A game-theoretic approach for studying nursing management performance in obtaining error notification

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Abstract

The interaction between nurses and their managers is a very important factor in nurses' error reporting behaviour, which is crucial to improve patient safety in health care organisations. However, little theoretical work has been undertaken to analyse this interaction. This paper attempts to take a modest step forward in closing this gap in the literature by considering a principal-agent model in which the principal (the nurse manager) asks the agent (the nurse) to perform a task with a certain patient. If the nurse makes a mistake while treating the patient, she has to decide whether to report it to the manager, taking into account that the manager can observe whether the patient suffered an accident. Considering different manager's leadership styles, the paper analyses their performance in obtaining error notification from nurses in this framework.

Keywords: Game with asymmetric information; nurse-manager interaction; leadership style; nurse error reporting; patient safety.

Acknowledgments

Alex Barrachina and Víctor González-Chordá wish to thank Universitat Jaume I under project P1-1B2015-48 and the Spanish Ministerio de Economía y Competitividad under project ECO2015-68469-R for its financial support.

1. Introduction

Patient safety is one of the most important priorities in healthcare organisations around the world and the development of a safety culture is one of the main objectives in healthcare organisations. The Joint Commission defines safety culture as "the summary of knowledge, attitudes, behaviors, and beliefs that staff share about the primary importance of the well-being and care of the patients they serve, supported by systems and structures that reinforce the focus on patient safety" (Hershey 2015). Chassin and Loeb (2013) identify 3 central components of safety culture: trusting, reporting, and improving. In addition, the existence of continuous improvement processes, teamwork, leadership, and error notification are the main predictors of a good safety culture (Ammouri et al. 2015).

The Institute of Medicine defines errors in health care as "the failure of a planned action to be completed as intended, or the use of a wrong plan to achieve the aim" (Kohn et al. 2000). The damage caused by these errors is known as adverse effects (AE), and those errors that could have harmed the patient but have not done so due to coincidence, prevention, or mitigation are known as near misses. Errors in healthcare have important clinical, economic and social implications. The incidence of AE in hospitals in different countries varies between 3.7% and 17% (Stryer and Clancy 2005), and AE has an annual cost of 4.4 million dollars in the United States (Levinson 2010). These rates may be underestimated (Hershey 2015), up to 50% of errors can be avoided by improving the care process (Stryer and Clancy 2005).

Errors are not only important for their consequences, also because they are a very important source of information to improve patient safety and quality of care. (Ritcher et al. 2014). The analysis of the errors provides information on the root causes of them and allows to establish improvement actions. For instance, according to a review carried out by the U.S. Joint Commission (Chatman 2009), poor communication is the root cause of approximately 70% of all errors in health care. According with Reason (1995), to reduce the number of AEs it is necessary to deal with near misses, in fact for each serious AE 10 mild AE and 600 near misses are produced. For this reason, healthcare professionals should notify near misses and AE so that the root causes of error can be studied to decrease the amount of errors, improving health care processes. The traditional approach is based on the study of individual failures caused by a lack of knowledge or skills, causing feelings of guilt, shame, anxiety, and loss of confidence among professionals (Mira et al. 2015). This approach can cause the non-notification of AE to increase to 96% (Barach and Small 2000), and it seems that the efforts made to improve the notification of AE and near misses do not have the desired results (Parmelli 2012).

Current strategies for achieving a safety culture go beyond individual responsibility, including a systems approach, open notification of errors, learning, and leadership, to implement improvements (Hershey 2015) in a multidisciplinary team made up of doctors, nurses, and other health care professionals (Riley 2009). Within this team, nurses spend the most time with users and are the most likely to make and detect errors (Page 2004), although there are intrinsic and extrinsic factors that determine whether a nurse will decide to report an error. Intrinsic factors relate to the training of the nurses and to a set of individual attitudes such as ignorance (not knowing what, or how, to notify), uncertainty (about responsibility of notifying), fear (work, professional, social, and legal implications), and lethargy (lack of interest) (De Angelis et al. 2016). These intrinsic factors are modulated by other extrinsic factors related to the work

environment (Badiyepeymaie Jahromi et al. 2014). On one hand, professionals' workload and lack of time are barriers that complicate notification because they mean extra effort (Hashemi 2012) and may increase the lethargy of nurses. On the other hand, nurses consider the management style and leadership from nurse managers and supervisors as one of the factors that influence their notifying intention the most (Badiyepeymaie Jahromi et al. 2014; Ritcher et al. 2014; Sammer et al. 2010).

Among these leadership styles of the nurse managers (Bass and Avolio 2000; Clarke 2013; Wong et al. 2013), transformational leadership is based on the relationship with employees and promotes healthy work environments, open notification, and non-punitive responses to an error notification (Cummings et al. 2010). This style of leadership is directly related to safety culture, reduces the number and severity of errors and is associated with greater satisfaction among nurses and better results in patients (Cummings et al. 2010; Merrill 2015; Wong and Giallionardo 2013). For its part, transactional leadership is based on a system of rewards and punishments (Cummings et al. 2010). A reward system enhances the commitment of nurses to the organisation (Hsu et al. 2015), but excessively authoritarian leadership where punitive responses or punishments preponderate increases fear among nurses and affects their preferences for notifying near misses or AE (Su 2013), making learning and continuous improvement difficult.

Therefore, the interaction between nurses and their managers plays a central role in nurses' error reporting behaviour, and it is important to know the consequences of this interaction if a high level of error notification is desired. The present paper analyses, from a game-theoretic approach, this interaction when a nurse might have made a mistake when performing a task with a certain patient (some details about nurses' tasks, their possible mistakes and their relation to patient accidents can be found in Alghamdi 2016 and Benner et al. 2002) and she has to decide whether or not to report the mistake to her manager. More precisely, the paper considers a simple principal-agent model in which the principal (the nurse manager, which will be referred as "he") asks the agent (the nurse, which will be referred as "she") to perform a task with certain patient. The nurse may make a mistake when treating the patient, and the patient may suffer an accident. If the patient suffers an accident, it is observed also by the manager, but if the nurse makes a mistake, it is known only by her and she must decide whether or not to report it to the manager. After the nurse performs the task, the manager has to decide between punishing (punitive and disciplinary solutions are the traditional solutions to nurse's mistakes and/or patient accidents, and they still exist against safety culture principles, see for instance Chassin and Loeb 2013), rewarding (based on trust or monetary payments; see for instance Hsu et al. 2015) or sending the nurse to a training program (Berdot et al. 2016) depending on whether he received a report of an error or observed whether the patient suffered an accident.

In this set-up, the objective of the paper is to analyse the performance of different manager's leadership styles in obtaining error notification from the nurse. To do so, it is considered the leadership style as if it were due to the personality of the manager, represented by his preferences over the three usual actions in nursing management considered above (punishing, rewarding or

training) in the various possible scenarios the model considers. In particular, following the nursing management literature (see citations above), the present paper considers four leadership styles. The two extreme styles are the *transformational style* and the *authoritarian style*. The former is characterised by a strong preference over non-punitive, formative and rewarding actions, while the latter prefers punitive actions and does not consider the possibility of training or rewarding the nurse in any situation. In between these two extreme styles, this paper considers the *transactional style* based on a combination of punitive, formative and rewarding actions. The paper considers two levels of the *transactional style* depending on the focus on punitive solutions: the *hard transactional* and the *soft transactional*.

The model also considers that nurses' willingness to report errors depends on, as stated above, personal attitudes and organizational aspects. In this sense, following the organisational behaviour literature, three styles of error reporting are considered, again as determined by nurse's personality. Each personality (style) is represented by nurse's preferences over reporting and not reporting a mistake in the different possible situations considered in the model. These three styles are *active*, *reactive* and *passive*.

