Revealing triage behaviour patterns in ER using a new technology for handwritten data acquisition

Christelle Despont-Gros a, Gilles Cohen a, Olivier T. Rutschmann b, Antoine Geissbuhler a, Christian Lovis a,∗

a Service of Medical Informatics, University of Geneva and University Hospitals of Geneva, Rue Gabrielle-Perret-Gentil 4, CH-1211, Geneva 4, Switzerland
b Service of Adult Emergency Medicine, University Hospitals of Geneva, Geneva, Switzerland

ABSTRACT

Introduction: Data acquisition is still one of the important challenges to be met in clinical settings. This is even more critical in settings with high cognitive workloads, such as emergency room (ER). Observations in these settings are difficult to realize without biases and there is little means to trace fine acquisition activities done in natural environments, using pen and papers. This study is based on the usage of a digital pen and paper (DPP) technology for the acquisition of triage information by nurses in ER. The DPP technology has been used to ease acquisition using a natural mechanism; it also minimizes the external influence of observation during acquisition activities. The aim of this study is to determine whether data recorded by the DPP technology allows explaining how ER triage nurses use the triage forms in real working conditions.

Methodology: The chief physicians of the ER service wanted to have answers about three main concerns pertaining to the triage process: (1) the average time spent during the triage process; (2) the sequence in which the fields of the forms were filled and; (3) the contribution of objective measurements, such as vital signs, to the triage emergency level and decisions. In order to answer these questions, detailed log data recorded by the DPP during form filling as been analyzed and allowed to built several representations of the triage process. In addition, we completed this analysis with ethnographical-like observations.

Results: For seven consecutive days, 1183 triage forms have been recorded in the ER for all patients admitted. Among them, 954 forms have been digitalized and 906 forms have been considered as valid and complete. Based on this set of data, the median duration of the triage process is 143 s. There are no converging habits in filling the forms and the sequence of filling fields present a high variability. The emphasis of the objective measurements in the decisional process is rather low, as vital signs are recorded in less than 17% of the cases.

Conclusion: The DPP technology is an original approach to study data acquisition processes in unbiased conditions. The technical raw data recorded by the DPP allows building the time series of all activities on the paper, therefore letting to constructing several representations of the process. However, the technology is not able to provide information about the context of use, for example interruptions of the form filling processes due to calls or other activities. Therefore, it is necessary to complete these analyses with qualitative approaches such as

∗ Corresponding author. Tel.: +41 22 3726201.
E-mail address: christian.lovis@hcuge.ch (C. Lovis).
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1. Introduction

Workflow and processes are of high importance in emergency rooms situations. Time is a critical factor and providing well-adapted computerized tools is therefore a particular challenge. Understanding processes and interactions is not easy and there is room for new approaches [1]. This is of particular importance when considering the high failure rate in the introduction of new computerized systems and the contribution of non-technical factors [2–6].

Triage decision making in hospital emergency rooms is a complex and little known process in practice despite the fact that numerous guidelines are available [7–12]. This paper focuses on trying to catch how nurses complete the triage form at the very first contact with patients in the ER. Previous work done with the digital pen and paper technology that allowed the authors to report that the digital pen largely mimics a normal pen and, except for its induced cognitive load [13], is accepted by care providers is the basis of this study. Paper based procedures are difficult to analyze and record because of a lack of log trace. In addition, users are often so familiar with their daily tasks that they omit features linked with the context of use or action [14]. In this context, the digital pen and paper technology is an original approach to study handwritten data acquisition by minimizing biases due to the influence of direct human observations. To our knowledge, a detailed analysis of the process of filling a paper-based triage form as never been published.

1.1. Context

Emergency departments have known an increasing number of consultations for the last 30 years [15]. Among the procedures developed to provide efficient care, the triage process plays a significant role. It does not only aim to quickly identify and categorize the urgency level of the patient's conditions, but it also helps to estimate the maximum time the patient could wait before he is taken care of. Furthermore, it enables the staff to determine the best place for the patient's treatment [16,17]. This process is usually assumed by emergency triage nurses. The triage decision is based on three types of information: the current disease history, a brief clinical assessment and vital signs [17]. In order to support this process, different triage instruments have been developed worldwide [18–21].

