Structured and Standardized Emergency Call Systems from an Automation Research Perspective

Simon Franke
German Red Cross Rhineland-Palatinate e. V.,
Germany

Christian Elsenbast
Ministry of the Interior and for Sport
Rhineland-Palatinate, Germany

Tilo Mentler
Trier University of Applied Sciences,
Germany

ABSTRACT

Medical emergencies require quick and appropriate responses from Emergency Medical Services (EMS). Neither oversupply nor undersupply are acceptable for reasons of patient safety and economic concerns. Nowadays, computer-based tools – emergency call or dispatch systems - support dispatch center operators in decision-making and documentation processes. The extent to which automation plays a role in this varies, especially between standardized and structured emergency call systems. Although both approaches have already been studied and deployed, insufficient attention has been paid to automation research findings in other (safety-critical) domains. In this paper, we fit emergency call systems into findings on safety-critical and human-centered automation research. Furthermore, we outline research and development needs with respect to holistic call-taking and dispatching process views as well as adaptive automation. We conclude that human-machine cooperation by better structuring of emergency call systems might be preferable to further standardization resulting in full automation.

Keywords

Emergency Call System, Levels of Automation, Dispatch Center, Control Room, Emergency Medical Services

INTRODUCTION

In the event of a medical emergency, it is essential that qualified professional help reaches the person(s) affected as quickly and appropriately as possible. While resource-related shortages or delays would be directly to the disadvantage of those affected, over-provision must also be avoided in order not to compromise the care of other injured or sick people on the one hand, and to meet economic requirements on the other (Swan & Baumstark, 2022).

In this context, computer-based tools are now widely used in dispatch centers of Emergency Medical Services (EMS) and fire departments, whether for decision making or for documentation reasons. Such approaches are referred to as ”medical priority dispatch systems” (Shaw et al., 2024), ”emergency medical dispatch system” (Andersen et al., 2013) or ”emergency call systems” (Mayr, 2020). It should be noted that not only are different terms used, but that concepts and implementation behind them may also differ in detail, depending on the overall pre-hospital medical care organization (see the following section).

As many rescue service systems around the world are confronted with increasing demands on the quality of their interventions and growing deployment volumes, the question arises as to what extent computer-based tools should not only provide functions, but also perform them in the sense of automation (Afzali et al., 2021; Dahlmann et al., 2025). In the context of this contribution, the latter refers broadly to the static or dynamic allocation of functions and tasks to people or computer-based solutions. With their question ”Automation in emergency medicine - our future or threat?”, Grudnik et al. (2023) concisely, if somewhat pointedly, summarize that an answer to an appropriate degree of automation is by no means easy to give.

Although emergency call systems have been studied in detail (see the following section), insufficient attention has been paid to automation research findings in other (safety-critical) domains that have been researching and developing human-centered automation solutions for decades. However, it is this human-centered perspective that is necessary to ensure that dispatch center operators can continue to fulfill their responsibilities in the future and are neither under- nor overburdened. Therefore, our contribution is twofold:

- Emergency call systems are integrated into the research field of automation in a cross-domain perspective.
- Further research and development needs in connection with emergency call systems are worked out in detail with regard to holistic process views of call-taking and dispatching as well as adaptive automation.

We conclude with the working hypothesis that, in terms of successful human-machine cooperation in dispatch centers and the need for interpersonal relationships in challenging situations, better structuring of emergency call systems in EMS dispatch centers might be preferable to further standardization that would result in full automation.

BACKGROUND AND RELATED WORK

Emergency call and dispatch systems and the entire emergency management process are explained in detail below. In addition, the essential principles and findings of decades of automation research are discussed. The link between these two thematic blocks is the subject of the following section.

Emergency Call and Dispatch Systems

In the context of emergency situations, dispatch centers play a central role in ensuring optimal emergency services. Operators receive emergency calls, collect emergency information, and coordinate emergency services. They act as the central control element of the rescue service and take responsibility for the effectiveness and efficiency of the overall rescue and emergency system (Luiz et al., 2019; Møller et al., 2021).

