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A Bayesian network model to predict the role of hospital noise, annoyance, and sensitivity in quality of patient care

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Abstract

Background: Hospital noise can adversely impact nurses' health, their cognitive function and emotion and in turn, influence the quality of patient care and patient safety. Thus, the aim of this study was to predict the contributing roles of exposure to hospital noise, staff noise-sensitivity and annoyance, on the quality of patient care.

Methods: This descriptive and cross-sectional study was carried out among nurses in an Iranian hospital. To determine nurses' noise exposure level, the noise was measured in 1510 locations across the hospital in accordance with ISO 9612 standards using KIMO DB 300/2 sound level meter and analyzer. An online survey was used to collect nurses' individual data. Study questionnaires included demographics, Weinstein noise sensitivity scale, noise annoyance scale, and quality of patient care scale. Finally, to analyze the data, Bayesian Networks (BNs), as probabilistic and graphical models, were used.

Results: For the high noise exposure state, high noise sensitivity, and high annoyance, with the probability of 100%, the probability of delivering a desirable quality of patient care decreased by 21, 14, and 23%, respectively. Moreover, at the concurrently high noise exposure and high noise sensitivity with the probability of 100%, the desirable quality of patient care decreased by 26%. The Bayesian most influence value was related to the association of noise exposure and annoyance (0.636). Moreover, annoyance had the highest association with the physical aspect of quality of care (0.400) and sensitivity had the greatest association with the communication aspect (0.283).

Conclusion: Annoyance induced from environmental noise and personal sensitivity affected the quality of patient care adversely. Moreover, noise and sensitivity had a separate direct adverse effect upon the quality of patient care, and their co-occurrence reduced the potential for delivering quality patient care.

Keywords: Bayesian network, Noise exposure, Annoyance, Sensitivity, Quality of patient care, Nurse

Background

Noise, as unwanted and disturbing sound, is considered an environmental stressor for people's health. In recent years, many studies have reported that the noise pollution level in hospitals is rising and becoming an adverse

factor for patient and staff health [1–3]. Regarding this, Florence Nightingale expressed that “unnecessary noise is the most cruel absence of care which can be inflicted on the sick or well” [4]. Various sources of sound, including that produced by hospital equipment, people, facility infrastructure, and local traffic noise in high density areas contribute to rising noise levels for staff and patients – often beyond recommended guideline limits [5]. Based on the WHO guideline, the noise levels in hospital wards should not exceed 35 dB (dBA) during daytime and 30 dB

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during nighttime. Moreover, it is recommended that the allowable peak noise level be no more than 40 dB at any time [6]. Increased noise levels beyond these limits can disturb nurses' performance and productivity. Higher background noise levels can disturb signal-to-noise ratio and in turn, intelligible communication. Ineffective and disrupted communication is one of the important factors negatively impacting nurses' performance and productivity [6–8]. Moreover, noise level exceedance above these limits may have adverse health effects on the patients and staff. Morrison et al. in a 2003 review concluded that hospital noise can trigger annoyance, stress, tachycardia, and higher heart rates in nurses [9]. Another study concerning the effect of hospital noise on nurses' health reported that 14.49% of nursing professionals complained about tinnitus, 34.78% about low concentration, 45.63% about auditory irritation, and 44.20% about sleep disturbances [5, 10]. Moreover, high noise level has a significant and negative effect on quality of patient care, nurses' mental workload and anxiety levels [11, 12]. Cognitive functions such as memory, attention, concentration and problem solving are also influenced by exposure to noises with various characteristics such as frequency, content, and intensity [13, 14]. These adverse health effects induced by chronic exposure to noise levels above recommended guidelines have a synergistic effect, disturbing nurses' performance and quality of patient care. Noise can influence the quality of patient care directly and also indirectly through the adverse health outcomes.

In addition to noise exposure, individual sensitivity to noise can intensify the effects and decrease performance. Abbasi et al. showed that noise sensitivity significantly increased noise annoyance and job stress and also decreased job satisfaction [15]. This is because noise-sensitive people are vulnerable to noise and other environmental stressors [16]. Therefore, hospital noise can threaten nurses' health, their cognitive function and emotion, and in turn, influence the quality of patient care and patient safety. Despite the importance of the effect of noise on the quality of patient care, there is a paucity of a strong literature base on this issue. Thus, the aim of this study was to predict the contributing roles of exposure to hospital noise, staff noise sensitivity and annoyance, on the quality of patient care.

Methods

Study population

This descriptive and cross-sectional study was carried out on 209 nurses in 2021 in one hospital in Tehran, Iran. Noise exposure data were gathered in a four-month period from April 10, 2021, to August 10, 2021. The study process began following preliminary measures such as obtaining permission from the research ethics committee

of Aja University of Medical Sciences (IR.AJAUMS.REC1400.060) and also getting permission from the hospital management. Questionnaires were distributed to staff nurses. These questionnaires included demographic information, noise sensitivity, noise annoyance, and quality of patient care. Since this study was conducted during the COVID-19 pandemic, in order to comply with preventive measures, the questionnaires were offered to the nurses based on their preference as an online link or printed hard copy. For those who opted for digital access, the questionnaire link was sent by hospital management to all nurses as they had access to the nurses' contact information. In both delivery formats, the goals and way of participating in the study were explained and nurses were invited to complete the questionnaires voluntarily. Finally, nurses with less than one year of work experience, incomplete surveys, nurses with dual employment, or those with a restrictive disease were excluded from the study. The online questionnaires were prepared and sent to all nurses employed in the studied hospital. To encourage increased participation, also printed hard copy questionnaires were distributed among voluntary nurses who did not complete the online questionnaire.

Questionnaires

Nurses completed the following self-report questionnaires.

Demographic questionnaire

The demographic questionnaire collected information such as age, experience, gender, marital status, education, and working department.

Weinstein noise sensitivity scale

To determine noise sensitivity, Weinstein noise sensitivity scale was used. This scale includes items related to attitude and affective reactions to noise in the various situations. It consists of 21 items with a 6-point Likert scale ranging from "agree strongly" to "disagree strongly". The total score ranging from 0 to 105 can be categorized into three groups of low sensitivity (scores less than 25th percentile), moderate sensitivity (scores ranging from 25th percentile to 75th percentile), and high sensitivity (scores more than 75th percentile). Alimohammadi et al. investigated and confirmed the reliability and validity of the Persian translation of this scale [17].

Noise annoyance scale

Moreover, a 100-point visual analogue scale with two verbally labelled poles ranging from "not at all annoying" to "extremely annoying" was used to assess nurses' noise annoyance [18]. In this single item measure, nurses rated their perceived annoyance due to hospital noise on

a 100-point graphical rating scale. The total score of noise annoyance was stratified as low (scores less than 25th percentile), moderate (scores ranging from 25th percentile to 75th percentile), and high annoyance (scores more than 75th percentile).