1.2. Study objectives

The board of medical directors of ER at the University Hospitals of Geneva (HUG) were interested in improving the triage process and quality. This required a better understanding of the way the triage form was used during the triage process in real conditions and daily practice. In a first try to help this understanding, a computerized triage simulator has been developed. This experiment performed by Rutschmann et al. [22] demonstrated that triage nurses had heterogeneous approaches towards taking care of the patient during triage. Consequently, there was a great variability in the triage process. Nevertheless, the triage simulator was only a surrogate of real working conditions, such as excluding interruptions in the workflow by phone calls, unexpected arrivals of new patients or questions of colleagues. Therefore, it has been decided to proceed to a real world analysis of the use of the paper-based triage form using the DPP to record data while minimizing observation biases.

The use of the DPP technology allows collecting large amount of data. The digital pen records the temporal and logical structure of a handwritten process, by logging all movements of the pen on the paper, as well as identifying the fields entered. The analysis of the log allows to describe the sequences in which fields are filled and their temporal relationships [23].

The aim of this study is to determine whether data recorded by the DPP technology allows to explain how nurses use the triage form under real working conditions, and more specifically the following questions that have been identified by the medical head of the ER: (1) what is the average duration of the triage process; (2) in which sequence do triage nurses collect data and finally (3) do the objective measurements, such as vital signs, systematically take part in the triage decision.

2. Materials and methods

2.1. Background and triage process

The study presented in this paper has been performed at the HUG, a consortium of hospitals on five campuses, comprising more than 2000 beds. About 150–200 adult patients are admitted to the ER everyday (60,000 patients per year). The ER is functioning 24 h a day for any level of emergency, including trauma emergencies. All patients are triaged by a trained triage nurse with at least 3 years experience in ER situation. Since 1997, this process has been performed using a standardized triage scale that classifies the urgencies in four levels (1 = immediately/imminently life-threatening situation, 2 = potentially life-threatening situation, 3 = stable situation, and 4 = non-urgent situation). The triage form is fulfilled as soon as the patient arrives in the ER. This form allows determining the emergency level based on a set of standardized elements. These elements comprise the chief complaint encoded in a standardized nomenclature of 93 reasons, a brief history of the current illness, a short clinical assessment and vital signs, including pulse, blood pressure, temperature and pain. Based on these elements, the emergency level and the orientation decision (resuscitation room, critical care area and urgent care, medical or surgical sectors of the ER) are decided. This is considered as the triage decision.
2.2. The DPP technology

The DPP technology comprises three components: (a) the Digital Pen 200 developed by Logitech®; (b) the HP® colour LaserJet printer (designed pattern by Anoto® Group) and; (c) the Forms Automation System (FAS) developed by HP® which include the beta 1 release of the software package.

The pen embeds a digital camera which enables the technology to read the pattern printed on the paper. The camera samples the position of the pen numerous times per second according to the coordinates defined by a pattern of small black dots printed on the form. These dots are hardly visible for humans. The recorded data contains enough information to create a time-stamped vector for each movement of the pen on the paper and identify when the pen enters, writes and leaves a structured field. Our staff developed the Application Service Handler (ASH) deployed on the server to analyze and store these data in a relational database. The following information is recorded:

- identification of the pattern (also used for identifying pictures);
- identification of the pen used;
- absolute stroke starting and ending time [ms];
- identification of the field on the form in which the stroke was written.

The pattern of black dots allows the unique identification of each form, which is an important advantage when the context requires that a document is attributed to a specific patient only.

When the nurse finishes filling the form, data has to be transferred from the pen to the server. The pen transmits data only if a validation box situated at the bottom of the form has been checked. Validated data is transferred on the server when the pen is docked in its USB cradle.

2.3. Study design

The study has two major goals. The first one, the main objective of the study, concentrates on analyzing the process of filling the forms. The second goal was an additional ethnographic-like observation to help analyzing the data acquired during the process. The study was conducted prospectively without interruption for seven consecutive 24 h shifts. All patients admitted to the ER during this period have been included. There was no exclusion criterion. The study has been approved by the HUG ethical committee, provided that patient could not be identified during the analysis.