The paper analyses the interaction between each leadership style and each style of nurse in this error reporting set-up and attempts to evaluate the performance of each leadership style in obtaining error notification. According to the results, the performance of the soft transactional style is generally better than the performance of the hard transactional and the authoritarian styles, although the last two styles may make a reactive nurse more inclined to report a mistake. The problem with a pure transformational style is that passive and reactive nurses take advantage of this leadership style's preference for non-punitive actions, discouraging them from reporting a mistake when there is a patient accident. In this sense, the performance of the soft transactional style is also better than the performance of the transformational style. Given that the soft transactional style is a combination of the transformational and the hard transactional styles, these results are coherent with the conclusion of Clarke (2013) suggesting that the most beneficial leadership style for improving safety culture (which in the health care context includes error reporting from nurses as a fundamental tool for continuous improvement; see Riley 2009; Squires et al. 2010; Chiang and Pepper 2006) would be a combination of this kind.

The paper is related to several research strands. The first strand is the literature on the management of health care organisations in general and the nursing management in particular, extremely focused on nurse schelduling and rostering (see for instance Duenas et al. 2009). The paper extends the spectrum topics in this literature since the management performance in obtaining error notification has not been considered yet.

The paper is also related to the theoretical models of interaction among health care organisations' members (such as managers, physicians, nurses and patients), which has typically focused on the physician-patient relationship (for instance Ancelot and Oros 2015, and Xie et al. 2006), the

hospital manager (or public regulator)-physician interaction (Chan 2015; Crainich et al. 2011; Levaggi and Rochaix 2003), the hospital manager-physician-nurse relationship (such as Tavares 2014) and even on the inter-physician relationship (Chan 2016a) or the interaction between physicians and nurses (Chan 2016b). However, to our knowledge, the interaction between nursing managers and nurses has not been theoretically analysed by this literature, and the present paper represents a first step in this direction.

Regarding the principal-agent literature, although some papers have considered that the agent may make a mistake when performing a task[1] (Demougin and Fluet 2001; Prendergast 2002), the situation analysed by the present paper - in which the agent has to decide whether to report the mistake - has not been analysed before[2].

Finally, the paper is related to economic analyses of leadership styles made by Aghion and Tirole (1997), Jost (2013) and Rotemberg and Saloner (1993). Similar to the present paper, these papers attempted to investigate the optimal leadership style using a principal-agent approach and Rotemberg and Saloner (1993) assumed that the principal's personality completely determines his leadership style. However, they considered a different context (more precisely, the development and implementation of a project) and different set-ups and leadership styles.

The remainder of the paper is organised as follows. After establishing the model in Section 2, Section 3 compares the performance of the different leadership styles in obtaining error notification based on the equilibria of the game (which details are relegated to the Appendix). Section 4 concludes the paper and discusses some possible extensions.

2. The model

The interaction between the nurse manager (the principal, denoted by NM and referred to as "he") and the nurse (the agent, denoted by NU and referred to as "she") is modelled by a simple three-stage game. In the first stage, the manager asks the nurse to perform a task with a certain patient, and she performs it. While treating the patient, the nurse may make a mistake, and the patient may suffer an accident. Let $p \in (0,1)$ be the probability that the nurse makes a mistake[3]. Regarding patient accidents, it makes sense to assume that it is more likely that the patient suffers an accident if the nurse makes a mistake. Therefore, let q be a probability higher than $1/2$, $q \in (1/2,1)$, and assume that a patient accident will occur with probability q if the nurse made a mistake and with probability $1-q$ if she did not. These probabilities are exogenously given, and they are commonly known by both the manager and the nurse.

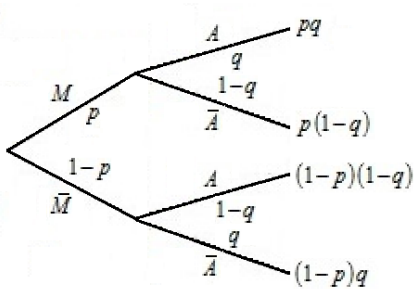
[1] The case in which the agent can make a mistake choosing the contract offered by the principal is more frequently analysed.

[2] The principal-agent literature has considered cases in which the agent can report (truthfully or not) her type to the principal, but not the case in which her type comes from the fact that she made a mistake performing a task, as in the present paper.

[3] Hence, the probability p can be interpreted as a measure of the nurse's capability to treat the patient.

Let M denote the event "the nurse made a mistake" and A the event "the patient suffered an accident". Note that there are four possible scenarios in this first stage of the game: the scenario $(M \cap A)$, whose probability is given by $\Pr(M \cap A) = pq$; the scenario $(M \cap \bar{A})$, whose probability is $\Pr(M \cap \bar{A}) = p(1-q)$; the scenario $(\bar{M} \cap A)$, whose probability is $\Pr(\bar{M} \cap A) = (1-p)(1-q)$, and the scenario $(\bar{M} \cap \bar{A})$ with probability $\Pr(\bar{M} \cap \bar{A}) = (1-p)q$. These scenarios and their probabilities are summarised in the following figure.

Fig 1. The possible scenarios in the first stage of the game and their probabilities



In the second stage of the game, if the nurse makes a mistake while treating the patient, it is known only by her[4] and she has to decide whether to report it (R) or not (NR) to the manager regardless of whether there was a patient accident. If she does not make any mistake, although there may be a patient accident, she has no mistake to report to the manager and, hence, she does not have to make any decision.

Finally, in the third stage of the game, the manager, who can observe whether there was a patient accident or not but knows only that the nurse made a mistake if she reports it, has to decide what action to take. More precisely, if he observes an accident, he has to decide between a punitive (P) or a non-punitive (NP) action, regardless of whether a mistake was reported to him; if he does not observe any accident and no mistake is reported to him, he has to decide whether to reward (Rw) or not (NRw) the nurse given that the patient did not suffer any accident; and finally, if he observes an accident and the nurse reported a mistake, he has to decide between a formative (T) or a non-formative (NT) action (namely, whether to send the nurse to a training program)[5]. All these actions can serve more or less as strategies to incentivise error reporting from the nurse depending on the preferences of both the manager and the nurse over the different outcomes and their strategic interaction, and this is precisely what the present model attempts to analyse.

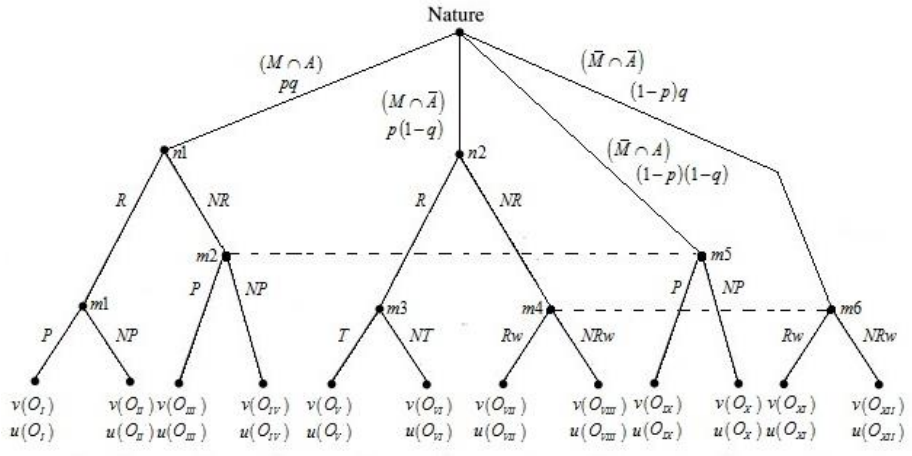
Hence, this is a game of incomplete information and it is analysed, using Harsanyi's approach, as a five-player game, in which the players are the four types of nurses (note that she has two types,

[4] Here, similarly to Qian et al. (2001), we follow the Hayekian assumption that the best local information about task-related aspects is obtained by those people doing the tasks.

[5] Note that a non-punitive action of the manager in the case where he observes the patient suffered an accident and the nurse reports a mistake would include formative actions.

the type who made a mistake and the type who did not, when there was an accident and when there was not) and the manager. However, as stated above, the types of nurses who did not make any mistake only has one strategy available, NR, because she does not have any mistake to report. Therefore, there are only three active playersin the game, which simplifies the analysis. The following figure summarises the game.

