From Insights to INTEL: Evaluating Process Mining Insights with Healthcare Professionals

Iris Beerepoot
Utrecht University
i.m.beerepoot@uu.nl

Niels Martin
Hasselt University
niels.martin@uhasselt.be

Jelmer Koorn
MLC
jelmer.koorn@m-lc.nl

Abstract

As healthcare organisations are looking for ways to improve their processes, process mining techniques are increasingly being used. Current process mining methods do not offer support for translating process mining insights into actionable improvement ideas. By performing action research at two healthcare organisations, we introduce and illustrate the INTEL funnel, a novel three-staged method consisting of process familiarisation, domain explanation and improvement ideation. Our method complements existing process mining methods and constitutes the first attempt to open the black box regarding the path from process mining insights to actionable process improvement ideas. In this way, it can contribute to a more systematic uptake of process mining in healthcare practice.

Keywords: process mining, healthcare, domain experts, evaluation, process improvement.

1. Introduction

In hospitals, process management has always been of interest, but the pandemic has sparked that interest even more (Bogodistov et al., 2021). Healthcare organisations are permanently confronted with the challenge of providing high-quality care with limited resources (Dixon-Woods et al., 2012; Harper, 2002; Mans et al., 2015). To identify process improvement ideas, carefully analysing how the process is currently being executed is a valuable starting point. Process mining can play a pivotal role in that respect as it enables the extraction of non-trivial insights from an event log, a data file containing real-life process execution data recorded by information systems (Martin et al., 2020; Van der Aalst, 2016). Over the past decade, the process mining community has proposed a plethora of techniques to analyse processes in a data-driven way, of which many have also been applied in a healthcare context. Common use cases in healthcare include the automated discovery of a process model expressing how the process has been executed in reality, as well as to study whether the real-life process conforms to, e.g., a clinical pathway (Dallagassa et al., 2021; Peleg, 2013; Rojas et al., 2016). While these use cases underline the potential of process mining, the translation from the output of process mining techniques to process improvement ideas is far from trivial, especially in complex contexts such as healthcare. The involvement of healthcare professionals is essential to give meaning to particular patterns appearing in the data and to convert findings into actionable ideas to improve the process (van Eck et al., 2015).

To date, the focus of process mining research has largely been on the development of techniques and less on the use of these techniques in practice (Grisold et al., 2020; Thiede et al., 2018). While existing techniques enable process analysts to generate a wide range of process analysis insights, translating them into improvement ideas requires providing healthcare professionals with the information they need. Currently, process mining literature does not provide support for this stage in a process mining project. Existing process mining methodologies, such as the PM² methodology (van Eck et al., 2015), recognise the importance of the evaluation of process mining insights with domain experts, but provide limited guidance as to how it should be operationalised in an efficient and diligent way. In addition, it is expected that the healthcare sector has specific information needs in comparison with other sectors (Martin et al., 2020). As a consequence of the lack of methodological support for the evaluation stage and the lack of knowledge on information needs of decision-makers in healthcare, the path from process mining insights to process improvement ideas remains a black box.

Against this background, we derive the following research question: "How can process analysts evaluate process mining insights with healthcare professionals in order to generate actionable process improvement ideas?". To answer this research question, this paper uses action research to introduce a novel three-staged method, the INTEL funnel, to support process analysts when evaluating process mining insights with

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healthcare professionals. Through the stages of process familiarisation, domain explanation and improvement ideation, the method structures the path from process mining insights to actionable process improvement ideas. As such an overarching method to evaluate process mining insights with healthcare professionals has not been defined before, this novel method provides a valuable contribution to process mining in healthcare as a research domain. In particular, by facilitating moving from the analysis phase towards actually improving healthcare processes, our work can contribute to a more systematic uptake of process mining in healthcare, which is marked as a crucial challenge in the field (Martin et al., 2020).

The remainder of this paper is structured as follows. Section 2 provides an overview of the related literature. Section 3 describes the action research method that has been used to develop and refine the proposed method. The INTEL funnel, which is the method resulting from action research, is introduced in Section 4. Section 5 discusses the introduced method in relation to extant literature. The paper ends with a conclusion and recommendations for future work in Section 6.

