Creating an Explainable Artificial Intelligence Framework to Increase Nurses' Confidence in an Interhospital Transfer Scenario

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Abstract

Emergency patients' Interhospital transfers (IHT) is becoming important due to adverse clinical outcomes and overcrowding of the transferred emergency department (ED). Since determining whether referred patients should be authorized needs deep consideration of multiple influencing factors, experienced ED patient flow nurses take the critical responsibility of making this decision in order to enhance the efficiency of ED management. Artificial Intelligence (AI) systems have been developed to support health providers' decisions. However, it is questionable whether health providers are willing to follow the decisions recommended by such AI systems due to its unclear decision-making process. In this study, we propose an XAI framework to increase nurses' confidence in the decision recommended by the AI system in an IHT scenario.

Introduction

In the modern healthcare system, interhospital transfer (IHT) of emergency patients is inevitable to secure specialized care and minimize any potential risks of adverse clinical outcomes and overcrowding of the transferred emergency department (ED) (Hernandez-Boussard et al. 2017; Kulshrestha and Singh 2016). Since various influencing factors from health providers are involved to determine if a referred patient is authorized, experienced ED patient flow nurses are often assigned to improve the efficiency of ED management. Although many AI prediction models reveal a high accuracy of decision-making in a health domain (Jiang et al. 2017; Salathé, Wiegand, and Wenzel 2018; Vaishya et al. 2020; Kelly et al. 2019), little is known about how much each model can explain decision-making process that leads to the results in an understandable way. Also, it is questionable whether such models would provide health providers with clear rationales about why the decision from the AI system is worth considering. Furthermore, there still remain questions about how to create an approach to increasing healthcare providers' confidence in the AI system in hospital decision scenarios (van der Waa et al. 2021; Payrovnaziri et al. 2020). Here, we propose an XAI framework for increasing ED patient flow nurses' confidence for the decision proposed by the AI system in an IHT scenario, which is considered one of the most time-critical hospital decision problems.

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Overview of Our Proposed XAI Framework

The goal of creating an XAI framework is to enable ED nurses to decide with high confidence under the time- sensitive emergency scenario by interacting with an AI system using the XAI approach we propose. According to prior work (Meske et al. 2021), the primary role of the XAI framework in our scenario is to enable AI users (i.e., ED nurses) to understand the AI system's reasoning with their own reasoning through explainability features (e.g., visualizing factors that affected a decision-making process). The XAI framework consists of an XAI model and an XAI interface (see Figure 1). The XAI model is generated by performing the following three tasks: (1) creating personas using demographic data, internal factors, and external factors, (2) calculating the expected utility value using the values of internal and external factors (see Tables 1 and 2), (3) converting each expected utility value to a percentage. Each converted expected utility value is then used to generate a bar chart on the XAI interface.

Simulation to Demonstrate Value of Our Proposed XAI Framework

To assess the value of our proposed XAI framework, we performed a simulation using personas of three virtual ED nurses who are likely to be in a real-world scenario.

Creating personas with multiple factors

In order to evaluate our XAI framework, first, we created personas using demographic data, internal factors, and external factors. As illustrated in Figure 5, to demonstrate the value of our proposed the XAI framework, we created three personas that present ED nurses responsible for making a decision in an IHT scenario. Personas were related with (1) demographic data (e.g., age, gender, years of working experience), (2) internal factors (e.g., work stress of IHT decision-making, a burden of inappropriate decision-making), and (3) external factors (patient/guardian complaints due to refusal).