Fig 2. The game in extensive form



As Figure 2 shows, the decision node of the nurse-type who made a mistake that resulted in a patient accident is $n1$, and the decision node of the nurse-type who made a mistake that did not result in any accident is $n2$. Note that the nurse-types who made no mistakes do not have any decision node since they do not have to make any decisions (they have no mistake to report). Regarding the manager, when a mistake is reported to him, he has to make a decision at decision nodes $m1$ (he observes a patient accident)[6] and $m3$ (he observes no accident), and, when no mistake is reported to him, at information sets $i1 = \{m2, m5\}$ (he observes an accident) and $i2 = \{m4, m6\}$ (he does not observe any accident).

In line with Rotemberg and Saloner (1993), it is assumed that the manager's personality, represented by his preferences over the usual actions in nursing management discussed above (punishing, rewarding or training the nurse) in the different possible situations considered in the model, completely determines his leadership style. The paper considers four different leadership styles (personalities) for the manager and analyses for the level of error notification from the nurse achieved by each one. Similarly, the model considers three styles towards error reporting for the nurse, which also are determined by her personality as defined by her preferences over reporting or not reporting a mistake in the different possible scenarios the interaction with the manager can reach.

[6] According to what has been considered above, the non-punitive action (NP) of the manager in at decision node $m1$ would include formative actions.

2.1. Leadership styles

As stated above, following the nursing management literature[7], four leadership styles are considered for the manager, and they are defined according to the manager's preferences about his possible actions (punish, reward or train) in the different possible situations (the patient suffered an accident or not and a mistake was reported to him or not). These preferences are represented by the manager's payoffs in the different outcomes of the game. Let $v(\cdot)$ be the manager's payoff in a particular outcome of the game. For instance, $v(O_{VII})$ is the manager's payoff if the game reaches the outcome O_{VII}.

Before analysing each leadership style, note that when the nurse makes a mistake that does not result in a patient accident but she does not report it to the manager, it makes sense to assume that if the manager knew she has made a mistake, he would prefer, no matter his leadership style, not to reward the nurse because, although there was no accident, she made a mistake. Hence, it is assumed that $v(O_{VII}) < v(O_{VIII})$ for every leadership style.

Next, the four leadership styles are defined according to the manager's preference for the different outcomes of the game, as represented by the relation between his payoffs.

The transformational style

The transformational manager is defined by the following relation between his payoffs (representing his preference relation over game outcomes),

(1) $v(O_I) < v(O_{II})$, $v(O_{III}) < v(O_{IV})$, $v(O_{IX}) < v(O_X)$, $v(O_{VI}) < v(O_V)$, $v(O_{XII}) < v(O_{XI})$; and

(2) $v(O_{XI}) - v(O_{XII}) > v(O_{VIII}) - v(O_{VII})$.

According to (1), on the one hand, if the transformational manager observes that the patient suffered an accident, he always prefers the non-punitive action to the punitive one, regardless ofwhether the nurse hasreported a mistake. Namely $v(O_I) < v(O_{II})$, $v(O_{III}) < v(O_{IV})$ and $v(O_{IX}) < v(O_X)$. On the other hand, if he observes no accident and the nurse reports a mistake, he will send her to a training program ($v(O_{VI}) < v(O_V)$). If the nurse does not report any mistake in this case (the patient suffered no accident) and he knew she has not made any mistake, he would reward her because of the good job she did ($v(O_{XII}) < v(O_{XI})$). According to (2), when there is a patient accident, the cost for the transformational manager (in terms of lost utility) of not rewarding the nurse when she made no mistake ($v(O_{XI}) - v(O_{XII})$) is higher than the cost of rewarding her when she did make a mistake but she did not report it ($v(O_{VIII}) - v(O_{VII})$).

The soft transactional style

[7] See the "Introduction".

The soft transactional manager is similar to the transformational manager except that, if the soft transactional manager knew that the nurse actually made a mistake when he observes a patient accident and no mistake is reported, he would punish her ($v(O_{IV}) < v(O_{III})$). Despite this, the cost for the soft transactional manager of punishing the nurse when she actually made no mistake ($v(O_X) - v(O_{IX})$) is higher than the cost of not punishing her when she did make it ($v(O_{III}) - v(O_{IV})$). Note that this cost relation is also satisfied by the preferences of the transformational manager.

The hard transactional style

The hard transactional manager is defined by the following relation between payoffs,

(1) $v(O_{II}) < v(O_I)$, $v(O_{IV}) < v(O_{III})$, $v(O_{IX}) < v(O_X)$, $v(O_{VI}) < v(O_V)$, $v(O_{XII}) < v(O_{XI})$; and

(2) $v(O_X) - v(O_{IX}) < v(O_{III}) - v(O_{IV})$ and $v(O_{XI}) - v(O_{XII}) < v(O_{VIII}) - v(O_{VII})$.

According to (1), the hard transactional manager is similar to the soft transactional manager but the hard transactional will punish the nurse when observing a patient accident and she reports a mistake ($v(O_{II}) < v(O_I)$). According to (2), in contrast to both the transformational and the soft transactional managers, the costs for the hard transactional manager of punishing ($v(O_X) - v(O_{IX})$) or not rewarding ($v(O_{XI}) - v(O_{XII})$) a nurse who actually made no mistake are smaller than the costs of not punishing ($v(O_{III}) - v(O_{IV})$) or rewarding ($v(O_{VIII}) - v(O_{VII})$) a nurse who did make it, respectively.

The authoritarian style

The authoritarian manager is defined by the following relation between payoffs,

$$v(O_{II}) < v(O_I),\ v(O_{IV}) < v(O_{III}),\ v(O_X) < v(O_{IX}),\ v(O_V) < v(O_{VI}) \text{ and } v(O_{XI}) < v(O_{XII})$$

On one hand, when there is a patient accident, the authoritarian manager always prefers the punitive action to the non-punitive action regardless of whether a mistake was reported($v(O_{II}) < v(O_I)$, $v(O_{IV}) < v(O_{III})$, $v(O_X) < v(O_{IX})$). On the other hand, if the authoritarian manager observes that the patient suffered no accident but the nurse reports a mistake, he will not send her to any training program ($v(O_V) < v(O_{VI})$). If the nurse does not report any mistake in this case - in which there was no patient accident - and the authoritarian manager knew she has not made any mistake, he would not reward her because of the good job she did ($v(O_{XII}) < v(O_{XI})$).

2.2. Styles of nurses in error reporting

As stated in the "Introduction", as a nurse's willingness to report a mistake may depend on her personal attitude and organisational aspects, the model considers three styles of error reporting, following the organisational behaviour literature. These styles are defined according to the nurse's preferences about reporting a mistake in each possible situation (the patient suffered an accident or not and the punitive, formative and rewarding actions the manager can take). Similar to the manager's case, these preferences are represented by the nurse's payoff in the different outcomes

of the game. Let $u(\cdot)$ be the nurse's payoff in a particular game outcome. For example, $u(O_{III})$ is the nurse's payoff if the game reaches the outcome O_{III}.

Before analysing each style, note that it makes sense to consider that a nurse prefers a manager's non-punitive action to a punitive action, regardless of her style of error reporting. In this sense, it is quite logical to consider that if a nurse makes a mistake, she will prefer to report it and not be punished by the manager to not report it and be punished. Therefore, the model assumes that $u(O_{II}) > u(O_I)$, $u(O_{IV}) > u(O_{III})$ and $u(O_{II}) > u(O_{III})$ for every error reporting style.

Now, the three styles of error reporting are defined, similarly as the manager's case, according to the nurse's preferences for the different outcomes of the game, as represented by the relation between her payoffs.

Passive style

The passive nurse is defined by the following relation between her payoffs (representing her preference relation over game outcomes),

$$u(O_I) < u(O_{III}) < u(O_{II}) < u(O_{IV}) \text{ and } u(O_V) < u(O_{VI}) < u(O_{VIII}) < u(O_{VII})$$

If the passive nurse makes a mistake and the patient suffers an accident, she prefers in general not to report the mistake. If she makes a mistake and there is no patient accident, not only does she absolutely prefer not to report the mistake regardless ofthe manager's decision (about training or rewarding her), but after not reporting the mistake, she prefers to be rewarded by the manager because there was no accident ($u(O_{VIII}) < u(O_{VII})$).