2. Related Work

Process mining techniques have been applied more frequently in healthcare contexts than in any other domain (Dakic et al., 2018). As opposed to other domains, healthcare processes are particularly characterised by their complexity. While this may have contributed to the interest of process mining researchers in the healthcare domain, it also makes it challenging to apply process mining in healthcare. Over the years, several authors have pursued solutions to tackle the complexity of analysing healthcare processes. Many of these solutions revolve around the development and application of trace clustering techniques (Bose & van der Aalst, 2009; Mans et al., 2008; Song et al., 2008). More recently, increasing research attention has also been paid to event log quality, which is especially relevant in a healthcare context where data recording often depends on a manual action. The presence of event log quality issues such as missing data or incorrect data (Mans et al., 2015), can make the application of existing process mining techniques difficult, or even impossible (Andrews et al., 2019, 2020; Fox et al., 2018; Ghasemi & Amyot, 2016; Martin et al., 2019). Proposals to resolve such data quality issues often require domain knowledge (Alvarez et al., 2018).

Both the complexity of healthcare processes, as well as the event log quality issues that typically prevail, result in a heavy reliance on healthcare professionals to evaluate analysis results (Rojas et al., 2016). Many of the studies applying process mining in healthcare result in the discovery of potentially valuable insights, but do not elaborate on the evaluation of those insights with domain experts to assess their value in implementing process improvements. Often, it is mentioned that additional domain knowledge is required to give meaning to the patterns found (Emamjome et al., 2019; Huang et al., 2014; Martin et al., 2020). As such, there is a need for methodological guidance to incorporate the knowledge of domain experts in process mining projects, especially in healthcare contexts.

A variety of methods have been proposed to guide the execution of process mining projects in general. These methods include among others the Process Diagnostics Method (Bozkaya et al., 2009), the L* life-cycle model (Van der Aalst, 2011), and the Process Mining Project Methodology (PM²) (van Eck et al., 2015). They generally adopt the following structure: (1) definition of questions, (2) data collection, (3) data pre-processing, (4) mining & analysis of results, (5) stakeholder evaluation, and (6) implementation (Emamjome et al., 2019). Whereas in-depth methodological guidance has been developed for other phases such as data collection and analysis (e.g. Jans et al. (2019) and Bozkaya et al. (2009), respectively), existing process mining methods lack actionable support for insights evaluation, especially in involving domain experts (Koorn et al., 2021).

Although methodological support is currently missing for how to approach the evaluation of process mining results with healthcare professionals, approaches to enhance the interpretability of process mining insights have been developed. These approaches predominantly revolve around breaking down the complexity of healthcare processes in order to make them easier to understand. In the pre-processing phase of process mining projects, complexity is often decreased by breaking down event logs into smaller logs (Mans et al., 2008). By abstracting from in-depth details and taking a high-level view of the process, the amount of information presented to the process analyst is limited and, hence, potentially easier to interpret (Mans et al., 2008).

The techniques proposed to break down information in an effort to enhance the interpretability of process mining insights currently focus on process analysts. However, in terms of evaluating analysis insights with domain experts, the same need for breaking down information arises. In their overview of the literature on process mining in healthcare, Rojas et al. note an “absence of a good visualisation of the process models and the results obtained, especially in

complex and less-structured processes, such as those found in the healthcare domain" (2016, p. 232). The authors point out the need for improved visualisations and analytics to better guide the interpretation of process mining findings in healthcare settings. Huang et al. reach a similar conclusion in a study undertaken on mining clinical pathways, concluding that the "spaghetti-like" patterns are difficult to understand by clinicians and therefore are not very helpful in analysis and improvement efforts (2014, p. 112). In particular, they note that existing process mining techniques do not tell the whole story; domain experts are needed to provide the meaning and significance to the insights. Therefore, there is a need to provide support for evaluating such insights in the context of process mining projects.