Quality patient care scale

Quality patient care scale [19] is a standard tool consisting of 65 questions in three dimensions including psychosocial (28 items), communicational (13 items) and physical (24 items). The items were answered based on a 4-point Likert-type ranging from 1 to 4 as rarely (1), sometimes (2), often (3), and always (4). The total score of quality of patient care ranged from 65 to 260 and the higher scores indicated higher quality of patient care. Scores less than 130 were considered as undesirable, 130–195 as partly undesirable, and 196–260 as desirable. Regarding the psychosocial aspect, scores less than 56 were considered as undesirable, 56–84 as partly undesirable, and 85–112 as desirable. Regarding the communicational aspect, scores less than 26 were considered as undesirable, 26–39 as partly undesirable, and 40–52 as desirable. Moreover, the physical aspect score was categorized as undesirable (scores less than 48), partly undesirable (scores from 48 to 72), and desirable (scores from 73 to 96). The reliability of this questionnaire was checked, with a Cronbach's alpha coefficient of 0.94 for this study.

Noise measurement procedure

To plot the noise map, measurement points (1510 points five meters apart) were determined on the hospital building map and the noise was measured at all points across different departments. Measurement was performed in accordance with ISO 9612 using KIMO DB 300/2 sound level meter and analyzer. Beginning April 2021, a one-minute equivalent continuous sound pressure level ($Leq_{1 \text{ min}}$) was measured at each point ten times over the course of the day: every two hours from 08:00 to 22:00 to cover all noise level changes during the whole day, and twice during the nighttime shift from 00:00 to 08:00 as representative of the noise level in this shift. This process continued until sound measurements from all 1510 points were obtained. Therefore, to determine noise level at each point, measurements were collected ten times for each point, resulting in a total of 250 hours of noise measurement. The logarithmic mean for each point was calculated and a noise map was plotted.

To determine nurses' noise exposure, nurses who participated in the study were asked to specify their workstations and the duration of their work at that point. Using these data and referring to the ISO 9612, the equivalent continuous sound pressure level (LAeq) was calculated

by the LAeq equation. Finally, the daily personal noise exposure level (LEP,d) was calculated for each nurse. Nurses' noise exposures with values less than 50 dBA, 50 to 60 dBA, and higher than 60 dBA were considered as low exposure, moderate exposure, and high exposure, respectively.

Statistical analysis

The statistical tests were carried out using SPSS software version 24 [20]. Descriptive statistics were calculated. Then the expectation-maximization method was applied to calculate and replace the missing values.

Bayesian Networks (BNs), as probabilistic and graphical models, were introduced by Pearl [21]. In this study, GeNIe academic software version 2.3 was used to analyze Bayesian network. After drawing the BN graphical structure, a Conditional Probability Table (CPT) was obtained by the model with the Expectation-Maximization algorithm [22]. Then, delta p sensitivity analysis was applied to rank the parameters [23]. Finally, 10-fold cross-validation analysis was exploited to examine the model validity. The dataset was randomly divided into ten equal folds, nine folds (9 subsamples) were applied to train the Bayesian network model, and the remaining fold (1 subsample) was used to validate the model. A sensitivity analysis also was conducted to examine the effects of the variables [24].

Results

This cross-sectional study was conducted in 2021 among nurses of Imam Reza Hospital affiliated with the Aja University of Medical Sciences. Of the total number of nurses employed, 209 nurses fully completed the questionnaires. The mean \pm standard deviation (SD) of the age and experience were 36.10 ± 7.43 and 11.33 ± 6.87 , respectively. Table 1 presents the demographic characteristics of nurses.

The mean \pm SD of the noise exposure, noise annoyance and noise sensitivity for all nurses were 54.72 ± 4.40 , 57.51 ± 21.93 , and 59.02 ± 18.80 respectively. Moreover, the mean \pm SD of total quality of patient care, psychosocial, communicational and physical aspects were 187.84 ± 32.59 , 76.45 ± 15.22 , 39.35 ± 7.35 and 71.60 ± 15.54 respectively. These variables were categorized and the mean \pm SD per each group is presented in Table 2.

The results indicate that the highest frequency in each quality of patient care category was: partly desirable quality of patient care total, partly desirable psychosocial aspect, partly desirable communicational aspect and desirable physical aspect. In term of physical aspects of care, 50.2, 35.4 and 14.4% of nurses provided desirable, partly desirable and undesirable levels of care,

Table 1 Demographic characteristics of the participants

| Variable | | Frequency | Relative frequency |
|------------------------|-----------------------------|-----------|--------------------|
| Age (years) | Less than 30years | 96 | 45.90% |
| | 30 to 50years | 71 | 34.0% |
| | More than 50years | 42 | 20.10% |
| Job experience (years) | Less than 10years | 98 | 46.90% |
| | 10 to 20years | 92 | 44.00% |
| | More than 20years | 19 | 9.10% |
| Gender | Male | 88 | 42.10% |
| | Female | 121 | 57.90% |
| Marital status | Married | 107 | 51.20% |
| | Single | 102 | 48.80% |
| Education level | Bachelor degree | 152 | 72.70% |
| | Higher than Bachelor degree | 57 | 27.30% |
| Department | ICU | 49 | 23.40% |
| | Emergency | 24 | 11.50% |
| | Surgery | 39 | 18.70% |
| | Internal medicine | 29 | 13.90% |
| | Blood transfusion | 31 | 14.80% |
| | Others | 37 | 17.70% |

Table 2 Mean ± standard deviation of the studied variables

| Variable | | Frequency | Percent | Mean | SD |
|---------------------------------------|------------------|-----------|---------|--------|-------|
| Noise exposure | Low | 47 | 22.5% | 48.80 | 1.84 |
| | Moderate | 126 | 60.3% | 54.92 | 1.69 |
| | High | 36 | 17.2% | 61.75 | 1.53 |
| Noise sensitivity | Low | 59 | 28.2% | 34.98 | 7.62 |
| | Moderate | 93 | 44.5% | 60.08 | 6.10 |
| | High | 57 | 27.3% | 82.17 | 5.81 |
| Noise annoyance | Low | 61 | 29.2% | 32.95 | 8.23 |
| | Moderate | 104 | 49.8% | 58.75 | 7.96 |
| | High | 44 | 21.1% | 88.63 | 15.18 |
| Quality of patient care (total score) | Undesirable | 19 | 9.1% | 119.52 | 5.31 |
| | Partly desirable | 97 | 46.4% | 175.83 | 18.78 |
| | Desirable | 93 | 44.5% | 214.32 | 14.29 |
| Psychosocial aspect | Undesirable | 24 | 11.5% | 47.16 | 8.20 |
| | Partly desirable | 116 | 55.5% | 73.16 | 6.81 |
| | Desirable | 69 | 33.3% | 92.18 | 5.94 |
| Communicational aspect | Undesirable | 21 | 10.0% | 24.95 | 1.96 |
| | Partly desirable | 101 | 48.3% | 36.37 | 3.32 |
| | Desirable | 87 | 41.6% | 46.29 | 2.66 |
| Physical aspect | Undesirable | 30 | 14.4% | 43.46 | 5.17 |
| | Partly desirable | 74 | 35.4% | 65.41 | 5.49 |
| | Desirable | 105 | 50.2% | 84.00 | 6.62 |

respectively. Table 3 also represents the Conditional Probability Table (CPT) for quality of patient care, which describes the coefficients among the variables.

