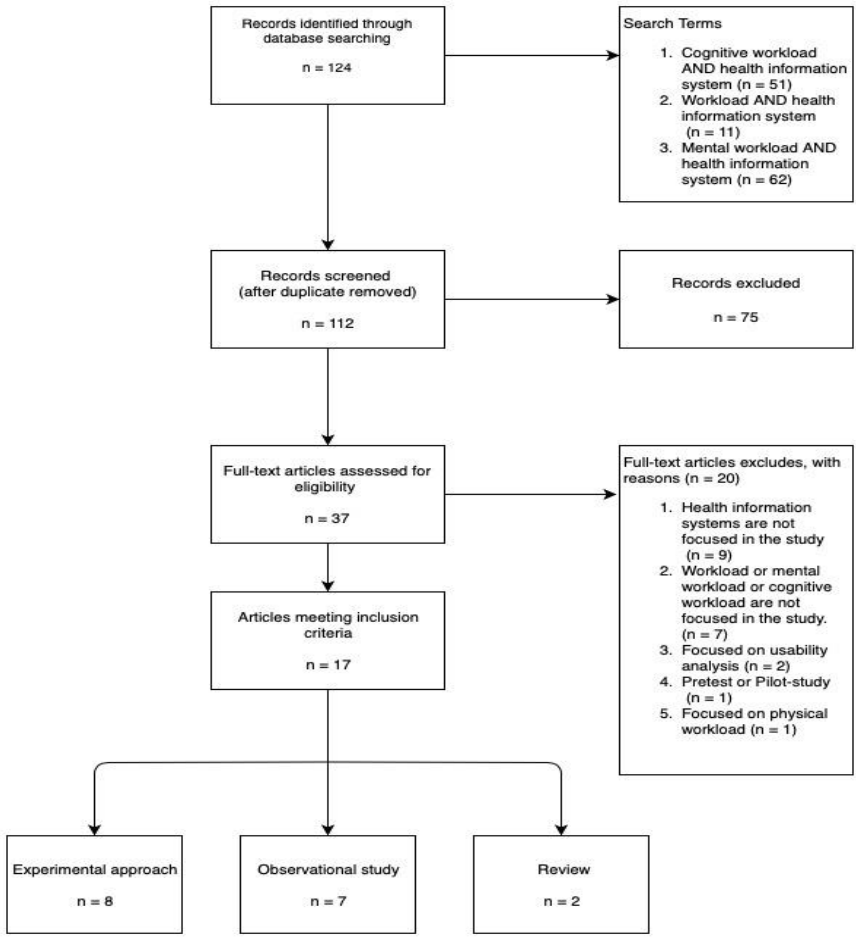


**Figure 1.** Methodical procedure for literature review with inclusion and exclusion criteria.

As shown in figure 1, we excluded another 20 articles after reading the full texts. Exclusion criteria were: *HIS aren't focused in the study* (n = 9), *Workload isn't focused in the study* (n = 7), *focus only on usability analysis* (n = 2), *Pre-test or pilot-study* (n = 1), *focus only on physical workload* (n = 1). The full-text analyses led to 17 articles that we took to further in-depth analyses. Both reviewers agreed that the remaining articles were relevant for our objectives. The remaining papers were grouped by different study designs (*(quasi-)experimental approach (QE/ E), observational study (OS), review (R)*). Additionally, we grouped them by evidence level (*AA* to *E*) to investigate the general study quality in this research field. In addition, we have grouped the articles into three research approaches (*Usability Approach (UA), System Analyses (SA), survey/review (SR)*). There are some first results regarding the relation between MWL and HIS.

### 3.2. Classification by study designs

We identified n = 8 studies that applied experimental approaches; only one of the studies could be classified as RCT (Randomized-Control Trial), n = 7 studies had a quasi-experimental study design. The majority of the research approaches used a pre-post comparison of newly implemented systems or the comparison of paper-based and electronic records. We identified n = 7 studies that applied observational and survey approaches. Researcher applied questionnaires or interviews and focused on usability and workload analyses of specific situations. The majority of studies applied only subjective measures: NASA-TLX questionnaire was most frequently used. One of the main results in both is the heterogeneity of perceived workload within the samples. Two articles could be classified as theoretical papers/ review. They both give an overview of open research topics in the field of human factors relating to HIS.

### 3.3. Evidence level

Shaddish, Cook and Campbell [32] developed a classification of studies relating to their evidence level: AA (highest evidence level) to E (lowest level). The majority of the studies analyzed here can be assigned to levels C and D. Although the evidence level of some studies is in the better or average range, external validity appears low due to lack of randomization and controlled conditions as well as small study samples.