3. Method

In line with our aim to discover the necessary stages in translating process mining insights into improvement ideas, we made the decision to heavily involve the client, i.e. the healthcare professionals, in the development of our method. Action research is an established method for client-researcher participatory studies. It is distinguished from other research methods by its collaborative character in which researchers perform a number of cycles of action and reflection within a research setting. Moreover, a characteristic of action research is the dual role of the researcher: as agent of the change on the one hand, and observer on the other (Bradbury, 2015). In the context of this study, these characteristics are reflected especially in the role of the first author, who also acted as process analyst. In that role, the first author was involved in reflecting on the lessons learned as well as taking part in the action. As opposed to other methods, this allowed the researchers to immediately see the effects of changes in the developed method.

The study was executed in line with the ethical procedures of Utrecht University and the healthcare organisations of study. The involved participants have given consent to the researcher to gather data on the action research cycles and how they acted throughout the project. For the data analyses, no personal data of individual patients or employees were collected to ensure compliance with the General Data Protection Rights (GDPR) data regulations. All event data extracted were anonymised before being provided to the researcher through encrypted servers. In the following sections, we explain the details of the methods used in the study.

3.1 Research Locations

The study was conducted at two separate hospitals in The Netherlands that differ in size and decision-making culture. The two locations make use of different hospital information systems (HISs), representing the dominant HIS vendors in the country. *Location 1* is a top clinical hospital with around a thousand beds. When improving processes and making changes to the HIS, they take pride in heavily involving healthcare professionals in the decision-making process. In order to take the complexity of different views into account, the team involved in the process mining project included: a policy officer, nurse, application manager, business intelligence specialist, and the first author. *Location 2* is a general hospital featuring around two hundred beds. Being a much smaller hospital, department managers are in close contact with healthcare professionals and support staff and are aware of the sentiment around processes. As the decision-making lies with the department managers, the team involved in the process mining effort included two of the involved department managers and the first author.

By conducting the study at two clearly different locations and project teams, we aim to provide a generalisable method that is applicable to different healthcare contexts. Moreover, location 1 acted as the location in which we could develop our method in an iterative way. Location 2 acted as a fresh context in which we could apply the findings from location 1 and evaluate the success of our method.

3.2 Background on the Process Mining Study

Although this study focuses on the evaluation phase of process mining projects, we will briefly set the scene and describe the preceding phases that were performed. In both locations, the processes that were to be analysed were predetermined by the team involved in the project based on the hospital's priorities. The processes fall under the category 'medical treatment processes' (Lenz & Reichert, 2007). In particular, we selected processes that were performed on a cross-departmental level, such that results from departments could be compared. For location 1, the decision was made to focus on processes performed on the nursing wards, specifically: (1) Screening a patient for malnutrition, (2) Recording the vital signs of a patient, (3) Placing a medication order, and (4) Discharging a patient. At location 2, we focused on processes performed at the outpatient clinics, namely: (1) Requesting and performing a peer consultation, and (2) Requesting and performing a radiology examination.

For each of the processes, a number of questions were defined that were to be answered during the project. Many of these were generic questions related to the three main pillars within process mining: discovery, conformance and enhancement (Van der Aalst, 2011). A number of them were related to a specific subcategory of conformance, namely the use of 'workarounds' within processes. Workarounds are intentional deviations from designed procedures, and some of them can be detected using process mining (Beerepoot et al., 2021).

The data necessary for analysing the selected processes and answering the questions were pseudonymised and provided to the process analyst by the business intelligence department of each hospital. We then transformed the data to the required event log format using Power Query, after which we used the PAFnow process mining plugin for Microsoft Power BI[1]. PAFnow provides a set of custom process mining visualisations that can be used alongside regular data visualisations, allowing for the creation of dashboards not possible using other tools. This allowed for presenting information in multiple ways, enabling the process analyst to anticipate upon the needs of the project team.

After importing the event log into PAFnow, the process analyst performed a series of analyses with the objective of answering the predetermined questions for each process. This resulted in a number of dashboards, containing both general information about the process, as well as specific dashboards with information that the process analyst deemed relevant for answering the research questions. More information on the event data and workarounds studied in location 1 can be found in Beerepoot et al. (2021).