The specific tasks and organizational structures of the dispatch centers vary significantly between different regions of the world. Within the scope of this work, we focus on emergency medical dispatch as it is employed in Germany, despite the fact that the 232 dispatch centers for non-police emergency services in Germany are not subject to a uniform standard. (Trautmann et al., 2022) Nevertheless, the ability to transfer the results of the discussion to other systems and regions is a desirable goal.

In the context of the dispatch center, two systems are commonly employed for the intern organization. The application of the call taker/dispatcher principle entails the division of tasks across distinct functions:

- The call taker is responsible for the management of emergency calls, the medical classification, and the determination of the operation code and emergency category.
- The dispatcher then assumes control of the case, selecting the appropriate responders, alerting them, providing ongoing documentation of the case, and supporting background work for the responders. (Norman G. Vinson et al., 2023)

Although this principle has been applied in many regions globally, a significant number of German dispatch centers operate without the allocation of distinct rolls, so the call taker assumes responsibility of dispatching. However, many organizations tend to use the call taker/dispatcher principle, especially with large dispatch centers or an increased number of incoming calls (Trautmann et al., 2022).

Separating call taker and dispatcher has the advantage of focusing work, where the dispatcher can have a full overview of the different operations in the operational area and the vehicles available. For example, the dispatcher can alert vehicles while the call taker is still on the phone. One disadvantage is that there can be a loss of information between call taker and dispatcher. In dispatch centers where the call taker and dispatcher are located in close proximity to each other, it can be seen that there is often a lively analogue exchange of information, although this cannot be adequately implemented by most software systems. Individual tasks are shown as an example in Figure 1. The handover between call taker and dispatcher is often software-supported and transfers dispatch code, priority and meta data such as the location of the operation.

The increasing technological possibilities and great challenges in dispatch center work increase the desire to support or even automate process steps with technological solutions. Different work steps can be automated or software-supported to varying degrees. Work steps are often already partially automated in dispatch centers. For