Figure 1 shows the dependencies among the marginal probabilities of the studied variables based on the Bayesian network model. Table 4 also reports the sensitivity analyses for noise parameters. At the low noise

Table 3 The conditional probability table (CPT) for overall quality of patient care

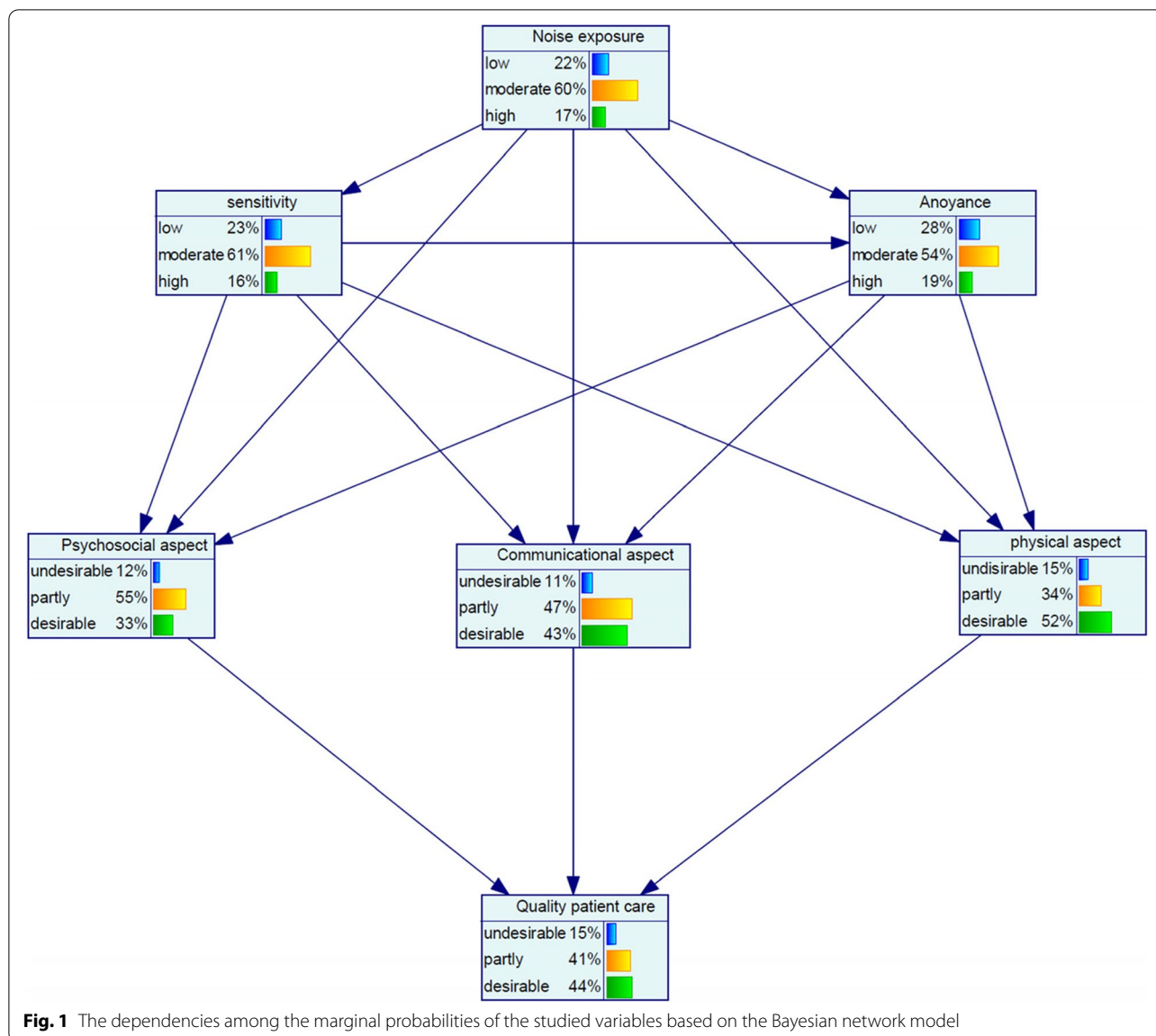
| Noise exposure | Noise sensitivity | Noise annoyance | Undesirable | Partly undesirable | Desirable |
|----------------|-------------------|-----------------|-------------|--------------------|-----------|
| Low | Low | Low | 0.037 | 0.333 | 0.630 |
| | | Moderate | 0.333 | 0.333 | 0.334 |
| | | High | 0.333 | 0.333 | 0.334 |
| | Moderate | Low | 0.167 | 0.083 | 0.750 |
| | | Moderate | 0.500 | 0.333 | 0.167 |
| | | High | 0.333 | 0.333 | 0.334 |
| | High | Low | 1.000 | 0.000 | 0.000 |
| | | Moderate | 0.000 | 1.000 | 0.000 |
| | | High | 0.333 | 0.333 | 0.334 |
| Moderate | Low | Low | 0.000 | 0.231 | 0.769 |
| | | Moderate | 0.118 | 0.353 | 0.529 |
| | | High | 0.333 | 0.333 | 0.334 |
| | Moderate | Low | 0.000 | 0.200 | 0.800 |
| | | Moderate | 0.038 | 0.481 | 0.481 |
| | | High | 0.333 | 0.333 | 0.334 |
| | High | Low | 0.500 | 0.500 | 0.000 |
| | | Moderate | 0.136 | 0.409 | 0.455 |
| | | High | 0.000 | 0.833 | 0.167 |
| High | Low | Low | 0.333 | 0.333 | 0.334 |
| | | Moderate | 0.000 | 1.000 | 0.000 |
| | | High | 0.333 | 0.333 | 0.334 |
| | Moderate | Low | 0.000 | 1.000 | 0.000 |
| | | Moderate | 0.000 | 1.000 | 0.000 |
| | | High | 0.273 | 0.455 | 0.273 |
| | High | Low | 0.333 | 0.333 | 0.334 |
| | | Moderate | 0.000 | 0.000 | 1.000 |
| | | High | 0.111 | 0.889 | 0.000 |

exposure with the probability of 100%, the probability of the variables of low sensitivity, low annoyance, and desirable quality of patient care increased by 23, 53, and 8%, respectively (Fig. 2(a)). Moreover, at the high noise exposure with the probability of 100%, the probability of the variables of high sensitivity and high annoyance increased by 17 and 59%, respectively, but desirable quality of patient care decreased by -21% (Minus sign is indicative of a decrease) (Fig. 2(b)). Regarding aspects of quality of patient care for the state of low noise exposure, most increase was related to the desirable psychosocial aspect by an increase of 21%. Moreover, desirable communicational and physical aspects increased by 3 and 6%, respectively (Fig. 2(a)). For the state of high noise exposure, undesirable communicational aspect, undesirable psychosocial aspect and undesirable physical aspect increased by 12, 8 and 6%, respectively (Fig. 2(b)).