3.3 Cycles of Action and Reflection

In line with the iterative character of both action research and process mining efforts, we performed a number of evaluation cycles across the two locations. Each cycle represents an evaluation session with the hospital team where the analysis insights of each of the processes were evaluated. Depending on whether new questions about the data arose, the researcher would start another round of data processing and analysis. Figure 1 illustrates the cycles of action and reflection, and is further explained below.

At location 1, we performed three evaluation cycles between January 2020 and May 2020. After those three cycles, no new information was requested by the participants and consensus on the improvement ideas was reached. The *evaluation* sessions were held in the form of interactive workshops and were facilitated by the process analyst, i.e. the first author. During the sessions, the analyst encouraged participants to think aloud with regards to how they interpreted the information presented to them, how they reached their conclusions, and optionally: what information they considered missing. After each evaluation cycle, the first author *reflected* on the discussions through qualitative synthesis (Denyer & Tranfield, 2006). The objective for the qualitative synthesis was as follows: (1) to define the type of

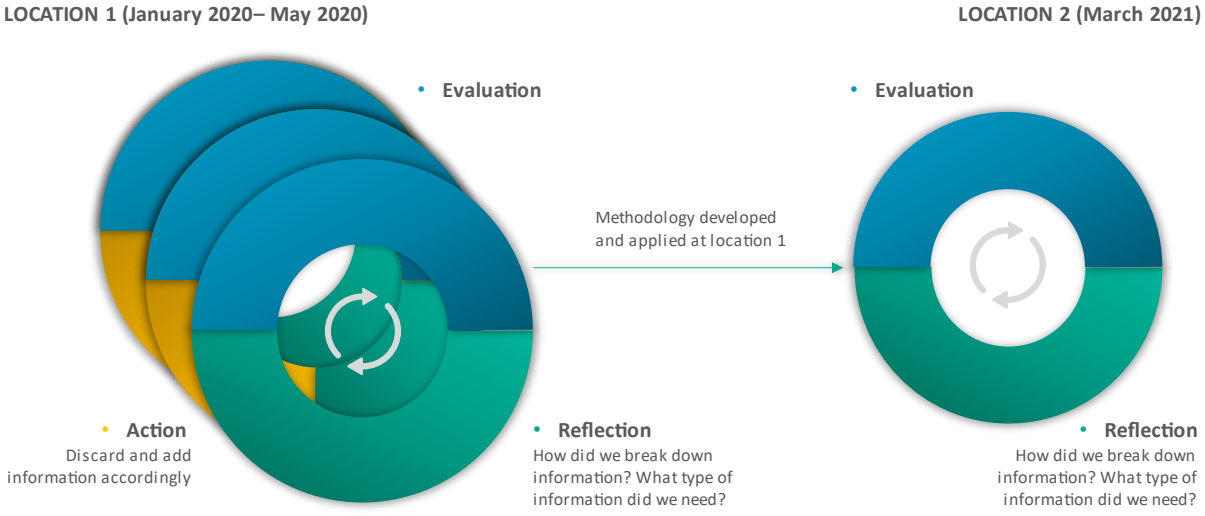

Figure 1 - Action Research Cycles

[1] https://pafnow.com/

information in the dashboards that was considered the most helpful for the evaluation team, and in extension (2) to discover the path for moving from insights to improvement ideas, by abstracting from the dashboards and defining the general steps necessary to fulfil the participants' information needs. In the case of starting a new cycle of data processing and analysis, the analyst took *action* and changed the dashboards accordingly, discarding information deemed unimportant and adding information deemed important. The third and last iteration did not include an action cycle as no further adjustments to the dashboards were needed. At location 2, after applying all lessons learned at location 1, only one cycle in March 2021 was deemed necessary by the team, providing evidence for the maturity of the method and its successful application in a different context.

The reflection and action cycles resulted in a method providing an overview of the evaluation stages and the type of information that was deemed most helpful in identifying insights to act on. This method is outlined in the following section.