Reactive style

The reactive nurse is defined by the following relation between payoffs,

$$u(O_{III}) < u(O_I) < u(O_{II}) < u(O_{IV}) \text{ and } u(O_{VI}) < u(O_{VIII}) < u(O_V) < u(O_{VII})$$

If the reactive nurse knew that the manager will punish her regardless of whether a mistake was reported when making a mistake that results in a patient accident, she would prefer to report it ($u(O_{III}) < u(O_I)$), in contrast to the passive nurse. Nevertheless, like the passive nurse, the reactive nurse, if she knew that the manager willnot punish her if she does not report the mistake, she would prefer not to report it,regardless of the decision the manager would have taken if she had reported it($u(O_I) < u(O_{II}) < u(O_{IV})$).

If the reactive nurse makes a mistake but the patient suffers no accident, in contrast to the passive nurse, the reactive nurse would not only prefer to be trained after reporting the mistake ($u(O_{VI}) < u(O_V)$) but also prefer to report the mistake if she knew the manager will send her to a training program and would have not rewarded her if she had not reported it ($u(O_{VIII}) < u(O_V)$). However, similar to the passive nurse, the reactive nurse's most preferred outcome is not to report the mistake and to be rewarded because there was no patient accident.

Active style

The active nurse is defined by the following relation between payoffs,

$$u(O_{III}) < u(O_I) < u(O_{IV}) < u(O_{II}) \text{ and } u(O_{VI}) < u(O_{VII}) < u(O_{VIII}) < u(O_V)$$

When the active nurse makes a mistake and the patient suffers an accident,the active nurse, similar to the passive and reactive nurses, prefers not to report the mistake and not be punished by the manager to reporting it and be punished ($u(O_I) < u(O_{IV})$). Moreover, like the reactive nurse, the active nurse, if she knew that the manager will punish her regardless of whether a mistake is reported to him, she would prefer to report it ($u(O_{III}) < u(O_I)$). However, in contrast to the passive and the reactive nurses, the active nurse would also prefer to report the mistake even though she knew that the manager will not punish her, regardless of whether a mistake is reported ($u(O_{IV}) < u(O_{II})$).

When the active nurse makes a mistake but there is no patient accident, if the active nurse knew that the manager will not send her to a training program if she reports the mistake, she would prefer, similar to the reactive nurse, not to report it,regardless the later decision by the manager. However, in contrast to the passive and reactive nurses, if the active nurse does not report the mistake, she prefers not to be rewarded ($u(O_{VI}) < u(O_{VII}) < u(O_{VIII})$). Moreover, if the active nurse knew that the manager will send her to a training program, she would prefer to report the mistake, regardless of the decision the manager would have made if she had reported it ($u(O_{VII}) < u(O_{VIII}) < u(O_V)$).

3. Performance of the nurse manager's leadership style in obtaining error notification

This section analyses the effectiveness and performance of the different nurse manager's leadership styles in obtaining error notification. The following discussion is based on the equilibria of the game described in the previous section for the different leadership styles and the different styles of nurses in error reporting. More precisely, it is based on the probabilities each nurse style assigns in equilibrium to report a mistake (taking into account whether the patient suffered an accident) when interacting with each one of the different manager's leadership styles. The details of these equilibria can be found in the Appendix.

Let $\Omega = \frac{1-q}{q}\frac{v(O_X)-v(O_{IX})}{v(O_{III})-v(O_{IV})}$ and $\Pi = \frac{q}{1-q}\frac{v(O_{XI})-v(O_{XII})}{v(O_{VIII})-v(O_{VII})}$. These two parameters play a central role in the equilibrium analysis because they are two thresholds to assess the probability, p, that the nurse makes a mistake while treating the patient (more precisely the parameter $\bar{p}$, where $\bar{p} = p/(1-p)$) and, hence, players' choices of action. To simplify the analysis it has been assumed that $\frac{v(O_{XI})-v(O_{XII})}{v(O_{VIII})-v(O_{VII})} > \frac{v(O_X)-v(O_{IX})}{v(O_{III})-v(O_{IV})}$, which together with $q > 1/2$ implies that $\Pi > \Omega$.

According to the equilibria of the game for the different manager's leadership styles and the different styles of nurses, the performance of the soft transactional manger in obtaining error notification is in general quite good compared with the performance of the other leadership styles. The following proposition summarises this result.

Proposition 1. *The soft transactional manager*
(1) dominates in terms of obtaining error notification the transformational manager regardless the nurse style;
(2) dominates in the same sense both the hard transactional and the authoritarian manager if the nurse is passive or active
Proof: *See Appendix*.

According to Proposition 1, the soft transactional style dominates all the other manager styles in terms of obtaining error notification from the passive and active nurses. However, when interacting with the reactive nurse, the soft transactional style only dominates the transformational manager. Let us start comparing these two manager styles.
Although both the transformational and the soft transactional styles obtain the same level of error notification when the patient suffered no accident (since there is no difference between both of them in that case) and even the active nurse always reports a mistake to both styles when there is a patient accident, the soft transactional manager obtains a higher level of error notification from the passive and reactive nurses than the transformational manager in this latter case. In particular, the passive and reactive nurses never report any mistake to the transformational manager, while with a soft transactional manager, they hesitate about reporting a mistake when he considers them likely to make one. This is because the passive and reactive nurses take advantage of the transformational manager's preference for non-punitive actions regardless of whether a mistake is reported to him. In particular, they never report a mistake because, knowing that they will not be punished, they prefer not to report[8]. However, the soft transactional manager, in contrast to the transformational style, would punish the passive and the reactive nurses if he knew they made it but did not report it. Hence, as he considers them less capable to treat the patient, the more he wants to punish them when no mistake is reported to him and the more these types of nurse want to report the mistake because they prefer reporting it and not being punished to not reporting it and being punished.
The soft transactional style also obtains a higher level of error notification than the hard transactional when interacting with a passive or active nurse. On the one hand, although none of

[8] In contrast to the passive and reactive nurses, if the active nurse knew that she is not going to be punished, she would prefer to report the mistake. This is the reason why this type of nurse is going to report a mistake for sure no matter the manager is transformational or soft transactional.

both manager styles are reported a mistake by the passive nurse when there is no patient accident, when the patient does suffer an accident the soft transactional manager makes this nurse style to hesitate while she never reports when interacting with the hard transactional manager. The hard transactional manager will punish the nurse when she reports a mistake and he observes a patient accident. Consequently, the passive nurse prefers not to report the mistake regardless of the later decision of this manager style. In contrast, the soft transactional manager will not punish the nurse if she reports a mistake, but he would punish her if he knew she made a mistake and did not report it. This makes the passive nurse to hesitate about reporting when the soft transactional manager considers her likely enough to make a mistake because she prefers reporting the mistake and not being punished to not reporting it and being punished.

On the other hand, although the active nurse always reports a mistake to both manager styles when there is no patient accident, when this nurse style makes a mistake and the patient does suffer an accident, she would always report it to a soft transactional manager while the hard transactional manager only can make her to hesitate. The hard transactional manager prefers to punish the nurse when a mistake is reported to him, and taking this into account, the active nurse would prefer to report a mistake only if she knew this manager style will also apply a punitive action if she does not report it. However, when no mistake is reported, the hard transactional manager would punish only if he knew the nurse actually made a mistake. Consequently, he only can make this nurse style to hesitate between reporting or not when he considers her likely to make a mistake. Nevertheless, the soft transactional manager will not punish the nurse if she reports, which makes the active nurse to prefer reporting regardless of the later decision of the manager if she had not reported.