2.3.2. Observations

Technical analysis of the filling of a triage form is only a proxy to the triage process. Some external information has to be added to improve the interpretation. Therefore, a psychologist performed additional ethnographic-like observations before and during the trial in order to complete data recorded by the technology. After a pre-observation stage, a standard observation questionnaire comprising the nine dimensions of descriptive observations according to Spradley was designed [24]. On this grid, information about the space, the actors, the activities, the objects, the acts, the events, time, and some feelings explicitly mentioned were collected. In this study, the goal was the same for all actors: performing the triage process.

The observations recorded with the grid were analyzed to enumerate events such as interruptions of the form filling process and their reasons or problems encountered during the usage of the DPP (for example problems related to the use of a DPP instead of a standard pen). We also analyzed effects of the context (for example the location where the form is filled) and effect of the object on the organization of the triage process (such as forgetting the pen or cap problems). These observations helped answering several questions about results obtained during the analysis of the recorded data.

2.4. Data extraction

2.4.1. Exclusion of invalid forms or data sequences

During the 7 days of the study, all patients have been included. However, not all triage forms have been used to perform the analysis. Two cases have been identified: (a) unsigned forms and (b) uncompleted forms.

Signing the forms is performed by checking a special box, the “validation box”. When the system did not record that the box was checked, the forms have been considered as invalid and excluded from the analysis. This helped to exclude forms used for testing or draft fillings.

In order to reduce the number of incomplete sequences, we defined two conditions to extract and analyse the data. First, only forms containing the emergency level, the code for the patient’s chief complaint, and the orientation decision have been considered. Second, since nurses may complete information on the triage form after having taken a triage decision, only data until a triage decision was taken were analysed. Data recorded after this decision are not considered. This allows considering only information that has effectively been used for triage decision.

2.4.2. Exclusion of invalid patterns

For all forms fulfilling the above-mentioned requirements, the sequences of fields have been extracted, that is all time series
of strokes written on the fields have been used in order to build the filling sequences. However, due to the layout of the form, the extracted sequences contained invalid transitions between the fields.

Fig. 1 represents the triage form with its various fields emphasized. As shown in this figure, the fields are really close together in order to encompass all written information. In addition, the limits of the fields are not visible on the form. For these reasons, it was sometimes difficult for nurses to write information within the boundaries of the fields. Typically, nurses were writing text larger than the box, with some pen draws on adjacent boxes. When one stroke goes through two distinct fields, the software package records two strokes with the same starting and ending time, one for each of the fields. Therefore, when we extracted the sequences of the fields, we ignored all strokes with these patterns.

2.4.3. Construction of sequences

The average duration of triage process, the triage duration, has been defined as the time elapsed during the first stroke anywhere on the form and the last stroke in the field devoted to the triage decision (field EL and O, Fig. 1). The comparison of triage duration between emergency levels is tested using a Wilcoxon rank sum test with continuity correction.

Based on these extractions, we built several representations ranging from textual to graphical ones, such as graph Markov chains. We also tested data mining methods such as sequence extraction (SPAM) [25] which allows identifying frequent non-contiguous sequential patterns [26]. All these representations have been presented to the ER head clinicians to let them choose the most appropriate and understandable representation. Only representations considered useful and pertinent by these clinicians are presented in this paper. These representations are the textual representation and the

![Fig. 1 – Front side of the triage form, and codes used for fields.](image-url)
3. Results

3.1. Pen strokes

During the study, 1183 patients have been admitted in the ER. These patients have been taken care of by 33 different triage nurses. For the 1183 patients, 954 forms have been correctly recorded on the server (80.6%). The 229 missing forms have been lost due to technical problems of synchronization between the pen and the server. This problem, corrected after the study, was due to the use of a beta release of the pen firmware. On the 954 remaining forms correctly recorded, 49 have been rejected because they did not include the code for the patient’s chief complaint and the orientation decision (5% rejection rate, see Table 1 for the distribution of the forms). Finally, 906 forms have been considered for the analysis.

Considering all emergency levels, the median triage duration is 143 s. The median has been used to avoid too strong influence of extreme values. See Table 1 for the median triage time for each emergency level.

There are significant differences between the emergency levels 1 and 2 (p-value = 5.899e−06), between the levels 1 and 3 (p-value = 0.00035), between the levels 2 and 3 (p-value = 0.00031), between the levels 2 and 4 (p-value = 1.354e−14) and between the levels 3 and 4 (p-value = 4.754e−13).