4. Results

Based on multiple evaluation sessions at the two locations, we propose a novel method for INsighTs EvaLuation, called the INTEL funnel. The concept of the funnel refers to the idea that information from process mining analyses is iteratively broken down and reduced to result in actionable insights. The proposed method, visualised in Figure 2, consists of three stages: process familiarisation, domain explanation, and improvement ideation. As the evaluation takes place after the analysis, we assume that one or more analyses have been performed by the process analyst without the involvement of domain experts. The evaluation is aimed at interpreting the insights of the analysis with the healthcare professionals, resulting in one or more improvement ideas. The three stages are performed during each evaluation cycle, i.e. they can be performed multiple times during one process mining project. They are typically facilitated by a process analyst and attended by at least one, but preferably several, healthcare professionals representing different perspectives. Depending on whether new information is deemed necessary to achieve consensus on improvement ideas, another round of data pre-processing and analysis can be performed by the process analyst, before the evaluation with healthcare professionals is continued.

Figure 2 also highlights, for each stage, to which process perspective(s) significant attention is attributed (Kriglstein et al., 2016; Van der Aalst et al., 2011):

- control-flow (concerned with the order of activities)
- time (concerned with temporal aspects)
- organisational (concerned with resources and other organisational information)
- data (concerned with data attributes of events and cases, sometimes also referred to as case perspective)

It is important to note here that each of the stages builds further on the activities of the earlier stage. Rather than disregarding certain process perspectives later in the evaluation, this should be interpreted as a gradual shift in focus. For example, control-flow information is not disregarded after the first phase but remains in the funnel. However, the process variants that are irrelevant in the context of actionable insights are disregarded for the purpose of finding actionable insights. When moving through the funnel, we start with a rather general view of the process and systematically zoom in on the relevant information to end up with actionable improvement ideas.

The first stage, *process familiarisation*, provides the evaluation team with an overview of the process and the order of activities. By presenting the process map and discussing the variants, the participants get a feel of the scope of the process studied, what activities are included and more importantly, what is not considered. Within the process familiarisation stage, the team identifies interesting variants which are considered relevant to zoom further in on. The stage is concluded when the team reaches consensus on a selection of variants that are of particular interest in the context of improving processes. This selection constitutes the input for the next stage.

The next stage, *domain explanation*, concerns further interpreting the selected process variants by applying domain knowledge. Especially regarding temporal and organisational aspects of the process, domain experts can explain certain findings and patterns. Disregarding insights deemed unsurprising by the healthcare professionals allows those involved in the evaluation to further zoom in on the surprising ones. The stage is concluded when the team reaches consensus on a set of surprising insights that may be valuable in deciding on possible process improvements. As such, those insights are the input for the final stage of the evaluation.

The final stage, *improvement ideation*, involves translating the identified surprising insights into specific improvement ideas. At this point in the session, the team performs in-depth discussions related to the time, organisational and data perspectives of the process. This stage results in specific improvement ideas, which are actionable and constitute the basis for an implementation trajectory.

