The Weight of Organizational Factors on Heuristics: Evidence from Triage Decision-making Processes

Structured Abstract

- **Purpose**
  The paper investigates the influence of organizational factors on individual decision-making under conditions of uncertainty and time pressure. A method to assess the impact of individual and organizational factors on individual decisions is proposed and experimented in the context of triage decision-making process.
- **Design/methodology/approach**
  The adopted methodology is based on the bias-variance decomposition formula. The method, usually applied to assess the predictive accuracy of heuristics, has been adjusted to discriminate between the impact of organizational and individual factors affecting heuristic processes. To test the methodology, 25 clinical scenarios have been designed and submitted, through simulations, to the triage nurses of two Spanish hospitals.
- **Findings**
  Nurses' decisions are affected by organizational factors in certain task conditions, such as situations characterized by complete and coherent information. When relevant information is lacking, and available information is not coherent, decision-makers base their assessments on their personal experience and gut feeling.
- **Research limitations/implications**
  Discriminating between the influence of organizational factors and individual ones is the starting point for a more in-depth understanding of how organization can guide the decision process. Using simulations of clinical scenarios in field research does not allow for capturing the influence of some contextual factors, such as the nurses' stress levels, on individual decisions. This issue will be addressed in further research.
- **Practical implications**
  Bias and variance are useful measurements for detecting process-improvement actions. A bias prevalence requires a redesign of organizational settings, whereas training would be preferred when variance prevails.
- **Originality/value**
  The main contribution of this work concerns the novel interpretation of bias and variance concepts to assess organizational factors' influence on heuristic decision-making processes, taking into account the level of complexity of decision-related tasks.

Keywords: bias and variance error, cognitive heuristics, individual cognition, organizational factors, triage.

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1. Introduction

Decision-making is a very challenging issue for organizations, as individuals can make suboptimal decisions caused by unbounded rationality and cognitive biases. Biases are drivers of human error in decision-making, since they affect an individual's strategy for assessing and processing information (for a review of individual biases and taxonomies see Arnott, 2002 and Arnott, 2006). The strategy selected by a decision-maker is the output of a problem's recognition and of an evaluation of the tasks, whereas it is the input of information-processing and choice (Beach and Mitchell, 1978). In other terms, the strategy connects the process of interpretation and the process of choice in a dynamic manner. The actions taken after the interpretation process can generate new information, changing the situation (Hodgkinson and Healey, 2008); consequently, the individual could revise his/her decisions. In many organizational situations, the strategy used for decision-making is usually not a "recognize and calculate" process associated with expertise in a task domain (Chi *et al.*, 1988), but relies on a heuristic process, namely a cognitive shortcut strategy employed to take a decision based on limited information, time and processing capacity (Simon and Newell, 1971). Heuristics are simplified rules that decision-makers use to look for the solution to a problem, disregarding some information or simplifying the process of elaboration.

In the management field, great attention has been paid to heuristics in decision-making (Wickham, 2003; Workman, 2012) and, as has emerged from Basel and Brühl's (2013) review, heuristics are considered useful strategies for taking decisions in uncertain and complex environments. For example, in the entrepreneurship stream, Bryant (2007) prompts scholars to abandon a skeptical attitude towards heuristics and recognizes their effectiveness and accuracy as decision-making tools. Selart *et al.* (2008) and Alcantara and Mitsuhashi (2015) emphasize the capacity of heuristics to combine both analytical and intuitive processes. In organizational and management control research, an interesting issue revolves around the question of how to improve decisions' quality and avoid errors through heuristics (Bazerman and Moore, 2008).

Heuristics have assumed a positive role in decision-making thanks to Gigerenzer and his research group: they demonstrated that heuristics can lead to accurate and fast judgment and they label them as "fast and frugal" (Gigerenzer *et al.*, 1999). Through heuristics, the decision-maker can reach a decision in a short amount of time (fast), basing his/her judgment on few cues (frugal) (Martignon and Hoffrage, 2002; Drechsler *et al.*, 2014).

Fast and frugal heuristics are adequate decision strategies in situations of uncertainty and ambiguous information, turbulent environments, and time pressure (Khatri and Ng, 2000; Baum and Wally, 2003; Reimer and Rieskamp, 2007; Artinger *et al.*, 2015). Their success is determined by "ecological rationality" (Gigerenzer *et al.,* 1999), referring to how a bounded mind "exploits the structure of the social and physical environments in which it must reach its goals" (Chase *et al.*, 1998, p.212). The "ecological rationality" concept reinforces the adaptive and non-linear nature of heuristic decision-making, which depends on the dynamic interplay between individual cognitive factors, the environmental and task's characteristics, and social context (Beach and Mitchell, 1978; Weeks and Whimster, 1985; Payne *et al.*, 1993). From a management perspective, the influence of the social context is mediated by organizational factors such as formal and informal rules, support systems, and institutional commitments, that provide some directions for the decisions and also leave room for cognitive errors during the interpretation phase (Vuori and Vuori, 2014).

Being aware of the impact of organizational factors on individual decision-making in different situations is relevant from a managerial point of view, because it allows managers to identify elements of the organizational context that can be used as levers to increase the quality of the decision-making process.

Although the management literature has emphasized that organizational factors influence decision-making (Weeks and Whimster 1985; Haley and Stumpf, 1989; Wilson, 1999; Pachur and Galesic, 2013), the interplay between individual and organizational factors remains poorly explored from a quantitative perspective.

According to this perspective, the research question that this paper seeks to answer is: "what is the weight of organizational and individual factors in heuristics used in dynamic decision-making?"

To answer this question, we adopt the bias-variance decomposition method proposed by Gigerenzer and Brighton (2009) to assess the accuracy of heuristics in specific environments. This method is adapted and experimented with to assess the weight of organizational and individual factors in triage decision-making process.