Each stroke recorded belongs to a defined field on the form. As mentioned before, when one stroke goes through two distinct fields, there is a discrepancy between the semantic content of the form and the data recorded by the system. This problem applies to 5.31% (7457/140,453) of the recorded strokes. To illustrate the problem, these strokes recorded on two fields let the system conclude that 211 forms were containing vital signs, while only 207 forms had real information on vital signs. Among these 207 forms, only 150 (72.5%) contained information about vital signs that was recorded before the stopping condition (indication of the triage decision). Vital signs have been recorded before triage decision in 16.6% (150/906) of the cases.

Fig. 2 represents probabilities of transitions between fields. In accordance with Markov graphs, one arrow between states A and B shows the probability that being in state B, the previous state could have been A. In order to improve readability, only the most important transitions (approximately 70% of probability) are sketched. For each state, the dominant incoming transition is drawn in bold. The double surrounded states indicate the incoming steps of the triage procedure. The bold surrounded states are the final states of the procedure as explained in Section 2.2. The probabilities mentioned nearby these states are the probability that the process finished by the corresponding step.

Analysis of the data could not identify any unique or dominant path through the triage form. However, some transitions were used predominantly, such as the transition from the code of admission to the emergency level.

3.2. Observations

The psychologist conducted observations over 20 h during 5 days in the ER. These observations allowed recording 115 processes of data acquisition, performed by 18 different care providers. Among the 115 processes observed, there were 101 (88%) new forms and 14 (12%) forms that already contained some information. The processes observed were most often performed at the central desk (approximately 80%), the remaining ones in the waiting room or at the admission entrance hall.

During the observations, 50 triage processes (50/115) have been interrupted. The most important causes (60%) were examinations on the current patient (taking blood pressure, measuring the heart rate, etc.), followed by arrival of a new patient with a higher emergency state (18%) and finally by other care providers asking questions (8%).

4. Discussion

4.1. Sequence of information collected during the triage process

The information recorded by the DPP technology allowed the construction of several textual and graphical representations of the patient’s chief complaint and the orientation decision (5% rejection rate, see Table 1 for the distribution of the forms). Finally, 906 forms have been considered for the analysis.

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of the triage process. Among the textual representations, Table 2 shows sequences built by ordering the fields by their order of appearance in the triage process. For each emergency level separately and for the overall emergency levels, the mean time between the beginning of the process and the first record in the considered field have been computed and ordered by this value. The fields emergency level (EL) and orientation (O), which end the triage decision when they are both present, are highlighted with a gray background. They do not always match the real process, but are a theoretical construct. However, they provide interesting insights of the use of the code for admission, the orientation decision and the emergency level. The sequence of overall emergency level (Table 2) corresponds exactly to the way triage nurses are expected to fill the triage forms. Nevertheless, this representation might also be confusing. Indeed, all fields are included in sequences without indication of their frequency. For example, vital signs have been filled in only 16% of the triage processes and the sequences do not reflect this fact. It conveys the incorrect idea that vital signs are an important part of the process.
The graphical representation presented to the ER staff completes the first conclusions obtained by the textual results. It highlights the non-consensual usage of the triage form. There are approximately as many usages of the forms as triage situations.

4.2. Importance of vital signs to take a triage decision

As shown by Fig. 2 and occurrence results mentioned above, vital signs are not an important component of the process. Fig. 2 shows that the section “vital signs” contains mainly incoming arrows and negligible outgoing arrows (under the threshold mentioned Section 3). As mentioned in Section 3, more than 25% of vital signs have been recorded after the triage decision. We observed that the triage leads to an unclosed decision and, except for borderline situations, nurses do not necessarily need supporting facts to establish an emergency level. This has been confirmed by the observations and is not due to an acquisition bias. It raised a lot of questions among the ER staff leaders as vital signs is considered to be of great importance and should be recorded systematically according to the guidelines. Consequently, they decided to modify the form based on this study. In order to encourage the nurses to take further vital signs, this section was emphasized and now occupies a central position on the form.