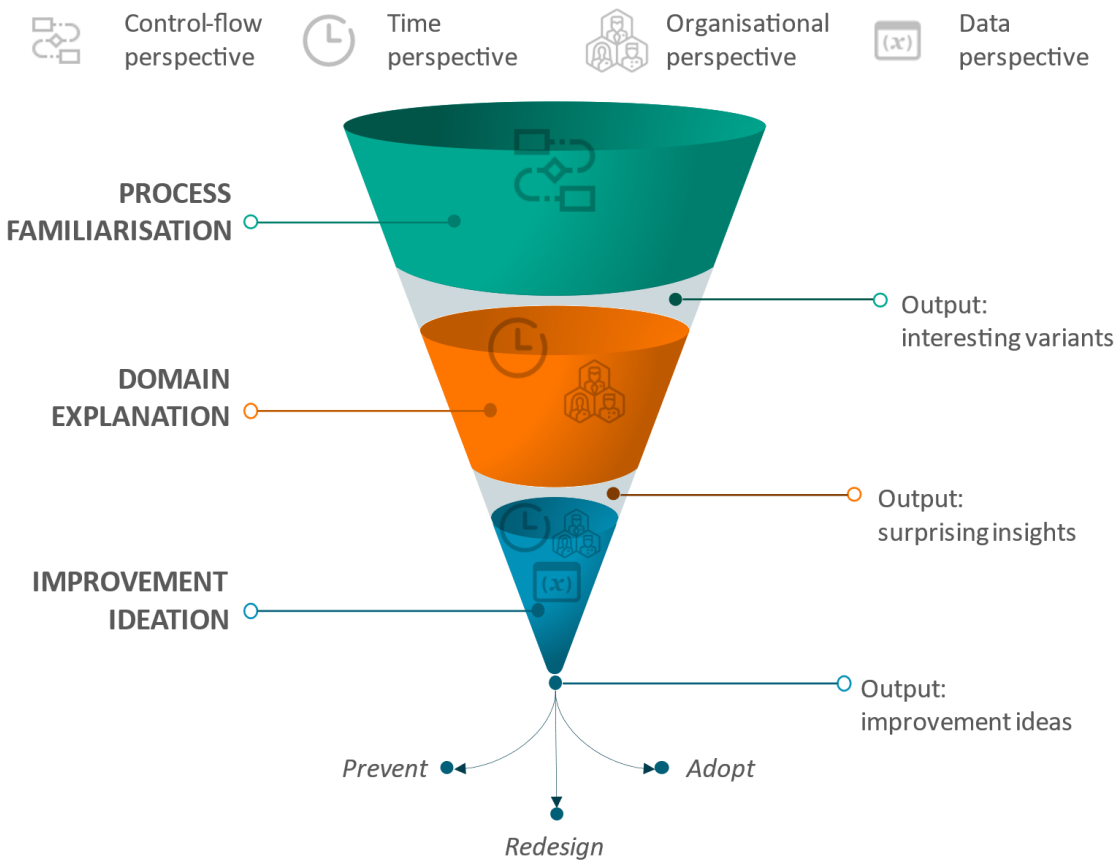

Figure 2. The INTEL Funnel

Three key categories of improvement ideas and associated actions can be distinguished:

- *Prevent*: ideas for developing measures to block particular process behaviour in the future;
- *Adopt*: ideas for formalising particular process behaviour into the formal process in the future;
- *Redesign*: ideas for changing the process, for example by making changes to information systems.

These three action types were adopted from the Workaround Snapshot Approach (Beerepoot & van de Weerd, 2018). At first, they were only used to discuss actions related to the detected workarounds, but found applicable to discuss generic process mining insights as well. Note that with choosing prevent, the normative process remains the same, while with adopt, it is changed. The difference between adopt and redesign is that with the former, process behaviour that already exists is formalised, while with the latter, the process as it exists is reimagined. The Workaround Snapshot Approach includes one more action, ignore, but as the key premise of the improvement ideation stage is identifying opportunities for process improvement, this was never considered.

Sections 4.1 until 4.4 describe each of the stages in detail, providing examples from the two locations and the information types, or process perspectives, that were used in each of the stages. The visualisations described can be found online at https://bit.ly/3SejLT2.

4.1 Process Familiarisation

The first stage of the evaluation, process familiarisation, is aimed at providing a high-level overview of the process and getting the team to understand the meaning of the information in the dashboards. To get familiar with the process, visualisations illustrating the control-flow were particularly helpful to the evaluation team. By showing the order of activities and corresponding variants, the team could grasp the available information on the processes and classify the variants into interesting and less interesting ones.

To illustrate the first stage of process familiarisation and the output thereof, consider the following example from our study. The process of *screening a patient for malnutrition* typically starts

with the patient arriving at the hospital. Afterwards, the patient is usually hospitalised and then screened, although it also occurs that the patient is screened before hospitalisation or that the time of hospitalisation is unknown. After the screening, the results are registered. When the results are registered, the process either ends, or a consultation with a dietician is planned and held. Discussing the order of activities shown in the process map helped identify interesting process variants to zoom into further. For example, the healthcare professionals deemed it particularly interesting that a number of patients is screened for malnutrition before they are officially hospitalised, a positive development. Another variant of interest was that of patients where no hospitalisation is registered. Last, there was a particular interest in the circumstances in which a consultation is held or not.