The paper is articulated as follows. Section 2 focuses on the theoretical background concerning the factors affecting the individual cognitive heuristics in a dynamic and adaptive decision-making process. Section 3 describes the methodological approach and how we have applied the bias-variance concepts for discriminating between individual and organizational factors affecting heuristics. Section 4 illustrates the experimentation with the methodology in two Spanish hospitals. Section 5 and 6 discuss respectively the results and implications for the research while the practical and managerial implications are reported in the conclusions.

2. Theoretical Background

Nowadays, organizations and their environments are analyzed according to a dynamic rather than static perspective that requires a continuous interplay between the organizational action and the information sense-making. This fact implies that decision-making is an adaptive dynamic process involving several individuals aimed at matching the organizational action with environment requirements (Child, 1997; Abatecola, 2014; Aloini *et al*, 2018).

In an adaptive decision-making process, the individual continuously looks for new information and interprets it to reassess the accuracy of his/her decision. Rudolph *et al*. (2009) analyze this kind of process in medical emergency situations and observe different physicians' behaviors when they are making the leading diagnosis. This process can be framed as a heuristic process because individuals use, in a certain way, their own rules to select the information that is taken into account in order to reach the decision quickly (Slovic *et al.*, 1977; Hogarth, 1981). Individuals apply different strategies, as they perceive data differently. Analyzing the main decision strategies with respect to task complexity and effort needed for accurate decisions, Payne *et al*. (1990) find that individuals "selectively process a subset of the available information and/or selectively apply operations to that information that are easier to perform" (Payne *et al*., 1990, p. 4). In a study on relationships between individual personality and bias affecting the heuristic process, Haley and Stumpf (1989) claim: "personality types demonstrate distinct preferences for collecting data, generating responses, and evaluating responses" (Haley and Stumpf 1989, p. 481). In the organizational and management research stream on heuristics, Loock and Hinnen (2015) highlight that individual decision-making processes can be assimilated to Gigerenzer's view of heuristics as adaptive processes (Gigerenzer *et al*, 1999). This is because the decision-making process relies on effort reduction, since it examines fewer cues, reduces the effort of retrieving cue values, simplifies the weighting of cues, integrates less information, and examines fewer alternatives (Shan and Oppenheimer, 2008; Lipizzi *et al.*, 2015).

Although heuristics is a strategy based on cognitive simplifications, decisions can reach a high level of accuracy in uncertain and potentially changing environments (Einhorn and Hogarth, 1975; Bertel and Kirlik, 2010; Brighton and Gigerenzer, 2012). In fact, in complex and uncertain environments, more effort can produce less predictive accuracy (Gingerenzer, 2008; Czerlinski *et al.*, 1999), and heuristics based on few cues can work well (Brandstätter and Gussmack, 2013; Iandoli *et al.*, 2014; Mousavi and Gigerenzer, 2014; Artinger *et al.*, 2015). The effort concept refers to the amount of information considered by the decision-maker.

A central aspect of heuristics as framed by Gigerenzer *et al.* (1999) is that the individual gives some kinds of data more weight than other ones (Markus and Zajonc, 1985), depending on both individual characteristics and factors related to the organizational context in which he/she is embedded. These data could lead to biases due to the "availability, accessibility or saliency of some information" (Haley and Stumpf, 1989, p. 481). Salient information constitutes a specific cue that strongly influences the individual decision-making process, as individuals can easily observe or recall it from memory (Bazerman, 1994). The accuracy of the decision-making process can also be affected by the individual's inability to distinguish between irrelevant and salient information (Pleggenhuhle *et al.*, 2013). Irrelevant information, if perceived as salient, can lead the individual to misinterpret the situation and make a wrong decision.

Nevertheless, the degree of information disaggregation and the weight assigned to information used to identify salient cues can also depend on the desired accuracy of the decision, that it is linked to the task's complexity (Payne *et al.*, 1990).

Based on the above concepts, the heuristic process in an "ecological rationality perspective" is based on a subset of available information that the decision-maker considers salient, and which is influenced by:

- individual factors;
- characteristics of the decisional task;
- factors related to the organizational context.

<Insert Figure 1 here>

Individual factors are related to the ability of individuals to learn from and adapt to situations according to a dynamic decision-making process that relies on taking action, interpreting the new information generated by action, and cultivating new solutions (Rudolph *et al.*, 2009). These factors include, among others: age, education, socio-economic roots, career and work experiences (Hambrick and Mason, 1984).

The decisional task is usually framed in terms of the effects of "those factors associated with the general structural characteristics of the decision problem, including response mode, number of alternatives, number of outcomes or attributes, time pressure, information display mode, and agenda constraints" (Payne *et al.*, 1993, p. 22). Generally speaking, task complexity concerns time pressure, information overload and other environmental factors (Maule and Edland, 1997; Ordonez and Benson, 1997).

Factors related to the organizational context concern the "articulated and often informal rules-of-thumb shared by multiple participants within the firm" (Bingham *et al.*, 2007, p. 31) that guide the individual decision-making process. The rules of thumb can be effectively spread within the organization through a social process of influence and imitation (MacGillivray, 2014). The decision therefore emerges from a social pattern in which individuals and their social context are strictly interwoven in any explanations (Hambrick and Mason, 1984; Cristofaro, 2016).

Despite the attention given by the literature to the connection between heuristics and individual and organizational aspects (Beach and Mitchell, 1978; Haley and Stumpf, 1989; Payne *et al.,* 1993; Bingham and Eisenhardt, 2011; Wolf, 2013; Mousavi and Kheirandish, 2014), the assessment of the impact of individual and organizational factors on the heuristic decision-making process remains an under-researched issue.