For the low noise sensitivity with the probability of 100%, the probability of the variables of the low annoyance and desirable quality of patient care increased by 40 and 13%, respectively (Fig. 3(a)). Concerning the

high noise sensitivity with the probability of 100%, high annoyance and desirable quality of patient care increased by 34% and -14%, respectively (Minus sign indicative of a decrease) (Fig. 3(b)). Among aspects of quality of patient care for the state of low noise sensitivity, most change was related to the desirable physical aspect with a 14% increase and for the state of high noise sensitivity, most change belonged to the desirable physical aspect with a -21% decrease (Fig. 3(a and b)).

At the low noise annoyance with the probability of 100%, the probability of the desirable quality of patient care increased by 19% and for the high noise annoyance with the probability of 100%, the probability of the desirable quality of patient care decreased by 23%. Among aspects of quality of patient care for the state of low noise annoyance, most increase was related to the desirable psychosocial aspect with a 21% increase and for the state of high noise annoyance, most increase belonged to the undesirable psychosocial aspect with a 15% increase (Fig. 4(a and b)).



Furthermore, at the concurrently low noise exposure and low noise sensitivity with the probability of 100%, the desirable quality of patient care increased by 16% and at the concurrently high noise exposure and high noise sensitivity, the desirable quality of patient care decreased by 26%. Among the aspects of quality of patient care for the low noise/low sensitivity states, most increase was related to the desirable physical aspect with a 22% increase and for the high noise/high sensitivity states, most increase belonged to the undesirable communication aspect with a 15% increase (Fig. 5(a and b)).

Table 5 represents the computed effective value for the association among the modeled variables. In this table, the parent (independent) is a variable influencing

the child (dependent) and the child is a variable affected by parent. Most influence values belonged to the association of noise exposure and annoyance (0.636), relationship of quality of patient care with physical aspect (0.475), with communicational aspect (0.441), and with psychosocial aspect (0.439), respectively. Annoyance had the highest association with the physical aspect (0.400) and nurses' noise sensitivity had the greatest association with the communicational aspect (0.283). Also, the association between noise exposure and annoyance (0.636) was greater compared to its association with sensitivity (0.257).

A ROC curve depicted to examine the validity of the fitted Bayesian model is shown in Fig. 6. The area under

Table 4 Sensitivity analysis for noise parameters

| Parameter | Level | Low (100%) | | | | High (100%) | | | |
|-------------------------|------------------|----------------|-----------|-------------|--------------------------------|----------------|-----------|-------------|--------------------------------|
| | | Noise exposure | Annoyance | Sensitivity | Noise exposure and sensitivity | Noise exposure | Annoyance | Sensitivity | Noise exposure and sensitivity |
| Annoyance | Low | + 53% | - | + 40% | + 72% | - 24% | - | - 22% | - 28% |
| | Moderate | -35% | - | - 22% | - 54% | - 36% | - | - 13% | - 49% |
| | High | -19% | - | - 19% | - 19% | + 59% | - | + 34% | + 76% |
| Sensitivity | Low | + 23% | - | - | - | - 19% | - | - | - |
| | Moderate | + 10% | - | - | - | + 2% | - | - | - |
| | High | -13% | - | - | - | + 17% | - | - | - |
| Quality of patient care | Undesirable | + 4% | - 6% | - 4% | - 3% | + 6% | + 11% | + 6% | + 7% |
| | Partly desirable | -12% | - 14% | - 9% | - 13% | + 15% | + 12% | + 8% | + 20% |
| | Desirable | + 8% | + 19% | + 13% | + 16% | - 21% | - 23% | - 14% | - 26% |
| Psychosocial aspect | Undesirable | + 1% | - 6% | - 3% | - 1% | + 8% | + 15% | + 2% | - 1% |
| | Partly desirable | -22% | - 15% | - 10% | - 18% | + 13% | + 8% | + 7% | + 24% |
| | Desirable | + 21% | + 21% | + 13% | + 19% | - 21% | - 23% | - 9% | - 22% |
| Communicational aspect | Undesirable | + 5% | - 7% | - 5% | - 7% | + 12% | + 4% | 0% | + 15% |
| | Partly desirable | - 9% | - 6% | - 3% | + 5% | + 8% | + 11% | + 13% | + 11% |
| | Desirable | + 3% | + 12% | + 7% | + 1% | - 21% | - 16% | - 14% | - 27% |
| Physical aspect | Undesirable | + 8% | - 8% | - 6% | - 8% | + 6% | + 9% | + 3% | + 11% |
| | Partly desirable | -15% | - 12% | - 9% | - 15% | + 10% | + 16% | + 17% | + 22% |
| | Desirable | + 6% | + 19% | + 14% | + 22% | - 17% | - 26% | - 21% | - 33% |

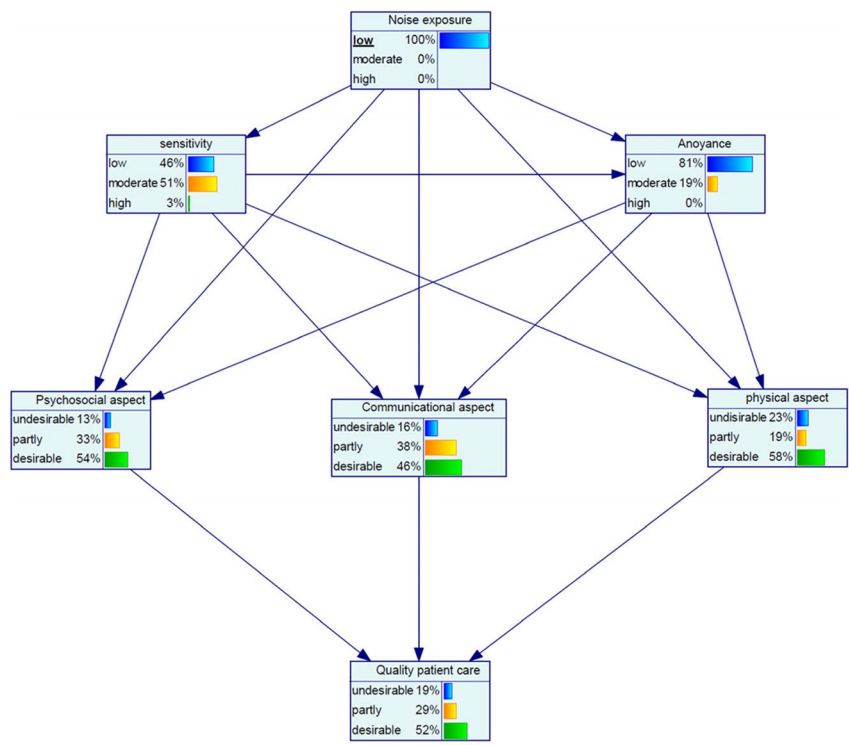
the curve was equal to 0.955. As reported in Table 6, the confusion matrix related to the classification of the quality of patient care status was also calculated and presented in Table 6. Moreover, the values of the sensitivity, specificity, and accuracy of the model were computed as 0.860, 0.971, and 0.842, respectively.