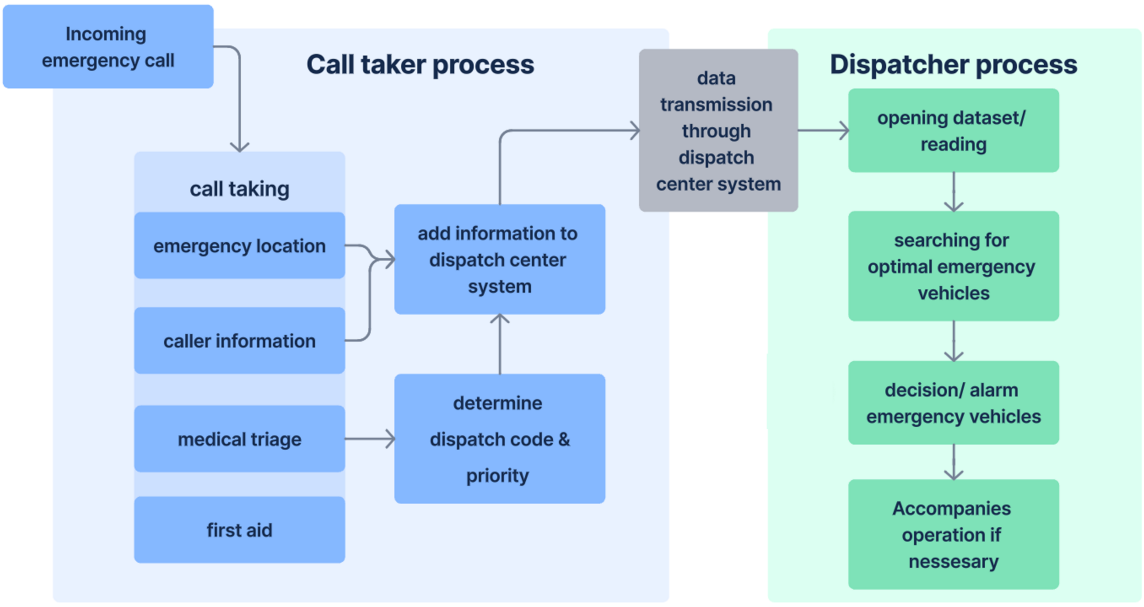

Figure 1. Example of dispatch center process

example, the selection of rescue vehicles (which is often based on the shortest distance to the scene of the emergency) is carried out in such a way that the dispatcher receives a suggestion from the system which they can accept or reject. Another example of different degrees of automation is the call-taking process, which is described in more detail in the next section.

Emergency Call Taking

The process of emergency medical call taking serves as a notable example for the investigation of the effects of varying degrees of automation. This is due to the existence of relevant research and literature, but also the practical implementation of different systems within the dispatch centers, which allow a comparison in practice.

The aim of the calltaking process "includes the gathering of the patient's Chief Complaint and primary symptoms and scene safety and hazard information, as well as assigning the correct priority level and determinant coding" (Scott et al., 2016). A rapid query and prompt decision making is especially important for particularly time-critical reports such as out-of-hospital cardiac arrest. At the end of the emergency call the call taker must define a disposition code. This determines what type of help will be dispatched to the scene and the priority the call is handled with (Breuer et al., 2024; Scott et al., 2016).

Call taking is therefore a central component of the dispatch center's work and is of essential importance for the quality of the rescue chain. At the same time, the process is subject to numerous influences and challenges that can be attributed to both the caller and the call taker. The main difficulty lies in the fact that calls can involve all kinds of (medical) requests for help, from minor complaints to life-threatening events. The callers are usually laypersons when it comes to healthcare and are often in a stressful situation as a result of the incident. During the call, the call taker has the task of reassuring the caller, identifying symptoms and guiding them to first aid. Call takers are underlying various influences, such as their training and experience, the organizational structures and the team structure and team feeling within the dispatch center. The call taker therefore needs both technical and non-technical skills like communication skills and stress resistance (Møller et al., 2021).

Call Taking Systems

Various systems have been established for carrying out emergency call-taking. These differ primarily in terms of the degree of freedom the call taker has in processing the emergency call, which can range from a lack of guidelines regarding how to conduct the call to the exact verbatim specification of the questions and the order in which they are asked. The introduction of interrogation systems dates back to the Medical Priority Dispatch System of 1978 (Gardett et al., 2013). The transitions between the different systems are fluid and cannot always be clearly defined (Luiz et al., 2019; Trautmann et al., 2022). Table 1 provides a quick overview.

The *structured emergency call system* offers the call taker a certain structure in contrast to the *free query* without any aid system. Nowadays, structured query is usually software-supported, but the usage of analog systems might

Table 1. Comparison of structured and standardized emergency call queries, modified (Breuer et al., 2024; Trautmann et al., 2022)

	Structured Emergency Call System	*Standardized Emergency Call System*
Predefined conversation structure	Yes	Yes
Exact wording of questions predefined	Can	Yes
Software-supported	Can	Yes
Automatic documentation of query results	Can	Yes
Transfer of query results to the dispatch system	Can	Yes
Automatic generation of a unique dispatch keyword	No	Yes
Questions are evaluable	Can	Yes
Questions are evidence-based	No	Should
Quality management through evaluation possible	Can	Yes
Automatic timestamps for every question	Can	Yes
Fulfills legal documentation requirements	Can	Yes
Increased legal security after call deletion when used properly	Can	Yes
Context-dependent dynamic order of questions	Not by software, should by call taker	Should by software
Requirements for the call taker's medical expertise and non-technical skills	High	Might be lower
Allows individual questioning for cases not implemented	Yes	No
Enables individual response to the caller's statements	Yes	No

also be possible. Typically, the structured call system provides a guideline for the course of the call, although it is possible for the call taker to deviate from the given structure. The call takers' expertise, as well as their technical and non-technical skills are particularly important here, as they have to react flexibly to the situation and the course of the call. The dispatch code and the emergency priority are manually selected by the call taker, who has to evaluate the information from the call himself. The aim of quickly recognizing critical situations and initiating appropriate measures immediately remains the same and is often implemented by specifying the first questions (Breuer et al., 2024; Luiz et al., 2019; Trautmann et al., 2022).