### 3.4. Mental Workload

Studies focused on the term of MWL from two inverse perspectives: High MWL from organizational/other factors caused barriers for using HIS and Using HIS caused high amounts of MWL. Studies related to the first perspective showed that high amounts of MWL led to even higher amounts of MWL by using HIS. Studies focusing on the second perspective gave different results on which factors increased workload amounts. In total, MWL increased after implementing a new system, but decreased after using it for a while. Nevertheless, even after a longer implementation period there still seem to be factors that favor a high workload. We could identify three major research approaches (*UA, SR, SA*) that show a dominance of usability approaches in this research field (n = 8). UA-Studies concentrated on design questions and usability related constructs. *SA* – approaches (n = 6) tried to measure MWL in a new, more valid way, mostly had more controlled study conditions and larger sample sizes.

**Table 1.** This table shows the resulting articles (n = 17) with study purpose, sample size, study design (SD), evidence level (EL) and research approach (RA).

| study | n | Findings | SD | EL | RA |
|---|---|---|---|---|---|
| [13] | 9 | Increased workload, poor staff involvement and training and absence of logistic support | OS | D | UA |
| [14] | 12 | Nurses' user interaction satisfaction was higher and MWL was lower with the integrated display | QE | C | UA |
| [15] | 1109 | Higher level of cognitive workload predicted higher level of SRIS | OS | D | SR |
| [16] | 106 | workload can be reduced by applying a computational model using time intervals | QE | C | SA |
| [17] | 74 | The cognitive workload increased during the early phases of EHR implementation | OS | D | UA |
| [18] | 112 | Staff became less likely to accept alerts as they received more of | OS | C | SA |

| | | | | | |
|---|---|---|---|---|---|
| | | them and there are no relations to workload effects | | | |
| [19] | 18 | Displays received high scores for different cognitive performance measures; scores for usability, frequency of use, usefulness were high | QE | C | UA |
| [20] | 16 | High subjective workload with regards to managing EHR inbox alerts was associated with burnout, on the contrary objective alert workload was not a significant predictor | OS | D | SA |
| [21] | 12 | Redesign of system led to reduction of the complexity and cognitive task workload of the user | QE | B | UA |
| [22] | 67 | Different workload scores between tasks, but not between different systems | OS | D | UA |
| [23] | 30 | Computerized nursing process contributes to lower cognitive workload (compared to paper-based) as a support system for decision making | QE | B | UA |
| [24] | 30 | Participants rated new displays significantly higher, workload was not increased by new displays, new displays showed improved situation awareness from middle to end of the session | QE | B | SA |
| [25] | R | Several open research fields in STSA in health care: including workload and cognitive analyses and approach concerning HIS | R | E | SR |
| [26] | 50 | New method is significantly correlated to NASA TLX method (scores); inversely correlated to performance; high predictive for NASA TLX | E | A | SA |
| [27] | 8 | Higher rates for usability and utility, lower for workload for the new system; no difference in efficiency between both systems | QE | C | UA |
| [28] | 188 | Prescribing errors were reduced by improving the information quality, user interface consistency, system ease of use and mental workload reduction; Mental workload is reduced by ease of use, error prevention, and consistency | OS | D | SA |
| [29] | R | Defining 6 topics in human factors that relate to HIS research and should come to the fore: 1) informatics and patient safety; 2) user interface design and evaluation; 3) workflow and task analysis; 4) clinical decision making and decision support; 5) distributed cognition; and 6) mental workload and situation awareness | R | E | SR |

## 4. Discussion

Our literature review revealed only a few articles which analyze MWL related to HIS. With *experimental approach, observational studies and reviews* we identified three categories, which may help to classify existing and develop future research in that domain. The three categories of *UA*, *SA and SR* underline the research approaches in this field. Although the total amount of articles is quite low, MWL seems to be a relevant factor especially while introducing new systems. Studies showed also that the relation between MWL and HIS needs to be analyzed as a bidirectional one because MWL has an impact on the use of HIS and vice versa. From a methodological point of view, it is interesting that only subjective measures (questionnaires) were used although there were innovative strategies as simulation studies as well as measures that could be more precise (f. ex. pupil dilation) available.

### *4.1. Limitations & Future Research*

The small number of articles found may be grounded in a search with very specific search terms in only one database (PubMed). Since MWL and cognitive strains are psychological concepts which might be relevant in a broader context than healthcare,

an extension to further databases like PsycInfo or WebOfScience may result in larger number of hits. In addition, an extension to search terms like "socio-technical systems" might have similar effects as some articles are not tagged with the Mesh-term HIS. While analyzing effects of HIS on medical staff and the potential stressors in daily care processes, more future research with sociotechnical focus is necessary. Psychological concepts like MWL may explain human behavior and give hints how to optimize HIS or the working environment. To increase validity, these measures should include field studies and simulation studies as well as experimental settings, which are hardly available at the moment.

## 5. Conclusion

In contrast to the high relevance only a few articles focus on MWL relating to Health Information systems. MWL seems to increase strongly directly after the implementation of a system and to decrease again after longer implementation. The quality of the studies in terms of evidence and external validity appears to be largely in need of development and should be improved in ongoing research.

## Conflict of Interest

The authors state that they have no conflict of interests.

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