The soft transactional style also dominates the authoritarian style in terms of obtaining error notification from the passive and active nurses. Regarding the passive nurse, the authoritarian manager, similarly to the hard transactional manager, never obtains any error notification when interacting with this nurse style. In the case where there is a patient accident, the authoritarian manager, as the hard transactional manager, will punish the nurse when she reports a mistake and, consequently, the passive nurse prefers not to report the mistake regardless of the later decision of the manager. When the patient suffers no accident, both the soft transactional and the authoritarian styles would not reward the nurse if they knew she made a mistake although she did not report it. Consequently, the passive nurse prefers not to report regardless of the later decision of the manager about sending her to a training program if she had reported. This is the reason why both styles obtain the same result when interacting with the passive nurse despite their different attitudes if she had reported a mistake when there was no patient accident.

Regarding the active nurse, although this nurse style always reports a mistake to both the soft transactional and the authoritarian styles when there is a patient accident[9], when this nurse style makes a mistake and the patient suffers no accident, she never reports it to the authoritarian manager while she would always report it to the soft transactional manager.

Observing that the patient suffered no accident, the soft transactional manager would send the nurse to a training program if he is reported a mistake and, given that, the active nurse prefers to report regardless of the later decision of the manager of rewarding her or not if she had not reported. However, the authoritarian manager not only would not send the nurse to a training program if she reports a mistake, he also would give no reward to her even if he knew she made no mistake. Consequently, the active nurse will not report any mistake when interacting with the authoritarian manager because, taking into account that she is not going to be sent to a training program if she reports, she prefers not to report and not being rewarded.

As stated before, according to Proposition 1, when interacting with the reactive nurse the soft transactional style only dominates in terms of obtaining error notification the transformational style, despite it is the manager style that dominates all the others when the nurse is passive or active. Actually, when the nurse is reactive, it is not that clear which is the manager style that dominates in terms of obtaining error notification. The following proposition deals with this aspect and completes the result summarised by Proposition 1.

Proposition 2. *When interacting with the reactive nurse,*

(1) the hard transactional manager dominates in terms of obtaining error notification the soft transactional manager;

(2) the authoritarian manager is dominated in terms of obtaining error notification only when there was no patient accident.

Proof: *See Appendix.*

Proposition 2 together with Proposition 1 implies that the hard transactional manager dominates all the other manager styles in terms of obtaining error notification from the reactive nurse only when there was no patient accident. The authoritarian style is the one that dominates in case the patient suffered an accident.

Let us first consider the performance of the soft and hard transactional managers' styles in terms of obtaining error notification from the reactive nurse. In particular, when this nurse style makes a mistake, both the soft and the hard transactional leadership styles make her to hesitate about

[9] Both manager styles get the same result when interacting with the active nurse and there is an accident, but for different reasons. In the case of the soft transactional manager, he will not punish the nurse if she reports a mistake, and given that, the active nurse prefers to report regardless of the later decision of the manager if she had not reported. Nevertheless, the authoritarian manager will punish the nurse no matter a mistake is reported to him or not and, consequently, the active nurse also prefers to report.

reporting it when they consider her quite likely to make it (regardless of whether the patient suffered an accident). When the patient suffers an accident, the reactive nurse would prefer to report the mistake (regardless of the later decision of the manager about punishing her or not) only if she knew the manager will apply a punitive action if she does not report it. However, both leadership styles would punish her when no mistake is reported only if they knew the nurse actually made it. Consequently, they only can make the reactive nurse to hesitate about reporting when they do not consider her capable enough to perform the task, more precisely when $\bar{p} > \Omega$. Actually, she will report with probability $\bar{\beta} = 1 - \Omega/\bar{p}$. Something similar happens when there was no patient accident. If the nurse reports a mistake in this case, both manager styles will send her to a training program. Given that, the reactive nurse would prefer to report only if she knew the manager will not reward her if she does not report any mistake. However, both leadership styles would not reward her only if they knew she actually made a mistake and did not report it. Consequently, they only can make her to report with probability $\bar{\alpha} = 1 - \Pi/\bar{p}$ when $\bar{p} > \Pi$.[10]

Nevertheless, note that both parameters Ω and Π are smaller under the hard transactional manager than under the soft transactional manager because the ratios $\left(v(O_X) - v(O_{IX})\right)/\left(v(O_{III}) - v(O_{IV})\right)$ and $\left(v(O_{XI}) - v(O_{XII})\right)/\left(v(O_{VIII}) - v(O_{VII})\right)$ are smaller for the former (see the definition of these leadership styles). This means that, when the reactive nurse makes a mistake but does not report it, the hard transactional manager needs to be more convinced about her capability to perform the task (the smaller p needs to be) than the soft transactional manager to make her to hesitate about reporting the mistake because he is somehow more inclined than the soft transactional manager to punish her when he observes a patient accident and to not to reward her when he does not observe any accident. Moreover, for the same reason, the probabilities that the reactive nurse will assign to report when she hesitates about reporting or not the mistake, $\bar{\beta}$ when the patient suffered an accident and $\bar{\alpha}$ when the patient suffered no accident, are higher under the hard transactional manager than under the soft transactional manager. Therefore, considering these two aspects, the performance of the hard transactional manager in obtaining error notification from the reactive nurse is better than the performance of the soft transactional.

The hard transactional manager also obtains a higher level of error notification from the reactive nurse than the authoritarian manager when there is no patient accident. Actually, the reactive nurse never reports a mistake when interacting with the authoritarian manager if the patient suffered no accident. If the authoritarian manager observes no accident, he not only would not send the nurse to a training program if she reports a mistake, he also would give no reward to her even if he knew she made no mistake. Consequently, the reactive nurse prefers not to report.

[10] See the equilibria of the game when the manager is hard and soft transactional in the Appendix for a proof of these equilibrium strategies and thresholds.

Nevertheless, the authoritarian style is the only manager style that makes the reactive nurse to report a mistake for sure when the patient suffers an accident. When the authoritarian manager observes that the patient suffered an accident, he is going to punish the nurse even if he knew she made no mistake. This manager's attitude makes that the reactive nurse prefers to report when she makes a mistake.

4. Summary and conclusions

To improve patient safety is a priority at the international level, and error reporting in health care organisations is a fundamental tool for it since it provides valuable information about the way assistance procedures should be modified and health care professionals should be trained. Nurses are the professional group in health care organisations that spends the most time with patients and, therefore, their error reporting behaviour is crucial to improving patient safety. Not only does this error reporting behavior depend on nurses' personal attitudes but it also depends on organisational aspects and manager's leadership style. Therefore, the interaction between nurses and their managers plays a central role in nurses' error reporting behaviour. However, little theoretical work has been undertaken to analyse this interactionhas attempted to take a modest step forward in closing this gap in the literature by considering a principal-agent model in which the principal, the nurse manager (for whom four leadership styles are considered: transformational, soft transactional, hard transactional and authoritarian), asks the agent, the nurse, (for whom three styles of error reporting are considered: passive, reactive and active) to perform a task with certain patient. If the nurse makes a mistake while treating the patient, she has to decide whether to report it to the manager, taking into account that the manager can observe whether the patient suffered an accident.

The paper analyses this interaction between each leadership style and each style of nurse in this error reporting context and attempts to evaluate the performance of each leadership style in obtaining error notification. According to the results of the model, there is no *"best leadership style"* for obtaining error notifications from nurses, but generally speaking, the soft transactional style is the one with the best performance, although the performance of the authoritarian and the hard transactional managers in obtaining error notification from the reactive nurse is better (the performance of the former is better when the patient suffered an accident and the performance of the latter when there was no patient accident).

This result is coherent with some management studies with applications to health care organizations and nursing management, such as Clarke (2013), which argue that that the most beneficial leadership style for safety (patient safety in the health care context, which includes error reporting from nurses) would be a combination of a transformational and an active transactional style, which, in the present paper, could be represented by the soft transactional leadership style.Nevertheless, more theoretical research is needed because the present paper does

not consider the effects that the transformational style's strong preference for non-punitive, formative and rewarding actions can have on nurses (according to the nursing management literature, these are greater satisfaction and confidence and participation encouragement), and the results show only that passive and reactive nurses can take advantage of this leadership style's preference for non-punitive actions and not report mistakes as frequently as would be desired. In this sense, it would be very interesting to extend the present model by adopting an evolutionary approach to include that nurses' preference for error reporting under transformational management may evolve from a more passive to a more active reporting style, namely, an evolution towards a safety culture, as the nursing management literature argues.