The *standardized call system* differs from the structured system. It is always software-supported and provides the call taker with the exact wording of the questions. Most of the questions need to be answered with 'Yes, No, unknown, unclear', and the system does not allow intermediate steps. The order of the questions is determined by a decision tree and depends on the caller's answers. The leaf nodes of the decision tree represent the different dispatch codes. In some implementations of the standardized call system, the call taker might have the possibility to increase case priority (Breuer et al., 2024).

The use of structured and standardized systems has increased in Germany in recent years. While around 50 % of the dispatch centers did not use any of these systems in 2018 (Luiz et al., 2019), the number decreased to around 31 % in 2022 (Trautmann et al., 2022). A variety of different solutions are used, from available commercial systems to ones developed in-house by the operators of dispatch centers. The degree of utilization within the dispatch centers that established such a system is also reported at different levels in various studies (Kraus et al., 2022).

Advantages and Disadvantages

The use of structured or standardized systems offers a number of advantages for the workflow in the dispatch center, but also the rescue service as a whole system. A study shows that the use of such systems has significantly improved the quality of dispatch center's work. The emergency doctor alarm rate was significantly reduced (more than 10 %)

in 10 of 24 examined dispatch centers, in just two centers the rate increased. It was also possible to reduce the number of cases in which the paramedics called an emergency physician for on-scene support. (Luiz et al., 2019) This can be explained by the fact that by using these systems, the most important symptoms, such as the state of consciousness or breathing, are queried much more frequently and accurately. (Sellin, S., 2011)

Further advantages are mentioned in particular in connection with the standardized call system and relate to the internal work processes of the dispatch center. Depending on how the structured call system is designed, the advantages mentioned can also apply to this.

The questions of the standardized call system can be developed and evaluated as part of an ongoing scientific process and the results of the call-taking are independent of the call taker and reproducible, as long as the process is strictly adhered to. A high number of dispatch codes (e.g. 5564 at (Breuer et al., 2024)) are also possible through automatic selection, which allows fine-grained dispatching. The legal documentation requirements are simplified by the software. This is particularly important in cases where telephone recordings are not stored long enough and are no longer available during an investigation. (Breuer et al., 2024) The evaluability of the questions, the reproducibility of the results and the strict documentation are expected to provide a certain degree of legal certainty for the survey process, although this is sometimes criticized (Trautmann et al., 2022).

The implementation of structured and standardized systems brings many advantages and is recommended by professional associations. However, the use of standardized systems, in particular, is not uncontroversial. They provide call takers with a fixed call structure and do not allow any deviation from this standard. Cases that are not modeled in the query tree cannot be processed by the software, and the call taker must suddenly become active themselves. As the software often only accepts 'yes' or 'no' (in addition to 'unknown' and 'uncertain') as an answer, call takers have to interpret the answer despite the predefined structure, which ensures that the desired comparability of the disposition is weakened again (Trautmann et al., 2022). Callers often describe a wide range of complaints, categorizing an emergency as the main complaint and answering it with yes and no questions often does not reflect complex health problems (Hippler et al., 2024).

Automation Research

Automation in the sense of delegating or taking over partial actions from humans to machines and the associated concepts of assistance, autonomy and artificial intelligence have been researched and developed in various safety-critical domains (e.g. aviation, automotive, logistics, plant control) for decades (Herczeg, 2014; Janssen et al., 2019). Corresponding approaches have also been and are being pursued in the field of rescue services, for example in dealing with mass casualty incidents (Berndt et al., 2017), transport management (López et al., 2008) and emergency call systems on traffic incidents (Blancou et al., 2016).