Discussion

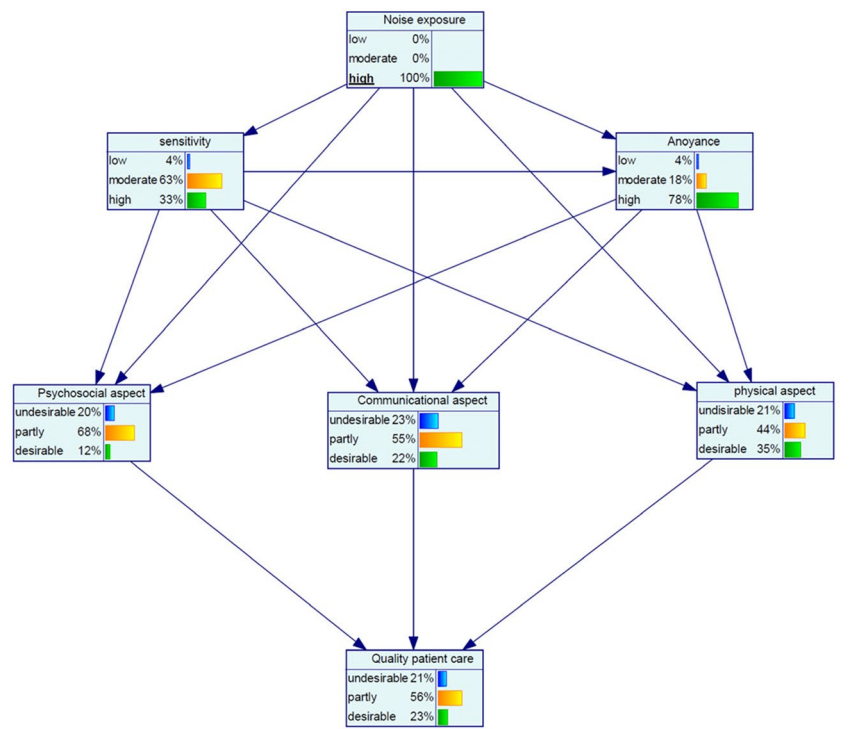
The World Health Organization has recommended that noise levels in hospital wards should not exceed 30 and 35 dBA during night and day time, respectively [25]. In this study, nurses’ noise exposure was beyond the standard developed by WHO and its mean was 48.80, 54.92, and 61.75 for low, moderate, and high noise exposure groups, respectively. Therefore, it is expected that some harmful effects such as health effects, decreased performance, absenteeism, and decreased cognitive functions occur among nurses even at the lower exposure levels. Regarding that, this study was conducted to predict the contributing role of noise, sensitivity, and annoyance on quality of patient care. Based on the assumed model, noise as an environmental stressor and sensitivity to noise as an individual factor can affect annoyance and

in turn, these factors can exert their effect on the quality of care as one of the performance indicators in nursing occupations.

At the low noise exposure with the probability of 100% and at the low noise sensitivity with the probability of 100%, the probability of the variables of low annoyance increased by 53, and 40%, respectively (Fig. 2(a)). Moreover, at the concurrently low noise exposure and low noise sensitivity with the probability of 100%, the low annoyance increased by 72%. This shows that annoyance is more influenced by noise exposure compared to sensitivity. These results are consistent with Monazzam et al. study, where the effect size of noise and sensitivity on annoyance were 0.57 and 0.52, respectively [26]. Moreover other studies have concluded that annoyance perceived by nurses is one of the main harmful effects of exposure to hospital noise [9, 27]. Noise annoyance is caused due to exposure to noise and also the level of individual sensitivity to the noise. In other words, noise sensitivity is considered as a mediator between the noise exposure and annoyance. Noise-sensitive people are more vulnerable to the negative health effects induced from noise exposure. As a

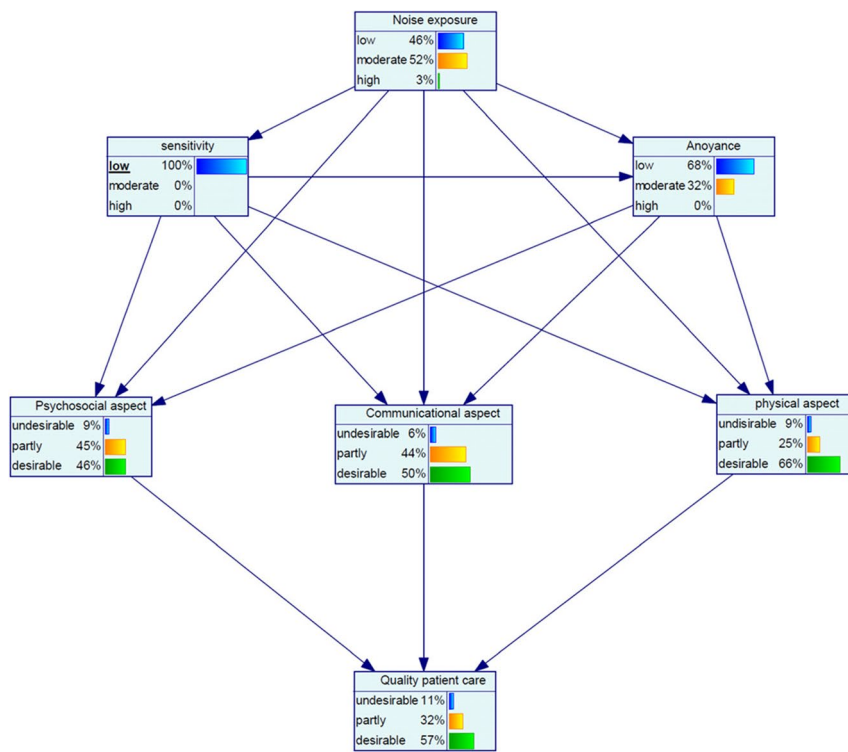


(a)