3. Methodological approach

The concepts of bias and variance are used in machine learning to evaluate the quality of some induction algorithms attempting to learn the underlying function of a noisy data sample. Averaged across many data samples, the bias of the algorithm is the difference between the true function and the mean function induced by the algorithm. Variance captures the algorithm's sensitivity to differences in the data sample.

According to Gigerenzer and Brighton (2009), it is possible to use the bias-variance decomposition formula to analyze how a human cognitive system makes decisions in different situations. Brighton and Gigerenzer (2012) employed the bias-variance decomposition method to demonstrate that heuristics allow for making accurate predictions in specific environments.

Given:

i) the set of available data: x

ii) the correct prediction represented by the underlying function, usually hidden: h(x)

iii) k predictions represented by a set of polynomial functions: y1(x), y2(x), …, yk(x)

iv) the mean function of the k predictions: Y(x), where

$$Y(x) = \frac{1}{k} \sum yi\ (x) \qquad (1)$$

the Total Prediction Error is divided into three components[1]: bias, variance and noise according to equation (2).

Total prediction error = Bias^2 + Variance + Noise (2)

where:

$$Bias^2 = \sum_{x=1}^{n} (Y(x) - h(x))^2 \qquad (3)$$

$$Variance = \sum_{x=1}^{n} \frac{1}{k} \sum_i (yi(x) - Y(x))^2 \qquad (4)$$

The bias represents the deviation of the mean function Ȳ(x) from the true function h(x). The variance is represented by the degree of systematic variation of the individual polynomial yi(x) from the average Ȳ(x).

We can apply the logic outlined above using an organizational perspective as follows. If all individuals in an organizational group make the same decision, aside from error, they share the same heuristic process and base the decision on the same cues. In this case, we can conclude that the organizational context plays a strong coordinating role as a normative environment which eliminates differences among individuals by constraining individual behavior to conform to tacit or explicit rules. This situation gives rise to a sort of groupthink as defined by Janes (1971). Conversely, if individuals make different decisions, this implies that they view the cues differently and do not share the same heuristic process. In this case, individual characteristics prevail during the decisional process.

According to this, the "Bulls-Eye diagram" (Fortmann Roe, 2012) shows how the bias-variance concept supports discriminating between individual and organizational factors affecting heuristics.

The center of the Bulls-Eye is the correct decision, and the shots fired on it are the decisions made by several individuals evaluating the same situation, characterized by salient data and irrelevant data.

Four cases can occur:

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[1] For a detailed explanation of how the equation (2) has been applied to encourage the accuracy of cognitive heuristics in specific environments see Artinger *et al.* (2015) and Brighton and Gingerenzer (2012).

1. **Low bias - Low variance**: The individual decisions are in the center of the target (low bias) and they are tightly grouped (low variance). This implies that individuals take decisions that are very close to the correct decision. They are able to consider only the salient data. As individual differences are minimal, we can assume that the organizational framing plays a central role.
2. **Low bias - High variance:** The individual decisions are spread across the bulls-eye, around the center. In this case, although the average decision is close to the correct one, the individual heuristics reflect a high sensitivity to irrelevant cues. In this case, we can infer that individuals develop their decision using both salient and irrelevant data. Perhaps they are using heuristics that are slightly different. The organizational framing of the situation is weak.
3. **High bias - Low variance**: The individual decisions are far away from the target. They miss the center, displaying the same error. This implies that all individuals are using the same heuristics. As individual differences are minimal, we can infer that organizational framing plays a negative role.
4. **High bias - High variance**: The individual decisions are spread around far away from the target. This is the worst situation: it implies the absence of a strong organizational framing, that is not compensated for by individual differences, as individuals both miss salient data and use irrelevant data.

In contrast to other statistical methods, such as the chi-square, the bias-variance decomposition formula allows us to explicate several features of the frames adopted by any decision-maker, and highlight the distortions of her/his behavior such as risk aversion. In this paper, we limit the use of the method to assessing the impact of individual and organizational factors on decision-makers' choices made under uncertainty and time pressure.

The described methodological approach has in fact been experimented with in reference to the decision-making process of triage nurses. These usually operate in hospitals' Emergency Departments with the aim of assessing in a few minutes the level of urgency for patients arriving at their desk, and assigning them a priority code.

We found that the triage process is a suitable context for testing the method, because of the following reasons:

a) the individual decision-maker, under conditions of uncertainty and limited time, focuses only on a small part of the available information and the decision can nevertheless be accurate (Gigerenzer and Kurzenhäuser, 2005);

b) the structure of the information characterizing the decision-making task (complexity, uncertainty, ambiguity) influences the judgment's accuracy (Cioffi, 1998);

c) the match between individual characteristics, the organizational context in which the decision is made and the nature of the decision-making task is decisive in determining the accuracy of the decision's outcome (Smith *et al.*, 2008).

This implies that the decision-making process of triage nurses is affected by factors related to nurses' individual biographies, to the organizational setting in which they operate, and to the information structure produced by the situation that they are involved in (Benner, 1985; Benner and Tanner 1987). In fact, although formal protocols for prioritizing patients according to their urgency are present, Göransson *et al.* (2005) claim that nurses take decisions differently, and prompt scholars to investigate nurses' rationality to understand how data are interpreted and what are the main data that they base their decisions on.

The following section of the work illustrates in detail the phases of the experiment, while section 5 describes the obtained results, which are then discussed in section 6.

4. Field research

The experimentation with the methodology implied the development of a protocol, which was then applied to two Spanish hospitals.

The protocol consists of the following steps, each of which will be examined in the following sub-paragraphs of this section:

- Definition of 25 clinical scenarios, simulating 25 cases of patients arriving to the triage with different health conditions. This phase was carried out with the support of an expert nurse, a trainer of the triage's operators;
- Selection of two hospitals in which to experiment with the methodology, and identification of a sample of nurses;
- Simulation of the 25 scenarios and data collection;
- Data processing using the bias-variance formula adapted to the specific context of investigation.