In situations like traffic incidents, in which the human actors (driver, passengers) may no longer be able to make an emergency call (unconsciousness, degree of injury), it makes sense to strive for full automation. However, it has repeatedly been shown across the aforementioned domains that purely technology-driven automation in the sense of "everything that can be done" is not advisable in many situations and contexts - and, on closer inspection, often not even possible (e.g. maintenance, exceptional situations, system expansion). In this regard, Bainbridge (1983) stated the classic ironies of automation. They can be summarized as follows:

- Automation is often justified by the (presumed) error-proneness of human actors - the developers of automation solutions are humans (in brief: Developers are humans).
- Since certain tasks, especially monitoring the automation solution and handling unexpected situations, cannot be automated, they remain with the human actors in a possibly quite arbitrary way. However, there is a practical consensus that people are not well suited to prolonged purely supervisory tasks (keywords: vigilance, motivation) and that this results in further problems in practice, e.g. deskilling (in brief: Inappropriate tasks remain with humans).
- The higher the degree of automation and the lower the need for human intervention, the higher the training and education costs for the human actors in order to be able to act correctly and efficiently in what are often very critical exceptional situations (in brief: High degree of automation, high training costs).

Automation approaches that go beyond "all or nothing" are often described in the form of levels or taxonomies (Vagia et al., 2016). They enable a more refined view of the transfer and retraction of decision-making and action processes between humans and machines. One of the well-known models that not only includes the output of a system or the action phase in automation considerations is the one developed by Parasuraman et al. (2000). It

is based on a simplified model of human information processing and distinguishes degrees of automation in a continuum of different processing stages:

1. information acquisition referring to the human processes of sensory pre-processing of data, perception and selective attention;
2. information analysis referring to human working memory and other cognitive operations like rehearsal, integration and inference;
3. decision and action selection referring to human decision making following cognitive processing;
4. action implementation referring to the human execution of the decision made before (e.g. response, action).

It must be emphasized that the static allocation of functions/tasks to humans or machines, especially at the time of system development, is increasingly viewed critically. Rather, "the level (and perhaps even the type) of automation could be designed to vary depending on situational demands during operational use" (Parasuraman et al., 2000). These demands can be specific system conditions, human performance or other attributes (e.g. cognitive load). This approach is known as adaptive automation. However, this flexibilization and refinement of automation levels can also be accompanied by problems, including the risk of mode error, i.e. the incorrect assessment of the status or degree of automation of a technical system and the necessary human action steps (Sarter & Woods, 1995).

However, an adaptive automation approach is considered the most promising for many scenarios. Or, as Dekker and Woods (2002) sum it up: "System developers should abandon the traditional 'who does what' question of function allocation. Instead, the more pressing question today is how to make humans and automation get along together."

METHODS

Considering structured and standardized emergency call systems from an automation research perspective is part of the context of use analysis within a human-centered design approach (see Figure 2). Building on this, design solutions with respect to human computer interaction and cooperation are realized iteratively based on regular user feedback. However, the starting point is an in-depth understanding of the context of use, i.e. people, tasks, needs, technology, organizational framework conditions and wider social requirements.