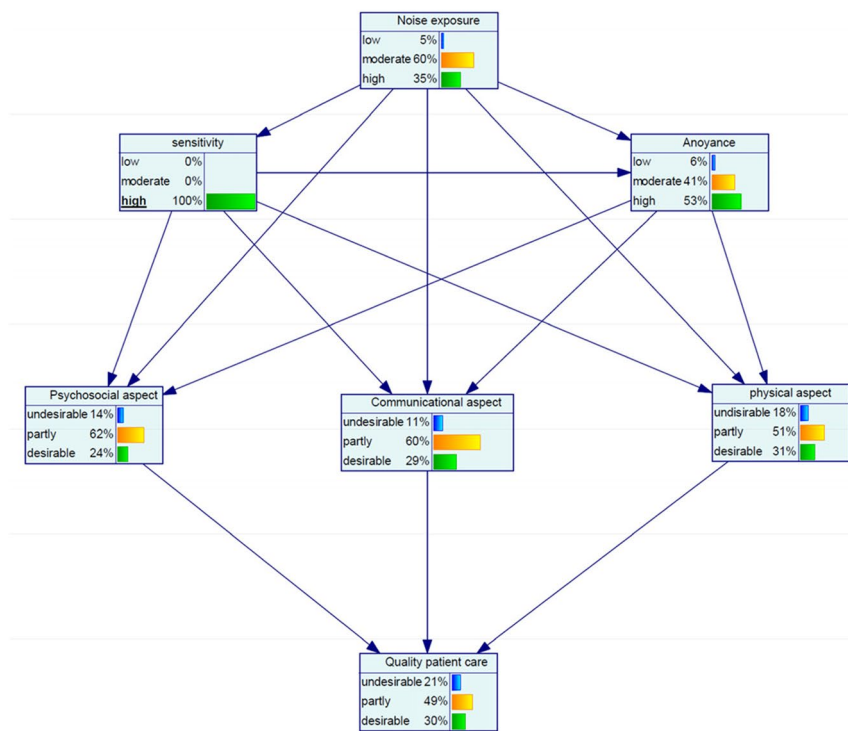


(b)

Fig. 2 Sensitivity analysis on noise exposure: (a) low and (b) high

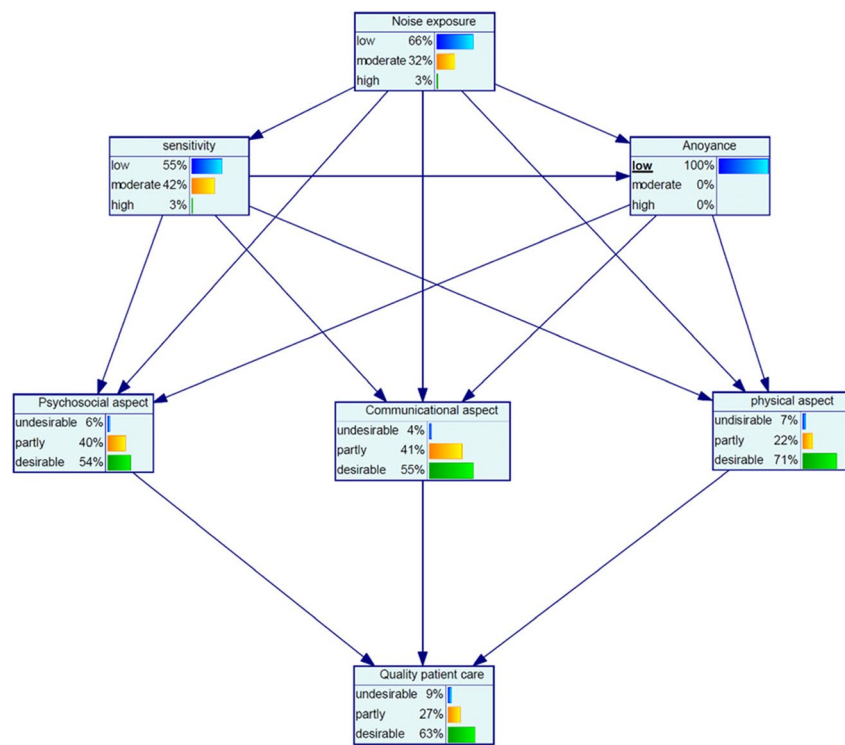


(a)

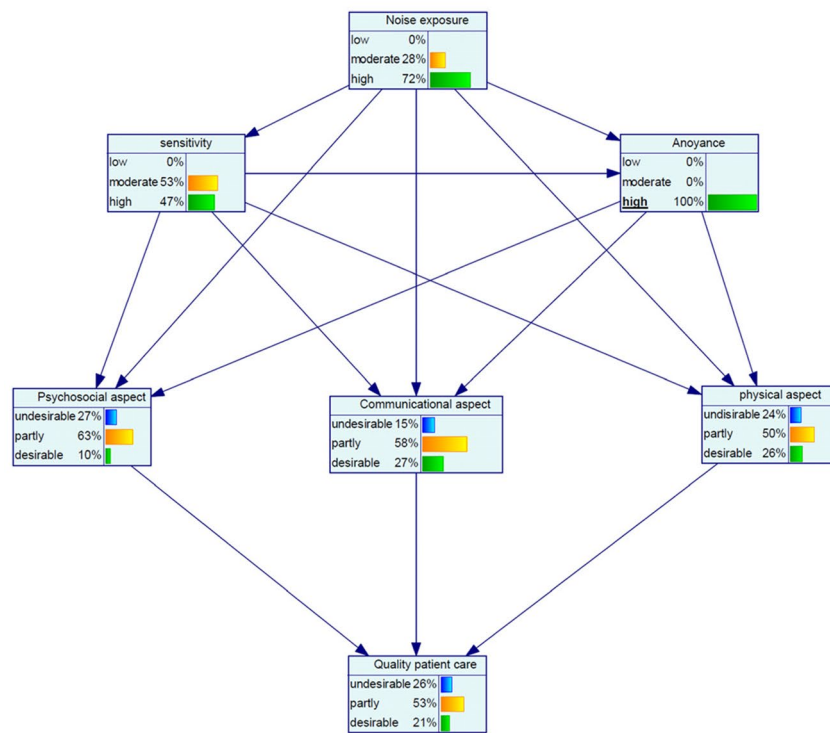


(b)