4.3. Duration of the triage process

Analysis of the duration of the triage process was more consistent, and results are less prone to interpretation. However, because the process can be interrupted by external causes, observations have been useful for the interpretation. As shown by the observations, if interruptions for the examination on the current patient (approximately 60% of interruptions) are not taken into account, 18% of triages were interrupted by events not related to the current patient.

4.4. Limits of the technology

We encountered two important limitations when analyzing the usage of the triage form with the digital pen. For example, nurses used the DPP technology as they used to do with normal pen and papers, such as drawing arrows between fields to link them, are drawing circles around written information to emphasize them. The analysis cannot differentiate between these behaviours and the normal back-and-forth between the fields. Approximately 20% of the forms concerned show such behaviours. The problem could be reduced by identifying strokes that belong to different fields but having identical starting and ending time. In these cases, it has been decided to keep the first field recorded in the database, which is identified by the start of the strokes.

Fig. 3 illustrates such a kind of problem induced by the arbitrary choice of a field. The number “3” has been written in the field EL, but it begins in the field M. If we remove the duplicate and undesired stroke, the field EL does not appear in the sequence of fields. In addition, when the pen detects a pressure on the form, even if the user does not write something, a stroke is recorded for the corresponding field. The fact that users write one data over several fields (Fig. 4) also explains the false positive for vital signs presented in Table 3. We considered as false positive events all correct events recorded after triage decision. In three forms, a stroke which belongs to an adjacent field goes through the field bound for the vital signs, and in one form the user just puts the pen on the paper but does not write anything. These have been manually corrected.

Clearly, analysis of the strokes of pens has not been sufficient to understand how triage nurses did work using the triage forms. Information about the context of use, brought
by the observations, has been an important element for the interpretation. However, considering both the information provided by the DPP and a reasonable amount of observations, it has been possible to have a better understanding of the triage process. For example, the field containing the administrative information of the patient is most frequently used as the starting point on the forms; vital signs are rarely documented before triage decision. These results have only been partially surprising for the clinical head of the ER, as the problem of insufficient vital signs was partly expected. Our observations confirmed these results, but they also provided some hints about the possible reasons. For example, we observed that nurses write already some information, such as the current date, while walking towards the patient or while asking him questions. In addition, our observations could also give some explanation why the code for admission and the emergency level appeared in sequence found in the analysis: the nurse will only enter the chief complaints’ code after enough information about the patient’s health status has been collected to ensure the best choice of this code. Each code is being associated with a set of emergency levels, the nurse then only selects, in this range, the most adequate emergency level one for the current situation. Afterwards, she determines an orientation decision and ends the triage process.

4.5. Limits of the study design

This study is a snapshot of the triage process over 7 days using one form. This design has some limitations. First of all, it shows that DPP recordings do not account for the real processes, but give a biased view of what happens in the reality. Observations made during the study can correct only partially this bias. Another important is related to the duration of the study. It was performed during only 7 days, while it was a new technology. It would have been interesting to carry out the study after a period of adaptation to the technology to limit the learning curve. This is especially true taken into account the high number of nurses involved.

5. Conclusion

The digital pen and paper technology is a new acquisition device which mimics natural handwritten data acquisition. In addition to providing computerized acquisition of information, the DPP allows also to record the temporal relationships on how the information has been acquired. However, in order to be of best use to understand the recording process, a good understanding of the context of data acquisition is required. The data recorded can be analyzed to build understandable models that give useful hints to improve clinical practice. However, the models do partially reflect the reasoning process that triggers the triage decision. Observations provided helpful additional information about the context of use and helped explaining detailed results provided by the models. Both sources of information used side-by-side provide a particularly good view of the triage process.

This study answered some important questions concerning the triage process and provided useful hints to improve the triage form and raised new clinical research questions about the clinical signification of a consensual triage decision and its necessity. The most interesting aspect was the discrepancy that exists between the acquisition of vital signs and their significance in the decisional process. As a result, the triage form has been entirely redesigned to improve and facilitate acquisition of vital signs, and special emphasis has been given to educate triage nurses to improve acquisition of these values.

In this paper, we purposely focused on analyzing the process of filling the forms using time series vectors, and we did not treat the content of the form, in terms of medical and clinical pertinence, aspects that have already been subject of publications in the ER domain.

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