4.3 Domain Explanation

After familiarisation with the process and identification of interesting variants to zoom in on, we continued with interpreting these variants further using the domain knowledge of the healthcare professionals. During this stage, we particularly made use of visualisations containing information from the time and organisation perspective. In doing so, the domain experts could explain certain insights deemed surprising by the process analyst but not very surprising by the domain experts, when taking into account the characteristics of certain departments, occupations, or time periods. Hiding information deemed unsurprising by healthcare professionals allowed a more focused analysis of surprising results.

To illustrate the domain explanation stage, consider the process of *placing a medication order*. Normally, doctors prescribe medication for patients, and nurses often administer this medication. However, in situations where the doctor has not done so and is not available, a nurse can place a one-time medication order and administer it right away. In order to discuss this, we visualised the time of the day where such one-time orders are created. Discussing this visualisation during the domain explanation phase allowed the clinicians to point out that the results largely translate to the usual medication cycles: just before 9 AM, noon, 6 PM, and 10 PM. However, they also noted that during these times the doctor should be available to prescribe the medication rather than have nurses do so, which constituted a surprising finding. The numbers between 10 PM and 8 AM were considered less surprising because doctors were not available. These insights provided input for the next stage in the evaluation, with the aim of minimising the use of one-time medication orders such that nurses' medication times decrease.

To illustrate the domain explanation stage with another example, consider again the medication order process, but this time the other path of placing a medication order: namely using a particular button that allowed nurses to specify a type of medication that their department had (almost) run out of. Using this functionality would result in the hospital pharmacy receiving an order to deliver the medication to that department. We provided the team with an illustration of the frequency with which the functionality was used to request different types of medication, over each of the departments. Zooming in on the types of medication requested per department allowed the domain experts to point out which results were surprising and which ones were unsurprising. Such information was deemed valuable for assessing whether a specific type of medication should be included in the standard medication set of that department, saving the nurses and pharmacy time. The latter is an example of a *redesigned* process, as changes are being made to the information system, thereby reimagining the normative process.

4.4 Improvement Ideation

The final stage of improvement ideation is aimed at identifying the key insights and brainstorm for potential improvement ideas. At this point in the evaluation, the unsurprising results are hidden from view, providing the domain experts with a focused presentation of where improvement efforts are necessary. This results in the identification of improvement ideas and the associated actions, categorised as prevent, redesign, or adopt. As in the previous stage, it was particularly helpful to look at the organisational perspective by comparing different departments. Improvements would typically be implemented on the departmental level, and comparing departments helps put absolute numbers into perspective which helps decide where to act. Other than the comparison of numbers over departments, the improvement ideation stage also involved focusing on the time and data perspective.

To illustrate the improvement ideation stage, consider the process of *discharging patients from the hospital*. Before a patient is discharged from a clinical department, a number of tasks need to be performed, one of which being the generation of a visit summary by a nurse. We visualised the number of times where such a visit summary was generated for each department, relative to the total number of patient discharges for that department. Based on this information, the evaluation team was able to conclude

that most departments meet this agreement, but that some departments are surprisingly underperforming in this respect. Drilling down to this particular part of the process and putting the numbers into perspective allowed the evaluation team to identify departments where improvement is possible and necessary. During the improvement ideation stage, plans were made to approach the departments that produced worrying results, to make them aware of the agreement and to monitor the developments over time. As such, the *prevent* action was chosen.

5. Discussion

In this study, we set out to develop a method to support process analysts when evaluating process mining insights with healthcare professionals in order to convert them to actionable improvement ideas. Although current literature does not provide such a method yet, parts of our findings resemble earlier reflections by other authors. We discuss such resemblances and differences in the following sections.