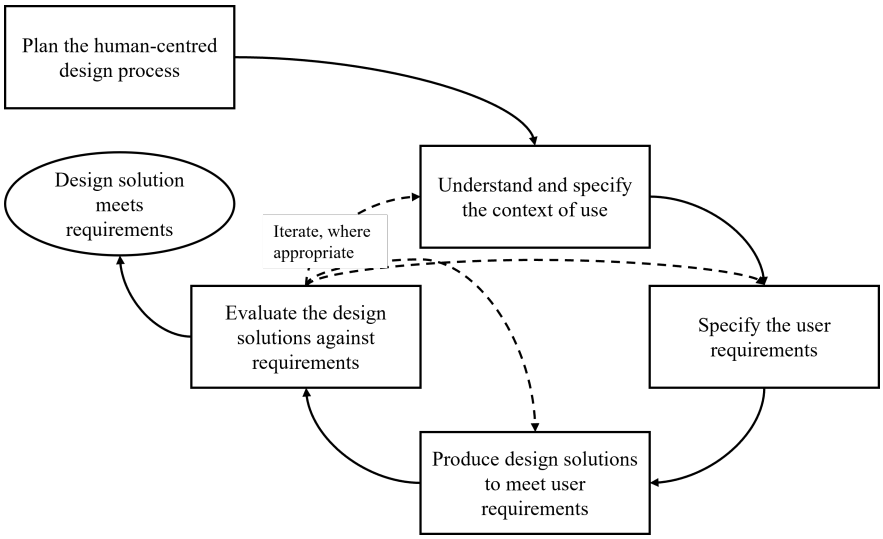

Figure 2. Human-centered design process as described in ISO, 2019

More specifically, the following sections are devoted to the context of use understanding and user requirements specification stages of this process model focusing on the emergency call management process and computer-based tool support. Insights are based on the evaluation of the state of research (see the previous section) as well as on the authors' own experience in automation research and dispatch center practice (Mentler et al., 2023; Pöhler et al., 2025).

COMPARISON OF STRUCTURED AND STANDARDIZED APPROACHES

In the following, the concepts of standardized and structured emergency call systems are first classified with respect to levels of automation. Then the aforementioned ironies of automation are examined.

Level of Automation

As Table 2 shows, there are some minor and some more significant differences between standardized and structured emergency call systems in the degree of automation in various processing steps according to the model of Parasuraman et al. (2000). The decision and action selection stage is the most striking one as the degree of automation differs significantly between the two approaches.

Table 2. Levels of automation at different stages for standardized and structured emergency call systems based on the model by Parasuraman et al. (2000) and comparison in Table 1

	Structured Emergency Call Systems	*Standardized Emergency Call Systems*
information acquisition	Human operator takes emergency call; call structure and question sequence specified, but if necessary, degree of freedom in formulating the question	Human operator takes emergency call; call structure, question sequence and wording specified. Context-dependent sequence of questions should be possible
information analysis	Query results can be automatically documented and transferred to the dispatch center system. However, there is no full and time-stamped documentation of questions and answers	Query results are automatically documented and transferred to the dispatch center system. Full and time-stamped documentation of questions and answers
decision and action selection	Dispatch keyword or code is not generated automatically	Dispatch keyword or code is generated automatically
action implementation	Immediate life-saving measures are guided by the human operator. Further actions may also be carried out by third parties, depending on the mission (see call taker vs. dispatcher roles)	Immediate life-saving measures are guided by the human operator. Further actions may also be carried out by third parties, depending on the mission (see call taker vs. dispatcher roles)

It should be noted that for structured emergency call systems many aspects fall under optional provisions, i.e. they can be realized in different ways. Nevertheless, the two approaches can be compared as shown in Figure 3.

Ironies of Automation

The ironies of automation identified by Bainbridge (1983) are largely independent of technology and context (see the previous section). A clarification with regard to emergency call systems is therefore necessary and can be carried out as follows with regard to existing studies and publications. The selected examples do not claim to be exhaustive and are not intended to contradict the fundamental need for (at least) semiautomated solutions in the area of emergency call management. They should illustrate that the ironies of automation must also be taken into account in this context.

Developers are humans

As Mayr (2020) explains, in 2020 there were several providers of emergency call systems in German-speaking countries alone. To the best of the authors' knowledge, their developers are human beings. This situation is unlikely to have changed in the meantime - even if automation, of course, also plays a role in software development.

In a study by Kraus et al. (2022), the implementation of standardized and structured emergency call handling in German EMS dispatch center was examined. Among other things, the following reasons for the rejection or limited introduction of such solutions were named: dissatisfaction with a product in general, product does not meet all requirements, lacking validation of available products.