4.1 The definition of a set of clinical scenarios

A set of 25 scenarios representing patients arriving at the triage desk, and characterized by different health conditions, was designed in collaboration with a triage expert. The expert was selected since he was a triage trainer for a long time in both hospitals. Scenario's elaboration was guided by the expert basing on the most frequent cases recorded in Alpha and Beta. The expert then assigned the priority codes, basing his choice on the general triage protocols and guidelines.

The simulation of clinical scenarios for data gathering is one of the methods used in triage research (Gerdtz and Bucknall, 2007; van der Wulp *et al.*, 2008). The choice for simulating clinical scenarios in this research was made because of different reasons: first, we needed to define a-priori a function representing the Expert Heuristic; second, we were interested, at this stage of the research, in developing and testing a protocol to apply the methodology depicted above.

For each clinical scenario, the expert defined the appropriate priority level according to triage guidelines and manuals. In Spanish triage, there are five levels of urgency, represented by integers ranging from 1 to 5. Level 1 is assigned to patients characterized by the maximum level of urgency.

Each scenario reports the clinical quantitative information usually recorded for triage assessment and several qualitative cues that can be considered when assigning the priority level.

The clinical information includes the complaint, symptoms, pain, vital signs, and medical history, based on evidence from the literature and technical triage manuals (Cone and Murray, 2002; Arslanian-Engoren, 2005; Garbez *et al.*, 2011; Castner, 2011). The cues concern a different type of information and have been grouped into three classes: subjective cues (complaint, symptoms and pain shown by patient), objective cues (vital signs recorded by the nurse using medical devices) and medical history. The last type of information is usually unavailable at triage because a patient rarely brings his/her medical documentation to the emergency room. For this reason, the descriptions of clinical scenarios focus on subjective cues and objective measures.

The 25 scenarios were grouped into three classes, based on their level of "complexity". These classes follow the classification of clinical situations proposed by Cioffi (1998; 2001), according to Cosier and Dalton's (1988): simple cases (there is a key cue useful for taking the decision; additional cues are compatible with the key cue; the prediction of decision variables is possible); intermediate cases (additional cues are not compatible with the key cue and the relevant information is not always available); and complex cases (cues are contradictory and some relevant information is lacking). The grouping of clinical scenarios according to their level of complexity is in tune with the relevant literature on decision-making in triage (Cioffi, 1998; Cioffi, 2001; Chung, 2005) that outlines the complexity of the decisional task as one of the elements impacting the elaboration and the outcome of the decision itself.

An example of information provided in a clinical scenario is reported in Table 1, with reference to simple scenarios.

< Insert Table 1 here >

Table 2 reports the distribution of the 25 scenarios across the three categories above and the priority levels assigned to each of them by the expert, based on what is prescribed by protocols and guidelines.

< Insert Table 2 here >

4.2 The research contexts and the nurses' sample

The method described in the previous paragraph has been applied in the Emergency Departments (EDs) of two Spanish hospitals, named Alpha and Beta for data anonymization purposes.

Both EDs serve the same number of patients: about 82,000 annually.

The Alpha and Beta EDs introduced the triage process in their emergency procedures in 2007 and 2009 respectively.

Nurses trained to perform the triage numbered 68 in Alpha and 48 in Beta at the time of the research.

In general, the basic training of Spanish nurses includes a Bachelor degree in nursing (four years of theoretical and practical training) and a Master's degree (two years).

The Alpha hospital allows nurses to perform triage only if they have at least three years of previous experience in EDs; in the case of Beta, one year of experience in EDs is sufficient.

With respect to beginners in triage, in Alpha these only work during the first shift (morning) or during the night, avoiding the shift characterized by the highest influx of patients (afternoon). In addition, they are always accompanied by more experienced nurses (tutors). The duration of this tutorial period is not established. In Beta, the period for training and parallel working is fixed to 2/4 months.

In Alpha, 19 out of 68 nurses (28%) participated in the field study, while in Beta 15 out of 48 nurses (31%) were involved. Nurses interviewed regularly carried out triage activities and accepted to be involved in the simulation after their daily shift. The total number of participants was 34.

In both samples, the number of female nurses is significantly higher than the number of male nurses. This sample's composition reflects that of the personnel involved in triage in both hospitals. Furthermore, triage nurses of Alpha's sample are more experienced in Emergency services than nurses of Beta's sample. On the other hand, the nurses of Beta exhibit a number of working years in nursing that are higher than the number of working years in the sector shown by triage nurses in Alpha. Even if the nurses of Alpha are probably younger, they have more experience in Emergency, as requested by Alpha's rules of engagement in triage.

4.3 Simulations and data collection

The field research occurred in the period January-May 2016; two researchers were involved in the data collection.

Scenarios' simulations were preceded by a short period of observation and desk analysis of procedures and formal documentation made available to researchers by the two hospitals. The aim of the observation was to allow the researchers to gather general information on the organization of the two different EDs, the composition of the personnel, and the characteristics of the triage process. In order to validate this preliminary information, both the manager of each ED (two physicians) and the person responsible for each triage service (two senior nurses) were interviewed.

The phase of data collection useful for the application of the proposed methodology was conducted by providing nurses with 25 clinical scenarios.

The simulation phase took place for each nurse separately, when she/he was not involved in her/his work shift. Clinical scenarios were provided in a random order. Nurses were not aware of the different levels of complexity of the clinical scenarios put before them. These two choices were made to make the experiment compatible with situations usually encountered by triage personnel in real cases.