Fig. 3 Sensitivity analysis on noise sensitivity: (a) low and (b) high

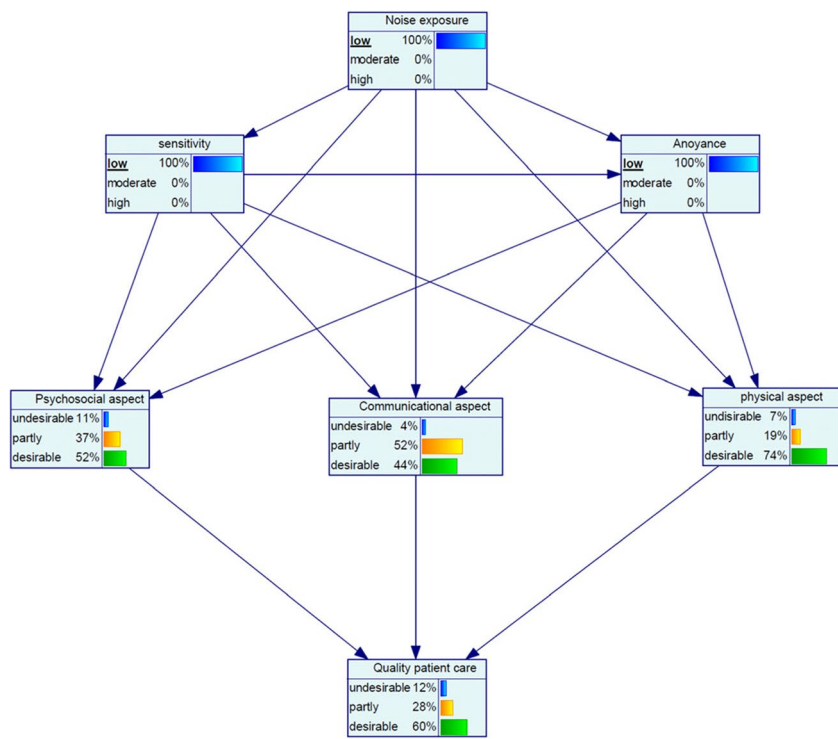


(a)

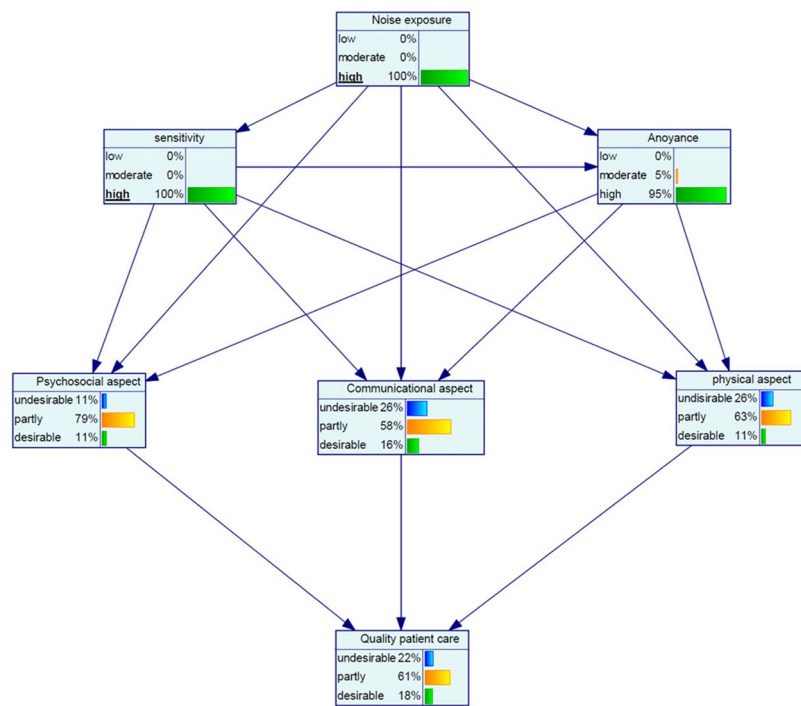


(b)

Fig. 4 Sensitivity analysis on noise annoyance: (a) low and (b) high



(a)



(b)

Fig. 5 Sensitivity analysis on simultaneous noise exposure and noise sensitivity: (a) low and (b) high

Table 5 The calculated influence value of the modeled relationships

| Parent | Child | Influence value |
|------------------------|-------------------------|-----------------|
| Noise exposure | Annoyance | 0.636 |
| Physical aspect | Quality of patient care | 0.475 |
| Communicational aspect | Quality of patient care | 0.441 |
| Psychosocial aspect | Quality of patient care | 0.439 |
| Sensitivity | Annoyance | 0.429 |
| Annoyance | Physical aspect | 0.400 |
| Noise exposure | Psychosocial aspect | 0.330 |
| Annoyance | Psychosocial aspect | 0.327 |
| Annoyance | Communicational aspect | 0.308 |
| Noise exposure | Communicational aspect | 0.306 |
| Sensitivity | Communicational aspect | 0.283 |
| Noise exposure | Physical aspect | 0.282 |
| Sensitivity | Physical aspect | 0.275 |
| Noise exposure | Sensitivity | 0.257 |
| Sensitivity | Psychosocial aspect | 0.245 |

result, it is reasonable to predict that they found noise more annoying [28].

Concerning the quality of patient care, it can be seen that at the low noise exposure, low annoyance, and low sensitivity with the probability of 100%, the outcome of interest increased by +8%, +19%, and +13%, respectively. Moreover, at the concurrently low noise exposure and low noise sensitivity with the probability of 100%, the desirable quality of patient care increased by 16%. This shows that the quality of patient care is more affected by annoyance than noise exposure and sensitivity. This reasonable result is expected because annoyance is regarded as the outcome of both noise exposure and sensitivity. Regarding the effect of noise exposure on quality of patient care, Terzi et al. confirmed that noise adversely affected the nurse’s satisfaction and anxiety and these unwanted outcomes can threaten the quality of patient care [29]. In this study, the quality of patient care is measured by three dimensions including psychosocial, communicational, and physical aspects. The results indicated that reduced noise could increase the desirable