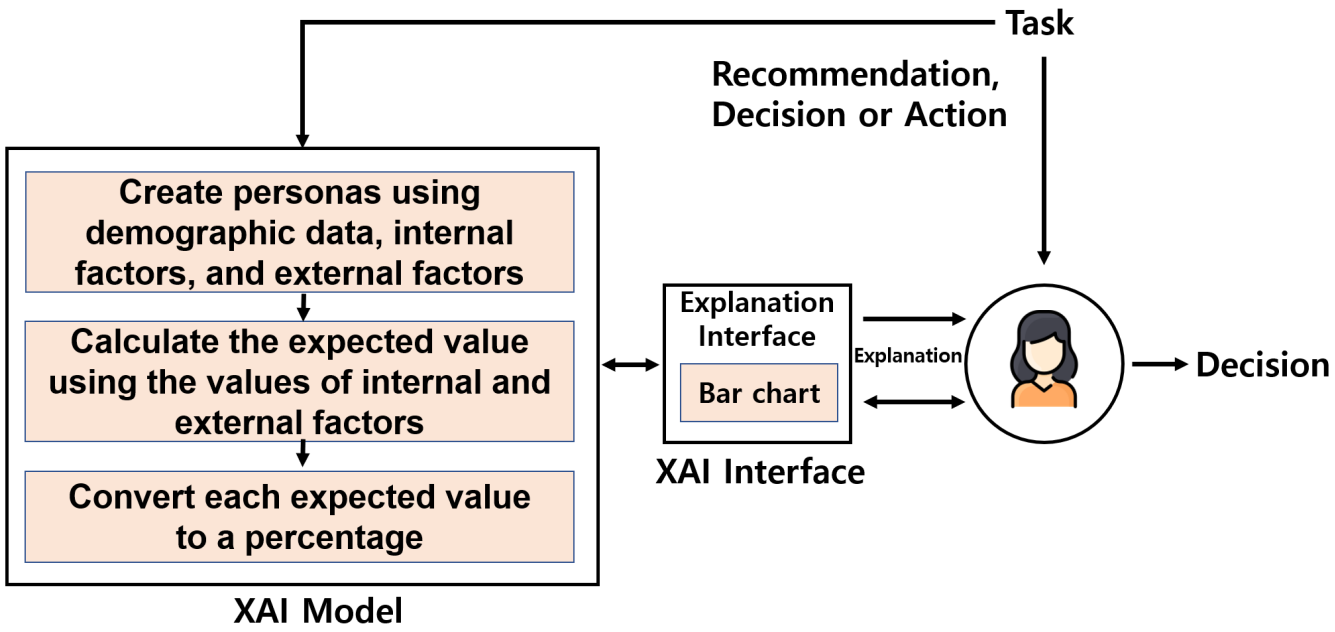

Figure 1: On the basis of prior work (Gunning and Aha 2019), we created an XAI framework that allow an ED nurse to interact with an XAI interface so that the ED nurse makes his/her decision in a way that reduces stress and anxiety in our ED scenario by obtaining explanation of a decision-making process from our proposed XAI framework.

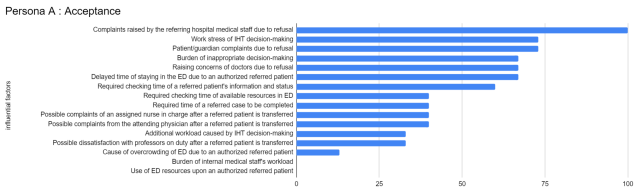

Figure 2: Persona A was considered to accept the patient due to multiple factors. According to the bar chart by our proposed XAI framework, the top five factors are as follows: (1) complaints raised by the referring hospital medical staff due to refusal; (2) work stress of IHT decision-making; (3) patient/guardian complaints due to refusal; (4) burden of inappropriate decision-making; and (5) raising concerns of doctors due to refusal. The primary factors that had a significant impact on persona A include a lot of work experience but were being afraid of evaluation and criticism from others health providers.

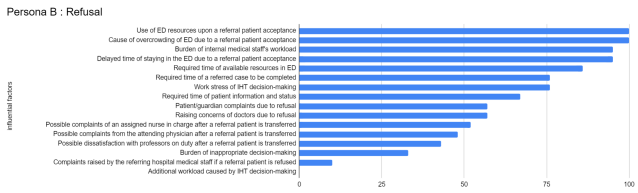

Figure 3: Persona B was expected to consider refusing the patient due to multiple reasons. According to the bar chart by our proposed XAI framework, top five factors are as follows: (1) use of ED resources upon a referral patient acceptance; (2) use of overcrowding of ED due to a referral patient acceptance; (3) burden of internal medical staff's workload; (4) delayed time of staying in the ED due to a referral patient acceptance; and (5) required time to check ED resources. The main factors that had a significant impact on persona B were the use of internal resources and the workload of ED staff members.

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Below are three personas used in our simulation: (1) persona A (M/39) has 13-year ED experience and is currently in the 4th year of an ED patient flow nurse. He is also very satisfied with his work but is sensitive to the evaluation and criticism of others; (2) persona B (F/32) has 8-year ED experience and is currently in the 1st year of an ED patient flow nurse. She is also very satisfied with her job but under a lot of stress lately. She is principled and stubborn; (3) persona C (F/29) has 4-year ED experience and is currently in three months as an ED patient flow nurse. She is still adjusting to the role of the ED patient flow nurse. She is overloaded with work and very stressed out.

Calculating the expected utility values by using internal and external factors

The expected utility values were calculated using the internal and external factors. For the actual value, the required time was calculated in minutes. The number of tasks was calculated on a scale of 10 for worry, dissatisfaction, and stress. The value was converted from the actual value to the 5 points scale. The weight was calculated by consensus among the authors based on the importance of each factor for each persona.