A researcher illustrated (through the description of subjective and objective information) each clinical scenario to each nurse participating in the study. Nurses assigned each case a priority level in a few (two to three) minutes. The time pressure served to partially simulate the realism of situations in which triage nurses make their decisions.

The assigned priority levels were developed according to the proposed bias-variance method, adapted to the specific field of experimentation (as detailed in the following section).

After the assignment of each priority code, nurses were asked to explain the reasons for their decisions. A semi-structured questionnaire was developed in order to collect the following information: i) the motivation given by each nurse for each assigned code; ii) the list of available subjective or objective data used to make the decision; iii) the importance attributed to each key data, assigned by referring to a verbal scale.

The qualitative information collected through these interviews was analyzed for different purposes (parallel researches) using Qualitative Comparative Analysis (Ragin, 1987) and Argument Mapping techniques (Fletcher and Huff 1990; Davis, 2011). The analysis of these qualitative data is beyond the scope of this work. It should be noted, however, that the collected qualitative information, whose systematic elaboration is still in progress, is useful for enriching the interpretation of the results obtained at this stage.

4.4 Data processing using the adapted bias-variance decomposition formula

The computation of bias and variance to assess predictive error according to the equation (2) was adapted to elicit the weight of individual and organizational factors in the assessment of triage priority levels by nurses (Table 3).

< Insert Table 3 here>

Considering *k* nurses and *n* situations during which each nurse has to take a decision, the individual decision concerning the *n* situations is:

$$y_j(x_i) \text{ with } \quad j = 1 \ldots., k \quad \text{and} \quad i = 1 \ldots., n$$

where $y_j(x_i)$ is the *Nurse$_j$ Heuristic,* while the function $Y(x_i)$ represents the *Nurses Average Heuristic*.

We set the underlying true function $h_e(x_i)$ as the *Expert Heuristic*. The expert's evaluations have been used as a reference for assessing the quality of nurses' decisions.

To calculate the equations estimating the *Expert Heuristic and* the *Nurse$_j$ Heuristics*, we firstly ordered clinical scenarios according to the priority levels assigned by the expert. In doing so, we transformed a classification problem into a sorting problem. To understand the rationale of this operation, it is sufficient to imagine patients arriving at the Emergency Department at the same moment. Consequently, the decision maker has to order them in terms of priority. The result is a discrete step-function.

Secondly, we transformed the step-function into a monotonic ascending function through a cumulative sum of priority values, where $\text{Scenarios}_{expert}$ and CumPr_{expert} represent the data for the estimation, through the *Least squared method,* of the parameters (a, b, c) of the second-degree polynomial $h = ax^2 + bx + c$.

In the third step, we computed the equation representative of the *Nurse Decision*. Nurses were asked to assign priority levels to scenarios that were randomly sorted. Then, the scenarios were sorted according to the order made by the Expert.

Similar to the estimation of the expert's equation, we transformed the step-function into a monotonic ascending function by adding up the assigned priority levels. Those data were used for the estimation, through the *Least squared method*, of the parameters (a', b', c') of the second-degree polynomial $y = a'x^2 + b'x + c'$.

Figure 2 illustrates the comparison between the expert's decisions and a nurse's decisions expressed by h (x) and y(x) respectively. This comparison gives us some information:

i) if the nurse function is under the expert function, there is a systematic error of over-assessment of the priority level by the nurse;

ii) if the nurse function is over the expert function, there is a systematic error of under-assessment of the priority level by the nurse.

< Insert Figure2 here >

5. Results

The data collection in the field produced 850 evaluations, representing the priority levels assigned by the 34 involved nurses to each of 25 clinical scenarios.

Table 4 reports, for each hospital and for each typology of scenarios, the percentage of correct, over-assessed and under-assessed codes attributed by Alpha and Beta's nurses respectively to simple, intermediate and complex clinical scenarios.

< Insert Table 4 here >

Table 4 shows that nurses in both samples, when they make the wrong assessments, tend to over-assess priority levels: the percentages of over-assessed codes are significantly higher than those related to under-assessed ones. Furthermore, we can notice that in the Beta sample, the percentage of over-assessed codes is higher than in the case of the Alpha sample. These data give us some general information about the frequencies of correct or wrong codes assigned by the nurses involved in the field research, but do not allow us to analyze in depth the potential drivers of the errors and their relative influence on the decision-making process and its outcomes.

To reveal the eventual impact of organizational factors on triage assessment, we recorded the evaluations made by nurses in two separate databases, related to Alpha and Beta hospitals respectively, and applied the bias-variance decomposition formula to them, adapted as described above. A prevalence of the bias error in the recorded evaluations could be attributed to shared organizational formal or informal rules and, thus, to organizational factors. On the other hand, the prevalence of variance indicates that nurses' individual factors play a central role in their decisions.

Furthermore, the answers of nurses were analyzed with respect to the clinical scenarios' complexity.

Finally, we applied the Chi-square test to statistically verify whether the difference in bias and variance proportion between the two hospitals under investigation was significant.

Results are reported in Table 5.

< Insert Table 5 here >

In Table 5, we notice that the total error in Alpha and Beta is of the same magnitude, with a little prevalence in the Beta hospital. On the other hand, the Chi-Square test shows that nurses' error in the Beta sample is largely due to the variance component (67,88%), in contrast to the Alpha sample in which error is largely due to the bias component (61,76%).

It seems that, in Alpha's ED, the heuristic process is more heavily affected by organizational factors.

Alpha and Beta's EDs present some relevant differences with regard to nurses' training and the work experience required for performing triage's activities (see sub-section 4.2 for more details). In Alpha, beginning nurses are always supervised by experienced nurses and work during less overcrowded shifts. Consequently, experienced nurses can show beginners how to apply triage protocols for priority levels' assignment. In addition, Alpha nurses are permitted to perform triage only after three years of experience in EDs.