Appendix

The present Appendix proves both Propositions 1 and 2 in the main text. To do it so, the Appendix provides the different Bayes-Nash equilibria of the game for each leadership style interacting with the different nurses' styles of error reporting. The proof of both propositions follows immediately from comparing the probabilities a given nurse style assigns in equilibrium to report a mistake to the different manager's leadership styles.

A. The manager's updated beliefs and expected payoffs

First, the expression for the nurse manager's updated beliefs when he observes that the patient suffered an accident is obtained. Let $\sigma = \{(M \cap A), (\bar{M} \cap A)\}$. Applying Bayes' rule, the probability that the manager believes that the nurse made a mistake, given that he observes NR, is given by

$$\Pr(\sigma / NR) = \frac{\Pr(NR / \sigma)\Pr(\sigma)}{\sum_{\sigma=\{(M\cap A),(\bar{M}\cap A)\}} \Pr(NR / \sigma)\Pr(\sigma)} \quad \text{(A1)}$$

where $\Pr(NR / M \cap A)$ is the probability assigned to NR at her decision node $n1$. Note that $\Pr(NR / \bar{M} \cap A) = 1$ always.

Consider next the case in which the manager observes that the patient suffered no accident and let $\bar{\sigma} = \{(M \cap \bar{A}), (\bar{M} \cap \bar{A})\}$. The probability that the manager believes that the nurse made a mistake in this case, given that he observes NR, is

$$\Pr(\bar{\sigma} / NR) = \frac{\Pr(NR / \bar{\sigma})\Pr(\bar{\sigma})}{\sum_{\sigma=\{(M\cap \bar{A}),(\bar{M}\cap \bar{A})\}} \Pr(NR / \bar{\sigma})\Pr(\bar{\sigma})} \quad \text{(A2)}$$

where $\Pr(NR / M \cap \bar{A})$ is the probability assigned to NR by the nurse at her decision node $n2$. Similarly as before, $\Pr(NR / \bar{M} \cap \bar{A}) = 1$.

Let $EU_{NM}(P/A\cap NR)$ and $EU_{NM}(NP/A\cap NR)$ be the nurse manager's expected payoffs for choosing P and NP, respectively, at information set $i2$, which can be obtained by applying (A1),

$$EU_{NM}(P/A\cap NR)=\Pr(M\cap A/NR)v(O_{III})+\Pr(\bar{M}\cap A/NR)v(O_{IX}) \quad \text{(A3)}$$

$$EU_{NM}(NP/A\cap NR)=\Pr(M\cap A/NR)v(O_{IV})+\Pr(\bar{M}\cap A/NR)v(O_{X}) \quad \text{(A4)}$$

Similarly, let $EU_{NM}(Rw/\bar{A}\cap NR)$ and $EU_{NM}(NRw/\bar{A}\cap NR)$ be the nurse manager's expected payoffs for choosing Rw and NRw, respectively, at information set $i4$, which can be obtained by applying (A2),

$$EU_{NM}(Rw/\bar{A}\cap NR)=\Pr(M\cap \bar{A}/NR)v(O_{VII})+\Pr(\bar{M}\cap \bar{A}/NR)v(O_{XI}) \quad \text{(A5)}$$

$$EU_{NM}(NRw/\bar{A}\cap NR)=\Pr(M\cap \bar{A}/NR)v(O_{VIII})+\Pr(\bar{M}\cap \bar{A}/NR)v(O_{XII}) \quad \text{(A6)}$$

B. Equilibria of the game

Each one of the following subsections analyses the equilibria of the game between a particular leadership style and the different nurse styles. A particular equilibrium of the game is represented by a vector of six elements. The first two elements are the strategies chosen by the nurse who made a mistake when there was an accident and when there was no accident, respectively. The last four elements are the strategies chosen by the manager. The third and fifth ones are the strategies he chooses when a mistake is reported to him, the third is the one he chooses when he observes the patient suffered an accident and the fifth one when there was no accident. The fourth and sixth elements are the strategies the manager chooses when no mistake is reported to him, the fourth is the one he chooses when the patient suffered an accident and the sixth when he observes no accident.

As stated in the main text, given that the nurse who made no mistake has only one strategy available (the strategy not to report), it is omitted from the equilibrium for simplicity and, in this sense, the different equilibria are not referred to as separating, pooling or semi-pooling. Also recall that it is assumed that $\frac{v(O_{XI})-v(O_{XII})}{v(O_{VIII})-v(O_{VII})}>\frac{v(O_{X})-v(O_{IX})}{v(O_{III})-v(O_{IV})}$ to simplify the analysis. This assumption together with $q>1/2$ implies that $\Pi>\Omega$.

Equilibria of the game when the manager is transformational

The following table summarises the equilibria of the game for the different styles of nurse and the possible values of $\bar{p}$ when the manager is transformational.

Table 1. Equilibria of the game when the manager is transformational

	Passive nurse	*Reactive nurse*	*Active nurse*
$\bar{p}<\Pi$	(NR, NR, NP, NP, T, Rw)	(NR, NR, NP, NP, T, Rw)	(R, R, NP, NP, T, Rw)

$\bar{p} = \Pi$	$(NR, NR, NP, NP, T, (x, 1-x))$ where $x \in [0,1]$	$(NR, NR, NP, NP, T, (x, 1-x))$ where $x \in [\bar{x}, 1]$	(R, R, NP, NP, T, Rw)
$\bar{p} > \Pi$	(NR, NR, NP, NP, T, NRw)	$(NR, (\bar{\alpha}, 1-\bar{\alpha}), NP, NP, T, (\bar{x}, 1-\bar{x}))$	(R, R, NP, NP, T, Rw)

Note: $\bar{x} = \left(u(O_V) - u(O_{VIII})\right) / \left(u(O_{VII}) - u(O_{VIII})\right)$ and $\bar{\alpha} = 1 - \Pi / \bar{p}$.

Proof:

Note that the transformational manager chooses NP at his decision node $m1$ and at his information set $i2 = \{m2, m5\}$. Taking this into account, if the nurse makes a mistake and the patient suffers an accident, she will choose NR at her decision node $n1$ only if $u(O_{II}) < v(O_{IV})$. When the transformational manager observes that the patient suffered no accident but a mistake is reported to him, he will choose T (namely, at his decision node $m3$). However, if he observes no accident and no mistake is reported to him, he would choose Rw only if he actually knew that the nurse made no mistake. This leads to different possible equilibria.

Equilibrium in which the nurse chooses R at her decision node $n2$

Note that, in this case, $\Pr(NR / M \cap \bar{A}) = 0$. Therefore, from (A2), it is obtained that $\Pr(M \cap \bar{A} / NR) = 0$ and $\Pr(\bar{M} \cap \bar{A} / NR) = 1$, and from (A5) and (A6), that $EU_{NM}(Rw / \bar{A} \cap NR) = v(O_{XI})$ and $EU_{NM}(NRw / \bar{A} \cap NR) = v(O_{XII})$. Hence, the transformational manager chooses Rw at his information set $i4$ because $v(O_{XII}) < v(O_{XI})$, and the nurse will not deviate from R to NR only if $u(O_{VII}) < u(O_V)$.

Equilibrium in which the nurse chooses NR at her decision node $n2$

Consider the case in which $\Pr(NR / M \cap \bar{A}) = 1$. Hence, it is obtained from (A2)

$$\Pr(M \cap \bar{A} / NR) = \frac{p(1-q)}{p(1-q) + (1-p)q} \tag{B1}$$

$$\Pr(\bar{M} \cap \bar{A} / NR) = \frac{(1-p)q}{p(1-q) + (1-p)q} \tag{B2}$$

Substituting (B1) and (B2) in (A5) and (A6),

$$EU_{NM}(Rw / \bar{A} \cap NR) = \frac{p(1-q)v(O_{VII}) + (1-p)qv(O_{XI})}{p(1-q) + (1-p)q} \tag{B3}$$

$$EU_{NM}(NRw / \bar{A} \cap NR) = \frac{p(1-q)v(O_{VIII}) + (1-p)qv(O_{XII})}{p(1-q) + (1-p)q} \tag{B4}$$

Note that (B3) is strictly higher than (B4) and, consequently, the manager will choose Rw at his information set $i4$ only if $\bar{p} < \Pi$.