5.1 Reflection on the Proposed Stages

The first stage that we distinguish in evaluation efforts relates to process familiarisation. Although this stage has not yet been proposed as a stage in the evaluation process, it has been mentioned as a necessary activity for *process analysts* in other phases in process mining projects. For example, Klinkmüller et al. (2019) identify the activity of familiarisation as one where analysts examine domain problems. Other studies mention familiarisation activities in the data preparation or pre-processing phases of process mining endeavours (Carvallo et al., 2017; Valle et al., 2019). As there is evidence that process analysts need to spend time and effort to get familiar with the process, its characteristics and particularities, the same holds for the moment the domain experts are involved in evaluating the findings and making sense of them. In fact, domain experts often lack experience with process mining and process thinking in general, making interpretation of findings difficult and time-consuming (van Eck et al., 2015). Approaching process familiarisation as a dedicated stage during evaluation may help smoothen the path to improvement.

The second stage in our method is domain explanation. Several studies in the field of process mining have hinted at the importance of domain knowledge for interpreting, explaining and enhancing findings (e.g. Baier et al., 2014; Dixit et al., 2015). Focusing and acting on the data alone is believed to give an incomplete picture of the process, and could lead to incorrect decisions. In healthcare, the contextual and domain-specific knowledge that healthcare professionals can offer is believed to be especially vital (Mannhardt & Blinde, 2017; Montani et al., 2014). Including domain explanation as a dedicated stage in the proposed method allows domain experts to systematically interpret findings and distinguish between surprising and unsurprising process mining insights. It can also facilitate making correct decisions in the final stage of the method as it sets a clear focus on surprising insights from the perspective of healthcare practitioners.

The final stage in the INTEL funnel, improvement ideation, is the least discussed one in current process mining literature. General process mining methods that have been proposed often prescribe a process improvement phase after the evaluation has been completed (Van der Aalst, 2011; van Eck et al., 2015). However, how the improvement ideas are generated has largely been unknown. The INTEL funnel constitutes a first attempt to structure the various stages of generating improvement ideas starting from process mining insights.

5.2 The Importance of Context

From the previous sections, it is evident that several ideas underlying the INTEL funnel are considered valuable in various other phases of process mining projects, such as pre-processing and analysis. However, one element has proven to be especially important in the evaluation phase, even more so than in other phases, and that is *context*. A common reason for failed process improvement projects, is the lack of context-awareness (Benner & Tushman, 2003; vom Brocke et al., 2014). Within process mining projects, the results of the evaluation are the input for process improvements. As such, the resulting improvement ideas need to take contextual factors into account in order to be successfully implemented. Indeed, in the evaluation sessions with healthcare professionals, it became evident that deciding on the most appropriate improvement actions depends highly on contextual factors. Insights that may seem surprising at first, are sometimes no longer surprising when temporal and organisational factors are taken into account. Discovered process behaviour may be prevented in one department, but adopted in another, depending on the circumstances within the department.

The importance of contextual factors in generating appropriate improvement ideas also highlights the significance of incorporating multiple process perspectives in process mining efforts. In process mining research and applications, there has

been and still is a predominant focus on the control-flow perspective on the process (Mannhardt et al., 2016). The time, organisational, and data perspectives have received far less research attention. In our study, we found a control-flow model to be highly valuable in the evaluation phase of projects, especially at the start of evaluation sessions. However, we also noticed the importance of the other process perspectives and found that the organisational perspective was particularly vital as hospitals tend to strongly focus on individual departments and how they compare to others. Techniques that help to visually compare process behaviour within departments and include contextual information are scarce, but would be highly valuable in facilitating decision-making within hospitals.

6. Conclusion and Future Work

In this study, we propose the INTEL funnel, a novel three-staged method to support process analysts when evaluating process mining insights with healthcare professionals. The method aims to assist process analysts in translating process mining insights into actionable improvement ideas through iterative cycles with healthcare professionals. It constitutes the first attempt to open the black box regarding the path from process mining insights to actionable improvement ideas. As the method is developed using action research at two distinct healthcare locations, we also pay particular attention to the complexity of healthcare processes and healthcare organisations. For future work, we aim for a broader application of the INTEL funnel in different types of healthcare settings to further substantiate its generalisability and generate high-quality improvement ideas in healthcare.

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