This case also shows that the development of technical solutions requires a high degree of human cooperation, especially when mapping requirements to software functions. IT development of call taking solutions and

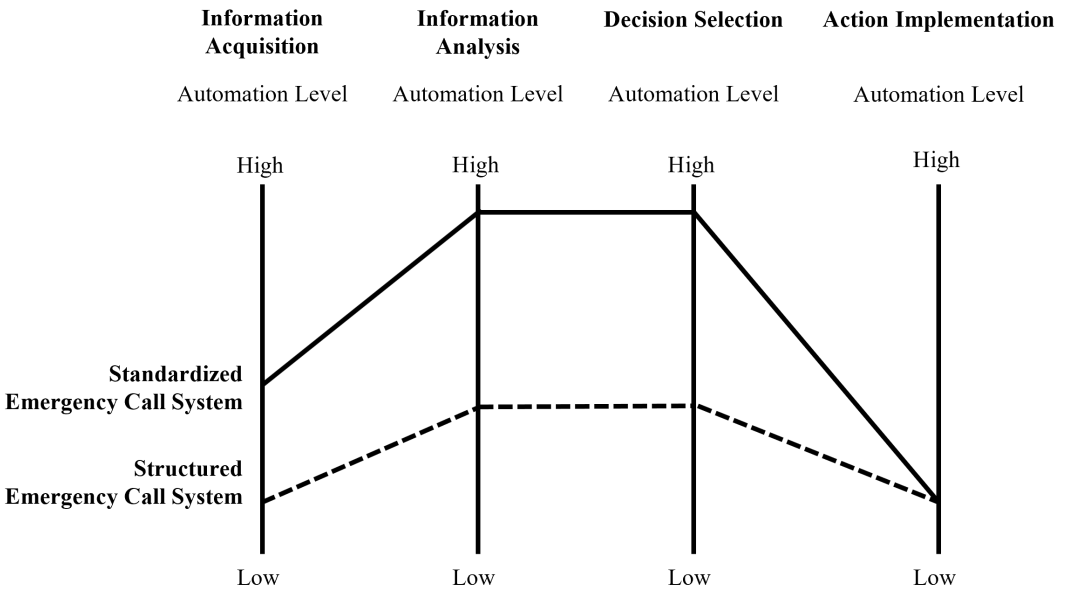

Figure 3. Comparison of standardized and structured emergency call systems according to levels and stages of automation

practice-oriented research need to be aligned in order to gain insights into complex communication and coordination processes within dispatch centers and with rescue forces in the field (**10.1145/3274468**). This is all the more true if the technical possibilities are further expanded in the coming years, such as video-based calling and picture sharing (Dash et al., 2022).

Inappropriate tasks remain with humans

A higher degree of automation in emergency call taking practically means that human actors are left with monitoring tasks and handling of exceptional situations in particular. However, emergency call taking work is characterized by the latter as Kraus et al. (2022) showed while studying factors that limit or hinder the use of structured or standardized emergency call systems. The following factors, among others, were mentioned several times:

- Language barrier,
- Uncooperative callers,
- Calls by professionals,
- Firefighting situations,
- Diffuse clinical pictures,
- Communication problems,
- Unusual situations.

Other studies also show that cases that represent an ”unclear problem category” (Otten et al., 2022) are a major challenge to emergency call systems and high levels of automation. This is where the problem arises that automation stops in precisely those cases where it is most urgently needed. Improved technical solutions, e.g. in the sense of multisensor integration in public-safety answering points (Grace and Potts, 2022), can support information gathering and decision-making. However, they also increase the technical complexity and require introduction and training measures.

High degree of automation, high training costs

Several studies and discussions on the introduction and use of computer-based tools for emergency call management indicate that the introduction processes as well as training and education measures are problematic and insufficiently implemented. For example:

- Mayr (2020) states that there is a need for optimization in employees' training.
- Breuer et al. (2024) identify regular training, further education, feedback mechanisms and error culture as core elements of modern control rooms and dispatch centers.