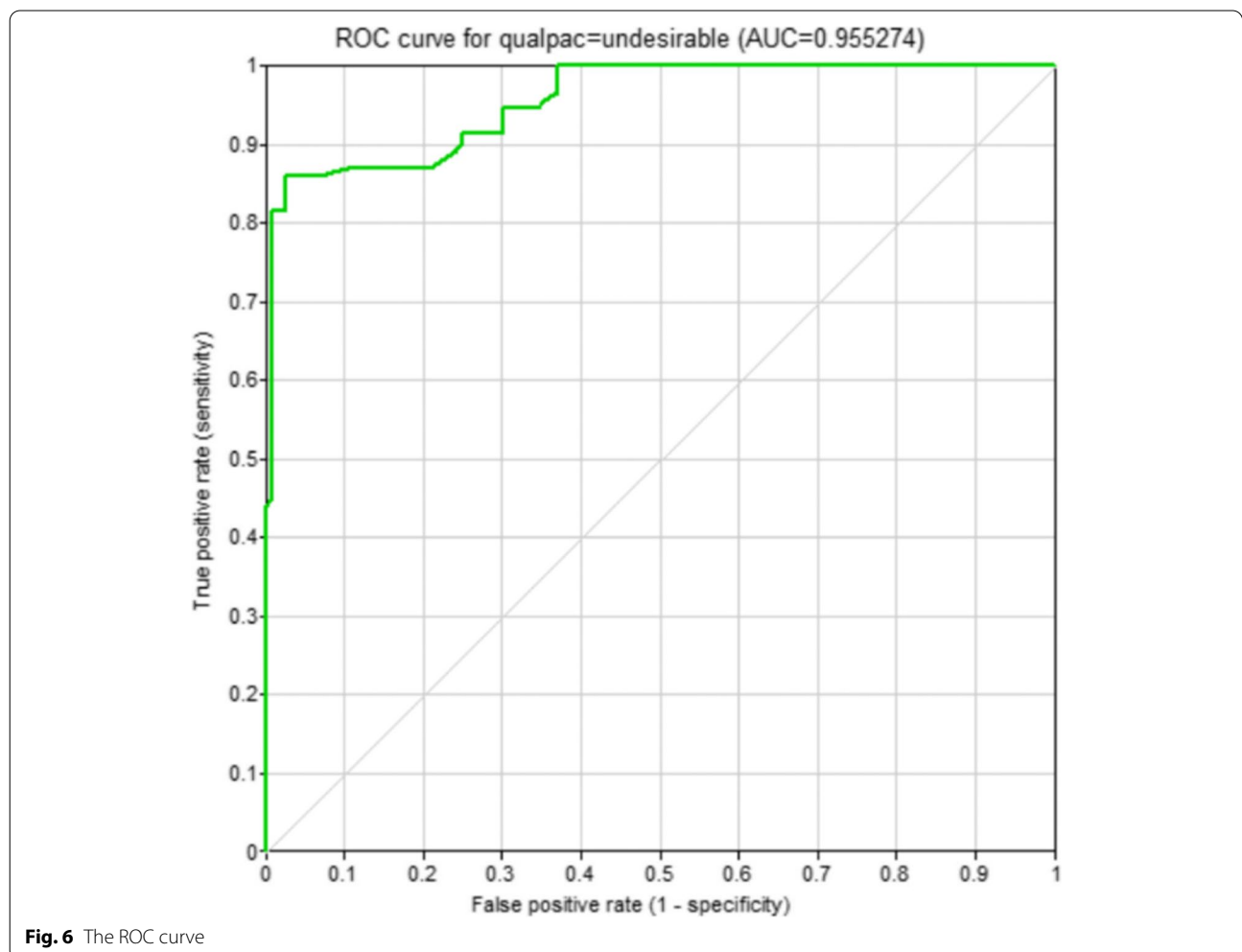


Fig. 6 The ROC curve

Table 6 The confusion matrix related to the classification of the quality of patient care status

| | Predicted | | | Actual |
|---------------------|-----------|------------------|-------------|------------------|
| | Desirable | Partly desirable | Undesirable | |
| Sensitivity = 0.860 | 13 | 0 | 80 | Undesirable |
| Specificity = 0.971 | 8 | 11 | 0 | Partly desirable |
| Accuracy = 0.842 | 85 | 5 | 7 | Desirable |

aspects of the aforementioned dimensions by 21%, 6%, and 3%, respectively. There are robust reports that noise can impair cognitive performance and productivity, disturb communication, and compromise speech privacy [30, 31]. Moreover, noise can influence the psychosocial aspect of health, annoyance, psychosocial stress, and behaviors [32, 33]. Disturbed communication can be followed by misunderstanding of the patient and colleagues' needs and in turn, reduce the quality of patient care. Moreover, it is well documented that annoyance as a negative psychological reaction induced by noise exposure can trigger more adverse health effects. Annoyance as a mediator can exert harmful effects of noise exposure on stress responses and other health consequences [34]. Stress responses also can impair functional and behavioral stability of nurses and in turn, influence their performance and quality of care. Moreover, Abbasi et al. stated that noise annoyance had a significant adverse impact on job stress and blood pressure and it decreased job satisfaction [15, 35, 36]. These consequences can justify the effect of noise and noise annoyance on the quality of patient care. In other words, noise and noise annoyance can lead to decreased quality of patient care through these consequences. In a study on the effect of ambient noise on annoyance and potential health effects, Amaty et al. reported that medical staff complained about noise and its effect on overall work performance and loss of concentration [37]. Therefore, it can be expected that noise can affect quality of care through these adverse effects.

The results of our study showed that reduced sensitivity to noise decreases high levels of annoyance by 19%. Moreover, desirable quality of patient care, psychosocial, communicational, and physical aspects increased by +13%, +13%, +7%, and +14%, respectively. In addition to noise, it is well known that noise sensitivity can predict noise annoyance [26, 38]. Therefore, similar to the noise, it can be stated that noise sensitivity exerted its effect on the quality of patient care through annoyance. According to the research literature, noise sensitivity can have negative psychological and physiological effects. Abbasi et al. stated that noise sensitivity has a negative impact on job stress and it can act in a synergistic manner with noise exposure on job stress [36]. Khan et al.

reported that as the noise sensitivity raised by 1 unit, the cortisol level raised by 0.032 $\mu\text{g}/\text{dL}$ [39]. Cortisol secretion as the main cause of increased stress has a significant adverse effect on individual performance [40]. Thus, it is expected that noise-sensitive nurses release more stress hormones and in turn, their performance and quality of patient care will be reduced. In addition to the subjective and psychological effects, noise sensitivity can trigger some physiological responses such as cardiovascular disease, hypertension and immune response [38, 41–43]. As a result, all of these reactions that may occur in noise-sensitive nurses may have an unfavorable influence on patient care quality. Furthermore, it has been noted that noise-sensitive people are more vulnerable to other environmental stressors and they may become inefficient and disrupted while they are exposed to stressors such as noise. According to the findings of the current study, when noise-sensitive nurses are exposed to noise, they perceive noise more annoying and in turn their quality of patient care will be further declined.

Alongside the valuable results obtained in this study, there are several limitations that future researchers will want to address. As a limitation, the noise level was the only studied variable and the effect of noise frequency and psychoacoustics indices were not considered. Moreover, the study was conducted during the COVID-19 pandemic. This issue can affect both noise pollution levels in hospitals and the quality of patient care regardless of the noise impacts. This study was cross-sectional and therefore limitations such as lacking temporal relationship and causal investigation are to be expected. To overcome these limitations, conducting longitudinal studies should be considered for future research. Moreover, using self-report instruments to collect individual data may cause some biases that should be covered off somewhat by applying objective data gathering methods.

Conclusion

The results of this study concluded that hospital noise and noise sensitivity as environmental stressors and individual traits can interact with each other and in turn influence nurses' perception of noise and quality of patient care. Annoyance as a subjective reaction to the noise and personal noise sensitivity has a significant

adverse impact on the quality of patient care. In addition to this, noise and sensitivity had a separate direct adverse effect upon the quality of patient care and their co-occurrence potentially reduced the quality of patient care.

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Authors' contributions

MA and NE contributed to the conception of the study; the design, acquisition, analysis, and interpretation of data; and MA was a major contributor to writing the manuscript. SYR contributed to analysis of the data and interpretation of the results. MF and MZ interpreted the data and substantively critically reviewed them. All authors read and approved the final manuscript.

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Availability of data and materials

The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study was approved by the institutional research ethics committee of Aja University of Medical Sciences (IR.AJAUMS.REC1400.060). All methods were performed in accordance with the relevant guidelines and regulations. In addition, written informed consent was obtained from each participant in the study.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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