In contrast, the Beta ED performs the training of beginners during daily working hours without direct supervision, only guaranteeing the presence of a more experienced nurse. In addition, the requested previous experience in EDs for performing triage in Beta is only one year. The training strategy of Alpha allows nurses to share simple heuristics that guide the decisional process. In substance, the training acts as a medium to share informal rules among individuals, as highlighted by Bingham *et al.* (2007). Furthermore, as reported in sub-section 4.2, the nurses of Alpha's sample are characterized by longer work experience in emergency services and in the specific ED under investigation than those of Beta. These data support the following interpretation of the results shown in Table 5: Alpha's nurses shared the same organizational context for a longer time-period than those of Beta and were more exposed to explicit or implicit organizational rules capable of influencing their decision-making process.

To assess how task complexity could eventually affect previous results, a stratified elaboration of the 850 nurses' evaluations with respect to the three typologies of clinical scenarios was carried out (Table 6).

< Insert Table 6 here >

Table 6 highlights that the total error decreases as the complexity of clinical scenarios increases. This result is surprising, as this is not revealed by the percentages collected in Table 4. In this regard, we recall that the adapted *bias-variance decomposition formula* determines error by not simply counting the proportion of correct and wrong answers, but also by taking into account the distance of the wrong answers from the logic underlying the answers of the expert. In this way, the total error, as it is computed according to the bias-variance decomposition formula, provides a measure of the potential impact that a deviation from the logic of the expert can have on the decision-making process and on its outcomes. For example, let suppose that the correct code is 1 and the nurse gives a code equal to 3. If we compute the frequencies of errors, this wrong answer has the same weight of another wrong answer. Instead, according to the bias-variance decomposition method, this wrong assignment has a greater weight on total error than another wrong answer closer to the correct one.

The data in Table 6 are difficult to understand without considering the characteristics of both the scenarios and the organizations under investigation.

Simple scenarios present coherent and complete information. Consequently, nurses should assign the correct decisions considering both qualitative and quantitative cues. The presence of a higher error with respect to other scenarios implies that nurses in both EDs tend to over- or under-assess priority levels due to other factors, that do not depend on available cues. In Alpha, the high impact of the bias component on total error could imply a prevalence of organizational factors in determining nurses' error. In this case, the long exposure to some organizational factors (in this case informal rules play a role), reinforced by active training, drives nurses to giving different weights to cues with respect to what is suggested by protocol guidelines. On the contrary, in Beta the training is weak and the high error in simple scenarios could be related to different nurses' behaviors and other individual factors. For example, a nurse could exhibit a risk aversion behavior and could over-assess simple cases as well. In fact, the main themes that emerged in the motivations that the nurses of Beta used to justify their assigned codes are as follows: "*In the case of doubt I tend to give a higher priority code than what is suggested by protocols, because I would not risk and let the patient be at risk*"; "*Especially when the patient has a certain age, I assign a high priority code to prevent the patient from getting tired and waiting too much*".

The intermediate scenarios present incoherent information, and salient cues are mainly the qualitative ones. The error in the Beta ED is mostly due to the bias component. This fact should imply an impact of organizational factors, like formal or informal rules shared by organizational members. As outlined before, in the Beta ED, formal organizational rules are weaker than in Alpha. As a consequence, informal organizational rules may give rise to shared behaviors and decisions as the ambiguity of scenarios increases. During interviews, the nurses of Beta emphasized that in situations characterized by incoherent clinical information, they prefer to base their decision on objective cues, because these are indisputable. It seemed that the objectivity of information reassures nurses when making decisions, replacing the security role of the organization.

The results related to complex scenarios showed that the heuristic process is guided mainly by individual factors (for example: individual work experience) when giving specific solutions to problems for which shared heuristics provide only a common structure with few details (Bingham and Eisenhardt, 2011). In these situations, the variance is higher than bias, and this implies the weak influence of organizational factors on individual decision-making processes. Thus, when relevant information is lacking, and available data are ambiguous, individuals mainly base themselves on their experience and personal knowledge, thus producing different answers to identical situations. Nurses of both samples often claimed the importance of their long experience and of their gut feeling when solving an ambiguous decisional task.

In conclusion, the above analysis reveals the presence of a significant difference between the bias and variance components in the Alpha and Beta hospitals, reinforcing the hypothesis that organizational factors play a major role in driving individual behaviors. The level of complexity of clinical scenarios, representing the uncertainty and the ambiguity of the decisional task, seems to play a role in the heuristic decision-making process of nurses. In fact, the difference between the two samples in bias and variance components of error is significant for simple and intermediate clinical cases. In complex cases, in which nurses' individual factors are dominant in influencing decision-making, the difference between the two hospitals is not relevant. Furthermore, we can notice that the total error is lowest when the heuristic process is affected mainly by individual factors.

6. Discussion

The proposed approach based on the *bias-variance decomposition formula*, tested in the context of triage decision-making, permits us to reinforce some themes characterizing the recent debate on the complexity of decisional processes in clinical settings, but also contributes to the more general discussion on heuristic decision-making in conditions of uncertainty and time pressure. In uncertain environments and under time pressure, management theory adopts the Gigerenzer *et al.* (1999) fast-and-frugal approach to investigate how the organization can guide the strategic decision process (Bingham, Eisenhardt, and Furr, 2007; Eisenhardt *et al.*, 2010; Bingham and Eisenhardt, 2011). Consistent with the findings on heuristics as adaptive processes (Gigerenzer *et al.*, 2011; Mitchell *et al.*, 2011; Bingham and Eisenhardt, 2014), scholars highlight the point that in this dynamic process, the decision-maker is influenced by individual and organizational factors as well as by the attributes of the decisional task (Beach and Mitchell, 1978; Payne *et al.*, 1993; Cioffi, 1998; Smith *et al.*, 2008).