Consider the following three cases.

Case 1. Consider the case in which $\bar{p} < \Pi$. In this case, (B3) is strictly higher than (B4), and the manager chooses Rw at his information set $i4$. The nurse will not deviate from NR to R only if $u(O_V) < v(O_{VII})$.

Case 2. Consider the case where $\bar{p} = \Pi$. In this case, (B3) is equal to (B4), the manager is indifferent between choosing Rw and NRw and will assign to Rw some probability $x \in [0,1]$. The nurse will not deviate from NR to R only if

$$u(O_V) \leq xu(O_{VII}) + (1-x)u(O_{VIII})$$

Equivalently, $u(O_V) - u(O_{VIII}) \leq x\left(u(O_{VII}) - u(O_{VIII})\right)$.

Case 3. Consider the case where $\bar{p} > \Pi$. In this case, (B3) is strictly smaller than (B4), and the manager chooses NRw. The nurse will not deviate from NR to R only if $u(O_V) < v(O_{VIII})$.

Equilibrium in which the nurse mixes R and NR at her decision node $n2$

Consider the case in which $\Pr(NR / M \cap \bar{A}) = 1-\alpha$, where $\alpha \in (0,1)$. From (A2),

$$\Pr(M \cap \bar{A} / NR) = \frac{(1-\alpha)p(1-q)}{(1-\alpha)p(1-q) + (1-p)q} \quad \text{(B5)}$$

$$\Pr(\bar{M} \cap \bar{A} / NR) = \frac{(1-p)q}{(1-\alpha)p(1-q) + (1-p)q} \quad \text{(B6)}$$

Substituting (B5) and (B6) in (A5) and (A6),

$$EU_{NM}\left(Rw / \bar{A} \cap NR\right) = \frac{(1-\alpha)p(1-q)v(O_{VII}) + (1-p)qv(O_{XI})}{(1-\alpha)p(1-q) + (1-p)q} \quad \text{(B7)}$$

$$EU_{NM}\left(NRw / \bar{A} \cap NR\right) = \frac{(1-\alpha)p(1-q)v(O_{VIII}) + (1-p)qv(O_{XII})}{(1-\alpha)p(1-q) + (1-p)q} \quad \text{(B8)}$$

Note that (B7) is strictly higher than (B8) and, consequently, the manager will choose Rw at his information set $i4$ only if $\alpha > \bar{\alpha}$, where $\bar{\alpha} = 1 - \Pi / \bar{p}$.

Consider the following two cases.

Case 1. Consider the case where $\bar{p} \leq \Pi$. In this case, $\bar{\alpha} \leq 0$ and every probability $\alpha \in (0,1)$ that the nurse can assign to R will satisfy $\alpha > \bar{\alpha}$,and the nurse is better off deviating from her mixed strategy to a pure strategy.

Case 2. Consider the case where $\bar{p} > \Pi$. In this case, $\bar{\alpha} \in (0,1)$. If the nurse assigns a probability of $\alpha = \bar{\alpha}$ to R, (B7) is equal to (B8), and the manager will assign to Rw some probability $x \in (0,1)$. The nurse will not deviate only if

$$u(O_V) = xu(O_{VII}) + (1-x)u(O_{VIII})$$

Equivalently, $x = \left(u(O_V) - u(O_{VIII})\right) / \left(u(O_{VII}) - u(O_{VIII})\right) \equiv \bar{x}$.

Note that $\bar{x} \in (0,1)$ and the equilibrium exists only for the reactive nurse because $u(O_{VIII}) < u(O_V) < u(O_{VII})$.

■

Equilibria of the game when the manager is soft transactional

The following table summarises the equilibria of the game for the different styles of nurse and the possible values of $\bar{p}$ when the manager is soft transactional.

Table 2. Equilibria of the game when the manager is soft transactional

	Passive nurse	*Reactive nurse*	*Active nurse*
$\bar{p} < \Omega < \Pi$	(NR, NR, NP, NP, T, Rw)	(NR, NR, NP, NP, T, Rw)	(R, R, NP, NP, T, Rw)
$\Omega = \bar{p} < \Pi$	$(NR, NR, NP, (y, 1-y), T, Rw)$ where $y \in [0, \bar{y}]$	$(NR, NR, NP, (y, 1-y), T, Rw)$ where $y \in [0, \bar{y}]$	(R, R, NP, NP, T, Rw)
$\Omega < \bar{p} < \Pi$	$((\bar{\beta}, 1-\bar{\beta}), NR, NP, (\bar{y}, 1-\bar{y}), T, Rw)$	$((\bar{\beta}, 1-\bar{\beta}), NR, NP, (\bar{y}, 1-\bar{y}), T, Rw)$	(R, R, NP, NP, T, Rw)
$\Omega < \bar{p} = \Pi$	$((\bar{\beta}, 1-\bar{\beta}), NR, NP, (\bar{y}, 1-\bar{y}), T, (x, 1-x))$ where $x \in [0,1]$	$((\bar{\beta}, 1-\bar{\beta}), NR, NP, (\bar{y}, 1-\bar{y}), T, (x, 1-x))$ where $x \in [\bar{x}, 1]$	(R, R, NP, NP, T, Rw)
$\Omega < \Pi < \bar{p}$	$((\bar{\beta}, 1-\bar{\beta}), NR, NP, (\bar{y}, 1-\bar{y}), T, NRw)$	$((\bar{\beta}, 1-\bar{\beta}), (\bar{\alpha}, 1-\bar{\alpha}), NP, (\bar{y}, 1-\bar{y}), T, (\bar{x}, 1-\bar{x}))$	(R, R, NP, NP, T, Rw)

Note: $\bar{y} = \left(u(O_{IV}) - u(O_{II})\right) / \left(u(O_{IV}) - u(O_{III})\right)$ and $\bar{\beta} = 1 - \Omega / \bar{p}$.

Proof:

The soft transactional manager chooses NP at his decision node $m1$, but, if he observes an accident and no mistake is reported to him, he would choose NP only if he actually knew that the nurse made no mistake. This leads to different possible equilibria.

Equilibrium in which the nurse chooses R at her decision node $n1$

This is the case in which $\Pr(NR / M \cap A) = 0$. From (A1), $\Pr(M \cap A / NR) = 0$ and $\Pr(\bar{M} \cap A / NR) = 1$, and from (A3) and (A4), $EU_{NM}(P / A \cap NR) = v(O_{IX})$ and $EU_{NM}(NP / A \cap NR) = v(O_X)$. Therefore, the soft transactional manager chooses NP at his information set $i2$, and the nurse will not deviate from R to NR only if $u(O_{IV}) < u(O_{II})$.

Equilibrium in which the nurse chooses NR at her decision node $n1$

Consider the case in which $\Pr(NR / M \cap A) = 1$. Hence, it is obtained from (A1) that

$$\Pr(M \cap A / NR) = \frac{pq}{pq + (1-p)(1-q)} \tag{B9}$$

$$\Pr(\bar{M} \cap A / NR) = \frac{(1-p)(1-q)}{pq + (1-p)(1-q)} \tag{B10}$$

Substituting (B9) and (B10) in (A3) and (A4),

$$EU_{NM}\left(P/A\cap NR\right)=\frac{pqv\left(O_{III}\right)+\left(1-p\right)\left(1-q\right)v\left(O_{IX}\right)}{pq+\left(1-p\right)\left(1-q\right)} \tag{B11}$$

$$EU_{NM}\left(NP/A\cap NR\right)=\frac{pqv\left(O_{IV}\right)+\left(1-p\right)\left(1-q\right)v\left(O_{X}\right)}{pq+\left(1-p\right)\left(1-q\right)} \tag{B12}$$

Note that (B11) is strictly higher than (B12) and, consequently, the manager will choose P at his information set $i2$ only if $\bar{p}>\Omega$.