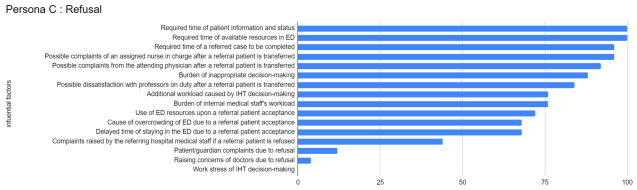

Figure 4: Persona C was anticipated to refuse the referred patient regarding multiple factors. According to the bar chart generated by our proposed XAI framework, the top five influential factors are as follows: (1) required time of patient information and status; (2) required time of available resources in ED; (3) required time of a referred case to be completed; (4) possible complaints of an assigned nurse in charge after a referral patient is transferred; and (5) possible complaints from the attending physician after a referral patient is transferred.

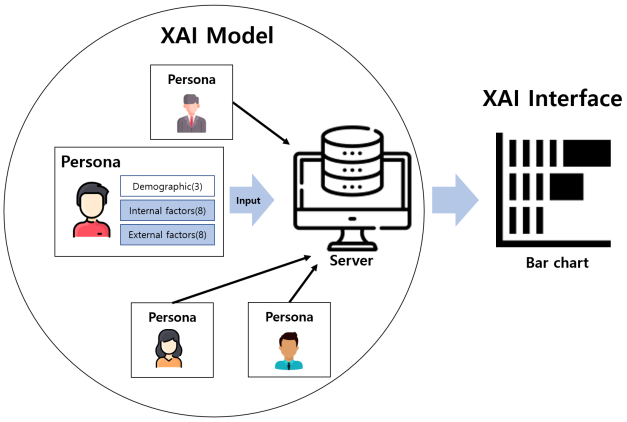

Figure 5: The XAI model is a process in which the internal and external factors of each persona are input to the server and go through a process within the server. The values converted through the XAI model are visualized in the form of a bar chart through the XAI interface.

Determining the values for generating a bar chart

The expected utility values were calculated by multiplying the value by the weight and converted to a percentage. We then created a bar chart indicating expected utility values for each internal and external factor.

Findings

In this section, we report how our proposed XAI framework was used to deliver a decision-making process to different personas. As illustrated in Figure 2, persona A considered the time to make a decision and the burden of the internal medical staff more important. The burden of external complaints and the civil complaints raised when all members were rejected showed a high impact. This may be because persona A had a lot of work experiences but was afraid of evaluation and criticism from others. As shown in Figure 3, in persona B, internal factors, such as overcrowding of ED, resources of ED, and ED length of stay had a high influence on decision making. In addition, complaints and the burden of complaints showed a low impact since persona B tended to be usually principled and stubborn. Persona C had a short work experience and less experience in making difficult decisions. Therefore, the processing time for the requesting patient, dissatisfaction with internal medical staff, and the burden of wrong decision-making had a high impact on persona C's decision making (see Figure 4). It occured because persona C had a short work experience and less experience in making difficult decisions.

Discussion

Our findings shed light on how to better support ED nurses by creating an XAI framework. In this section, we describe particular challenges and opportunities for creating an XAI framework to support stakeholders in hospital decision scenarios.

Factors affecting hospital decision making

Persona A showed that the burden of external complaints and the complaints raised when rejected was higher than the time required for work and the burden of internal medical staff when making decisions. This may be because Persona A has a lot of work experience but is afraid of evaluation and criticism from others. In a hospital decision scenario, we wondered if there are some cases where individuals make different decisions for a difficult decision problem. It was also questionable what factors might influence clinical decision-making. It was reported that influential factors in clinical decision-making include the decision-maker's experience, intuition, and work environment (Hernandez-Boussard et al. 2017; Kulshrestha and Singh 2016; Jiang et al. 2017; Salathé, Wiegand, and Wenzel 2018; Vaishya et al. 2020; Kelly et al. 2019; Wu et al. 2021; Kızrak, M¨uft¨uoğlu, and Yıldırım 2021; van der Waa et al. 2021). For these reasons, it was likely that there may be differences in each decision in the difficult clinical decision-making situation of nurses. Thus, a variety of factors may influence nurses' other hospital decision making situations.

Tools to improve trust in hospital decision making

In persona B, internal factors such as overcrowding of ED, resources of ED, and ED length of stay showed a high influence on decision making, and complaints and the burden of complaints showed a low influence on decision making. This could be because persona B is usually principled and stubborn. We wonder if there are any perfectly matched clinical decision-making tools that do not reflect the individual characteristics of decision makers. Several tools increase the confidence of clinical decision-making include antibiotic management systems, and triage (Meske et al. 2021; Andersson, Omberg, and Svedlund 2006; Jang and Lee 2019). However, it does not reflect the characteristics of individual decision-makers. In addition, it is said that the nurse's clinical decision-making process was concluded in between situational variables and contextual variables (Payrovnaziri et al. 2020). Therefore, it is likely that various factors may be reflected in nurses' difficulties in clinical decision-making.