Our experimental application of the bias-variance method produces new insights into this interplay. In particular, the results obtained reinforce the centrality of the attributes of the decisional task in determining the different influence of individuals and organizations on decisional process.

This research proves that the factors affecting the decisional process are strictly inter-related and that they cannot be analyzed without considering the task's complexity. Organization and management scholars claim that the organization can guide efficient decision-making processes, enable efficient communication strategies, help coordinate activities, and prompt individuals to focus their attention and time through guidelines (Eisenhardt and Brown, 1998; Eisenhardt and Martin, 2000; Eisenhardt and Sull, 2001; Bingham *et al.*, 2007; Rico *et al.*, 2008; Vuori and Vuori, 2014). Nevertheless, they emphasize that the activation of skillful exploration and the interpretation of ambiguous cues, based on a cognitive process or on the exploration of known procedures, is related to a typology of novel or routine tasks respectively (Rudolph and Repenning, 2002; Rudolph *et al.*, 2009).

We found that organizational factors affect the heuristics process mainly in situations characterized by low ambiguity. In novel tasks, usually characterized by ambiguous cues, the decision-maker will make his/her decision through an exploration and interpretation of information, based above all on individual factors. This finding supports Bingham and Eisenhardt's statement that the organization affects heuristics, giving a "common structure for a range of similar problems, but supply few details regarding specific solutions to address them" (Bingham and Eisenhardt, 2011, p. 1439).

In summary, we claim that organizational factors affect the decision-maker only in routine tasks as, despite time pressure, the individual bases his/her decision on exploring known procedures. In ambiguous situations, individual characteristics prevail in coping with incomplete cues and supplying the missing information in a way so as to reach a better solution to the problem.

Another interesting observation emerges from our study.

The aforementioned literature emphasizes the role of the organization in guiding the heuristic process through simple rules. Instead, our results show that the organization can also act as a constraint that prompts individuals to make an incorrect decision in order to protect themselves from the consequences of their choices. In situations characterized by incoherent information, individuals prefer anchoring their decisions in objective factors rather than in subjective elements, assuming a risk aversion attitude. This evidence is in agreement with Beach and Mitchell's (1978) model that shows how task characteristics and personal characteristics affect the selection of one decision strategy rather than another one. They claim that some general situational factors affect the strategy selection as well. These situational factors are the irreversibility of a decision (if it is not possible to monitor the effect of the decision and reverse it), significance (if the decision can be relevant to future actions as well), and accountability (if the decision-maker is accountable for the results of the decision). In the studied context, accountability and significance can be considered situational factors affecting the heuristic process, whereas the decision is partially reversible since the triage code can be reassessed during the patient's waiting-time required to receive medical assistance. According to the discussion above we can additionally claim that management should pay attention to situational factors, as these can act as drivers prompting the decision-maker to keep into account irrelevant information in order to reduce his/her accountability

The management, thus, could apply the proposed method to discriminate between situations in which the organization acts as a guide from those in which the organization acts as a constraint. This could support the fine tuning of managerial interventions in order to better match the requirements of diverse situations.

7. Conclusions

The paper analyzes the heuristic decision-making process in situations characterized by uncertainty and time pressure. Despite a growing number of studies on heuristics and their accuracy (Payne *et a*l., 1990; Gigerenzer, 2008; Gigerenzer *et al*., 2011) empirical studies measuring the weight of individual and organizational factors on decision-making processes in the above situations are lacking. To overcome this gap, we propose a novel interpretation of the bias concept as a measure of homogeneity when making decisions. Accordingly, we revised the bias-variance decomposition formula proposed by Gigerenzer and Brighton (2009); then, we applied a formal approach to assess the impact of individual and organizational factors on the decision's outcomes and experimented it in the context of triage. We analyzed two samples of nurses working in the EDs of two different hospitals. The results show that the method allows to discriminate between the impact of organizational factors and individual factors on the accuracy of the decision. The weight of the two typologies of factors depends strongly on the complexity level of the decisional task. These findings are relevant for managerial practice, not only in triage context. In fact, although the method has been settled for the triage process, it can be applied more generally to all uncertain and time-constrained situations where the decisional task is characterized by salient and irrelevant cues that can be coherent, sufficient and/or ambiguous. The application of this method could support managers in organizational contexts characterized by varying levels of uncertainty and time constraints to be aware of situations in which to leverage more on organizational or individual aspects. Whether the managers discover that decisional processes are negatively affected by organizational factors, they could design specific organizational interventions (e.g. re-design of organizational procedures, revise coordination and feedback mechanisms, team work) devoted to fine tune and balance organizational pressures. On the other hand, when individual factors mainly affect the heuristic process, managers should leverage the individual frames and attitudes, through education and specific training actions (e.g. training on the job, job rotation, supervision).

In this application, the method allows us to assess the weight of bias and variance on error, but further developments will be addressed to better understand the inclination to over- or under-assess. This analysis could be useful for all organizational situations where over- or under-assessment has an impact on the process or service quality. In the triage process, the over- and under-assessment affects the quality of emergency processes. In fact, if a patient receives a higher priority level than expected (over-assessment) the queue of urgent patients becomes longer. On the contrary, an under-assessment implies that the patient must wait longer to access care than required. Both situations impact the patient's safety and also their perception of service quality (Wuerz *et al.*, 1998; Considine *et al.*, 2004; Fernandes *et al.*, 2005; Stefanini *et al.,* 2018).

Main limitations of this study refer to the empirical analysis, since we adopted the simulations to test the method, before implementing it more extensively and in real situations. As a consequence, it was not possible to detect the impact of stress on nurses' decisions in real working situations, or their impressions of the visual signs, complaints and pain of the patients. These symptoms are only described in the patient scenarios.