The need for more education and training has long been recognized, regardless of the technical aids and levels of automation. For example, Hackstein et al. (2014) demand that the emergency call management process has to be be included in training standards as uniform as possible throughout Germany. As already indicated, automation efforts often go hand in hand with potential savings in the qualifications of human actors and a corresponding loss of expertise.

DISCUSSION & FUTURE WORK

As can be seen in Figure 3, the standardized emergency call system is characterized by a higher degree of automation in the information analysis and decision selection phases than the structured emergency call system. It is also noticeable that the degree of automation is lower in the first step of information acquisition for both variants, as the verbal responses of the caller to the questions from the operator must be understood by the operator and recorded in the corresponding application systems.

Looking at current developments in the areas of speech recognition and chatbots, a higher degree of automation seems conceivable, especially with respect to standardized emergency call systems and their predefined question catalogs and formulations. However, as already explained, a higher degree of automation does not necessarily go hand in hand with greater efficiency and safety for the overall emergency call handling system.

Adaptive Automation

In the context of emergency call management, different factors and scenarios can be named to which a more dynamic function allocation could be aligned. In this regard, it should be emphasized that many perspectives must be taken into account in a sociotechnical consideration, e.g. also the legal protection of responsible parties.

First, if there are a large number of emergency calls at the same time or shortly after each other, then information acquisition stage of call-taking could be automated to a higher degree. In any case, not getting through with an emergency call seems worse than being received by a semi-automated solution. However, this poses the challenge of reliably identifying critical cases that can only be treated by a human operator. The extent to which emotion recognition can be helpful and reliable, for example, is the subject of current research. Even if this is successful, it is easy to construct scenarios in which the emotional state of arousal is not decisive, e.g. if the emergency call is made by police officers or firefighters off duty, or people can only whisper due to threatening situations. These situations, which can certainly be described as extraordinary cases, should not be seen as an argument against highly automated emergency call systems. However, they must not be ignored.

In the information analysis and decision selection stages, the degree of automation could be adjusted by the human operator or adapted by the emergency call system if unusual call sequences or changes in situation occur. Factors here could be the time course and the level of stress of the people involved. However, the challenges here are similar to those mentioned above. In any case, considering emergency call systems as decision support systems would implicate that the system provided more than one suggestion to the human operator and could explain its recommendations at the users' request.

Adapting automation in the action implementation stage is related to the holistic consideration of emergency call-taking and dispatching. Therefore, it will be addressed later.

Holistic Emergency Process View

Currently, a break can be identified between the call-taking and dispatch processes, which requires additional communication and coordination between the people involved. This does not scale both situationally, in terms of the volume of operations, and fundamentally, in terms of the (physical) size of the dispatch center's control room.

In particular, it is important to carefully examine which degrees of automation fit together in which sub-tasks. As described before, mode error is a well-known phenomenon and problem that can be exacerbated if different people, e.g. call taker and dispatcher, are working along the entire automation process.

Following the human-centered design process outlined in the methods section, research and development work will continue design and evaluation of design solutions following an adaptive automation approach and considering the call taking and dispatching process as two sides of the same coin, providing efficient and appropriate support for those who require it.

Taking a holistic view to emergency management would also mean considering adoption processes, training support and guidelines for work reconfiguration with respect to automation irony "high degree of automation, high training costs".

CONCLUSION

Standardization and automation are tempting approaches to meet growing demands on quality, as in the emergency services, even with increasing demands on the human operators. There is undoubtedly potential that needs to be utilized further. However, the potential dangers associated with high levels of automation and the ironies of automation should also be kept in mind. This applies in particular to a field of application in which people often seek help in situations that are unusual and challenging for them - even if, from an EMS professional's point of view, these situations may not turn out to be dramatic at all. In order to do justice to the diversity of people and situations on both sides of the emergency call, we put forward the following thesis: Refined structuring and adaptive automation should be preferred rather than standardization and full automation. Following a human-centered design approach, design solutions which take this thesis into account will be developed and evaluated.

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