Consider the following three cases.

Case 1. Consider the case where $\bar{p}<\Omega$. In this case, (B11) is strictly smaller than (B12), and the manager chooses NP at his information set $i2$. The nurse will not deviate from NR to R only if $u\left(O_{II}\right)<u\left(O_{IV}\right)$.

Case 2. Consider the case where $\bar{p}=\Omega$. In this case, (B11) is equal to (B12) and the manager will assign to P some probability $y\in\left[0,1\right]$. The nurse will not deviate from NR to R only if

$$u\left(O_{II}\right)\le yu\left(O_{III}\right)+\left(1-y\right)u\left(O_{IV}\right)$$

Equivalently, $u\left(O_{II}\right)-u\left(O_{IV}\right)\le y\left(u\left(O_{III}\right)-u\left(O_{IV}\right)\right)$.

Case 3. Consider the case where $\bar{p}>\Omega$. In this case, the manager chooses P. Note that there is no equilibrium in which the nurse chooses NR in this case because $u\left(O_{II}\right)>u\left(O_{III}\right)$ for every style of nurse.

Equilibrium in which the nurse mixes R and NR at her decision node $n1$

Consider the case in which $\Pr\left(NR/M\cap A\right)=1-\beta$, where $\beta\in\left(0,1\right)$. From (A1),

$$\Pr\left(M\cap A/NR\right)=\frac{\left(1-\beta\right)pq}{\left(1-\beta\right)pq+\left(1-p\right)\left(1-q\right)} \tag{B13}$$

$$\Pr\left(\bar{M}\cap A/NR\right)=\frac{\left(1-p\right)\left(1-q\right)}{\left(1-\beta\right)pq+\left(1-p\right)\left(1-q\right)} \tag{B14}$$

Substituting (B13) and (B14) in (A3) and (A4),

$$EU_{NM}\left(P/A\cap NR\right)=\frac{\left(1-\beta\right)pqv\left(O_{III}\right)+\left(1-p\right)\left(1-q\right)v\left(O_{IX}\right)}{\left(1-\beta\right)pq+\left(1-p\right)\left(1-q\right)} \tag{B15}$$

$$EU_{NM}\left(NP/A\cap NR\right)=\frac{\left(1-\beta\right)pqv\left(O_{IV}\right)+\left(1-p\right)\left(1-q\right)v\left(O_{X}\right)}{\left(1-\beta\right)pq+\left(1-p\right)\left(1-q\right)} \tag{B16}$$

Note that the manager will choose P at his information set $i2$ only if $\beta<\bar{\beta}$, where $\bar{\beta}=1-\Omega/\bar{p}$.

Consider the following two cases.

Case 1. Consider the case where $\bar{p}\le\Omega$. In this case, $\bar{\beta}\le 0$, and every probability $\beta\in\left(0,1\right)$ that the nurse can assign to R will satisfy $\beta>\bar{\beta}$ $i2$,and the nurse is better off deviating from her mixed strategy to a pure strategy.

Case 2. Consider the case where $\bar{p} > \Omega$. In this case, $\bar{\beta} \in (0,1)$. If the nurse assigns a probability of $\beta = \bar{\beta}$ to R, the manager will assign to P some probability $y \in (0,1)$. The nurse will not deviate only if

$$u(O_{II}) = yu(O_{III}) + (1-y)u(O_{IV})$$

Equivalently, $y = \left(u(O_{II}) - u(O_{IV})\right) / \left(u(O_{III}) - u(O_{IV})\right) \equiv \bar{y}$.

Note that $\bar{y} \in (0,1)$ and the equilibrium exists for the passive and reactive nurses because $u(O_{III}) < u(O_{II}) < u(O_{IV})$.

When the soft transactional manager does not observe any patient accident, the equilibrium of the game is exactly the same as when the manager is transformational (see the proof of Table 1).

■

Equilibria of the game when the manager is hard transactional

The following table summarises the equilibria of the game for the different styles of nurse and the possible values of $\bar{p}$ when the manager is hard transactional.

Table 3. Equilibria of the game when the manager is hard transactional

	Passive nurse	*Reactive nurse*	*Active nurse*
$\bar{p} < \Omega < \Pi$	(NR, NR, P, NP, T, Rw)	(NR, NR, P, NP, T, Rw)	(NR, R, P, NP, T, Rw)
$\Omega = \bar{p} < \Pi$	$(NR, NR, P, (z, 1-z), T, Rw)$ where $z \in [0,1]$	$(NR, NR, P, (z, 1-z), T, Rw)$ where $z \in [0, \bar{z}]$	$(NR, R, P, (z, 1-z), T, Rw)$ where $z \in [0, \bar{z}]$
$\Omega < \bar{p} < \Pi$	(NR, NR, P, P, T, Rw)	$((\bar{\beta}, 1-\bar{\beta}), NR, P, (\bar{z}, 1-\bar{z}), T, Rw)$	$((\bar{\beta}, 1-\bar{\beta}), R, P, (\bar{z}, 1-\bar{z}), T, Rw)$
$\Omega < \bar{p} = \Pi$	$(NR, NR, P, P, T, (x, 1-x))$ where $x \in [0,1]$	$((\bar{\beta}, 1-\bar{\beta}), NR, P, (\bar{z}, 1-\bar{z}), T, (x, 1-x))$ where $x \in [\bar{x}, 1]$	$((\bar{\beta}, 1-\bar{\beta}), R, P, (\bar{z}, 1-\bar{z}), T, Rw)$
$\Omega < \Pi < \bar{p}$	(NR, NR, P, P, T, NRw)	$((\bar{\beta}, 1-\bar{\beta}), (\bar{\alpha}, 1-\bar{\alpha}), P, (\bar{z}, 1-\bar{z}), T, (\bar{x}, 1-\bar{x}))$	$((\bar{\beta}, 1-\bar{\beta}), R, P, (\bar{z}, 1-\bar{z}), T, Rw)$

Note: $\bar{z} = \left(u(O_{IV}) - u(O_I)\right) / \left(u(O_{IV}) - u(O_{III})\right)$.

Proof:

Note that the hard transactional manager chooses P at his decision node $m1$. This is, actually, his only difference from the soft transactional manager. Therefore, the proof of the equilibria of the game in Table 3 is similar to the proof of the equilibria in Table 2.

■

3.4. Equilibria of the game when the manager is authoritarian

When the manager is authoritarian and no mistake is reported to him, he always punishes the nurse when he observes that the patient suffered an accident ($v(O_{IV}) < v(O_{III})$ and $v(O_X) < v(O_{IX})$) and will never reward her when there was no accident ($v(O_{VII}) < v(O_{VIII})$ and $v(O_{XI}) < v(O_{XII})$), regardless of whether the nurse actually made a mistake. Therefore, his decisions when no mistake is reported to him (at information sets $i1$ and $i2$)and the equilibrium of the game do not depend on how likely he considers the nurse to make a mistake(namely, on the probability p) and the thresholds Ω and Π play no role.

The following lemma summarises the equilibria of the game when the manager is authoritarian for the different styles of nurse.

Lemma. *When the manager is authoritarian, the equilibria of the game with the different styles of nurse are the following:*

(1) If the nurse is passive, the unique equilibrium of the game is (NR, NR, P, P, NT, NRw) *;*

(2) If the nurse is reactive or active, the unique equilibrium of the game is (R, NR, P, P, NT, NRw)

.

Proof:

Note, on one hand, that the authoritarian manager chooses P at his decision node $m1$ and at his information set $i2 = \{m2, m5\}$. Taking this into account, if the nurse makes a mistake and the patient suffers an accident, she will choose NR at her decision node $n1$ only if $u(O_I) < v(O_{III})$. On the other hand, the authoritarian manager chooses NT at his decision node $m3$) and NRw at his information set $i2 = \{m4, m6\}$. Therefore, if the nurse makes a mistake, she will choose NR at her decision node $n2$ only if $u(O_{VI}) < v(O_{VIII})$.

■

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