	Influential Factors	Raw Data	Value	Weight	Expected Utility Value
Internal	Required time of patient information and status	5 min	-1	0.07	-0.07
Internal	Required time of available resources in ED	7 min	-2	0.05	-0.10
Internal	Required time of a referred case to be completed	15 min	-2	0.05	-0.10
Internal	Additional workload caused by IHT decision-making	6	-1	0.11	-0.11
Internal	Work stress of IHT decision-making	1	-5	0.01	-0.05
Internal	Burden of inappropriate decision-making	9	-3	0.01	-0.05
Internal	Complaints raised by the referring hospital medical staff if a referral patient is refused	10	-1	0.01	-0.01
Internal	Burden of internal medical staff's workload	6	-2	0.08	-0.16
External	Possible complaints of an assigned nurse in charge after a referral patient is transferred	5	-1	0.1	-0.10
External	Possible complaints from the attending physician after a referral patient is transferred	5	-1	0.1	-0.10
External	Possible dissatisfaction with professors on duty after a referral patient is transferred	5	-1	0.11	-0.11
External	Patient/guardian complaints due to refusal	1	-1	0.05	-0.05
External	Raising concerns of doctors due to refusal	1	-1	0.06	-0.06
External	Use of ED resources upon a referral patient acceptance	1	-2	0.08	-0.16
External	Cause of overcrowding of ED due to a referral patient acceptance	5	-2	0.07	-0.14
External	Delayed time of staying in the ED due to a referral patient acceptance	6	-2	0.03	-0.06

Table 1: Examples of acceptance: For persona A, it took 5 minutes to check the status and information of all referred patients. The value for this was -1 on a scale of -1 to -5. The weight of the factor of Persona A was 0.07 and the expected utility value was -0.07 points multiplied by the weight and the expected utility value.

	Influential Factors	Raw Data	Value	Weight	Expected Utility Value
Internal	Required time of patient information and status	3 min	-3	0.07	-0.21
Internal	Required time of available resources in ED	5 min	-3	0.05	-0.15
Internal	Required time of a referred case to be completed	10 min	-3	0.05	-0.14
Internal	Additional workload caused by IHT decision-making	5	-5	0.11	-0.55
Internal	Work stress of IHT decision-making	5	-5	0.01	-0.05
Internal	Burden of inappropriate decision-making	7	-3	0.02	-0.06
Internal	Complaints raised by the referring hospital medical staff if a referral patient is refused	5	-5	0.01	-0.05
Internal	Burden of internal medical staff's workload	5	-1	0.08	-0.08
External	Possible complaints of an assigned nurse in charge after a referral patient is transferred	1	-1	0.1	-0.10
External	Possible complaints from the attending physician after a referral patient is transferred	1	-1	0.1	-0.10
External	Possible dissatisfaction with professors on duty after a referral patient is transferred	1	-1	0.11	-0.11
External	Patient/guardian complaints due to refusal	5	-5	0.05	-0.25
External	Raising concerns of doctors due to refusal	5	-5	0.06	-0.30
External	Use of ED resources upon a referral patient acceptance	3	-1	0.08	-0.08
External	Cause of overcrowding of ED due to a referral patient acceptance	1	-1	0.07	-0.07
External	Delayed time of staying in the ED due to a referral patient acceptance	1	-1	0.03	-0.03

Table 2: Example of refusal: Persona A's fear of being criticized by the medical staff of the referring hospital when all members were rejected was 5 out of 5 and the value for this was -5 on a scale of -1 to -5. The weight of the factor of persona A was 0.01 and the expected utility value was -0.05 multiplied by the weight and the expected utility value.

Opportunities of XAI for hospital decision making

We found that persona C was highly influenced by the processing time for the requesting patient, dissatisfaction with internal medical staff members, and the burden of wrong decision-making when making decisions. One of the primary reasons was that persona C tended to have a short work experience and less experience in making difficult decisions in hospital scenarios. Prior work reported that a reliable algorithm solves the urban logistics problem as a study where explanatory AI was applied to complex and professional decision-making and even evaluated by experts (Moon and Park 2016). Thus, it is likely that a reliable algorithm can be applied to complex and professional clinical decision-making. This shows a potential opportunity of using an XAI framework to improve hospital decision making, which seems to be similar scenarios reported in the study (Moon and Park 2016).

Conclusion

The goal of this study was to demonstrate what specific types of explainability are helpful to ED patient flow nurses in a time-critical emergency scenario with an IHT setting. To demonstrate the value of our proposed XAI framework, we presented a simulation using personas of three virtual ED nurses who are likely to be in a real-world scenario. The results of this simulation provided empirical evidence that an AI system using our proposed XAI approach has the potential to increase the confidence of ED patient flow nurses when they make a decision. However, since only three personas were used in one scenario for validating the XAI framework, future work remains to confirm the usability and feasibility of the XAI framework in various hospital decision scenarios with study participants involving multiple stakeholders, such as health providers, staff members, and patients.

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