However, the results are equally reliable, as we have isolated the stress-effect for both organizational contexts, performing identical simulations and using the same pool of clinical scenarios. In addition, the two EDs have similar characteristics in terms of average served population and their waiting-time communication systems.

Another limitation concerns the fact that, at this step of the research, we did not distinguish between different typologies of organizational or individual factors impacting on the decision process. To address this issue, we are experimenting qualitative comparative methodologies in order to better investigate the interplay between different typologies of organizational and individual factors.

Future research developments will be focused on the definition of an experimental design devoted to collect a wider amount of data, in situations in which priority levels are assigned real time to patients. Basing on larger samples, it will be also possible to define and classify individual and organizational factors with their disaggregated impacts. This advancement, together with an analysis of personal attitudes to over- and under-assessment, could better contribute to identify guidelines for managerial and training interventions on clinical settings in which a central role is played by dynamic decision-making (Rudolph *et al.,* 2009; Cristoforo, 2016).

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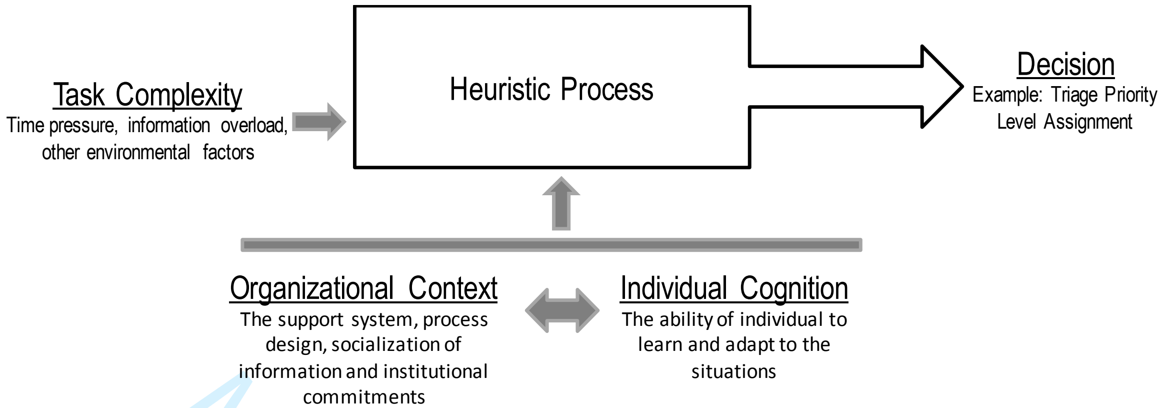

Figure 1: Factors affecting Heuristic Process

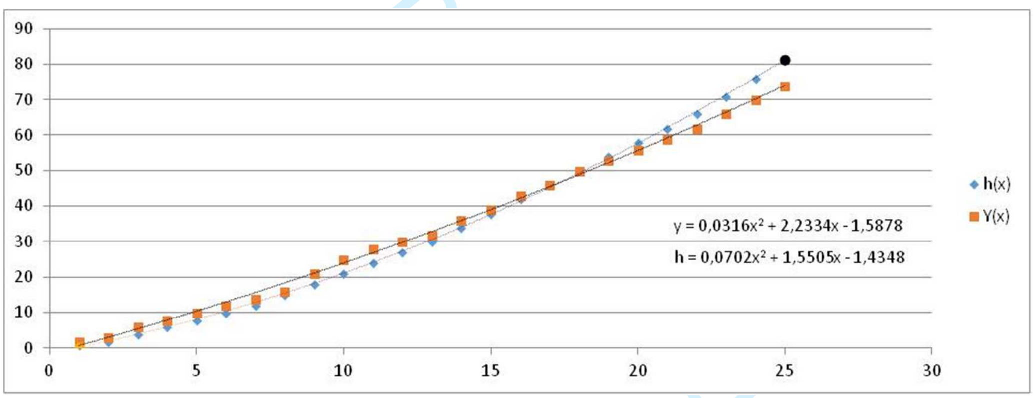

Figure 2: The estimation of Expert Heuristic and of Nurse Heuristic

Simple Scenario				
Description of chief complaint and clinical documentation (if it is present) Adult man in a state of agitation. He reports that has been verbally assaulted with threats of death in the street by a stranger. He is hypertensive				
Information on symptoms and pain		*Further Information to be asked to patient*		
No particolar symptoms				
Information on vital signs		*Further vital signs to be measured*		
- PA 168/89 mm/Hg *- SpO2 99%* *- FC 89/min* *- FR 18/min*				
Priority Level				
1	2	3	4	5
Comments:				

Table 1: An example of information characterizing simple scenarios

Complexity level	***Priority code*** 1	2	3	4	5	***Total***
Simple	1	1	1	7	2	**12**
Intermediate	1	4	1	1		**7**
Complex			4	1	1	**6**
Total	3	5	6	9	3	***25***

Table 2: The clinical scenarios, their complexity levels and priority codes

Components of Brighton and Gingerenzer (2012) model		***Components of the adapted model***
The set of available data	X	The set of n patients to be evaluated for priority level assignment in Triage
The correct prediction represented by underlying function usually hidden	$h(x)$	The correct priority levels assignment to n patients made by an expert
k predictions represented by a set of polynomial functions	$y_i(x)$	The estimated priority levels assigned to n patients by k nurses
The mean function of the k predictions	$Y(x)$	The mean of estimations of priority levels by k nurses

Table 3 – Adaptation of bias-variance model to triage assessment by nurses

	Alpha			Beta		
Clinical Scenarios	% Correct codes	% Over-assessed codes	% Under-assessed codes	% Correct codes	% Over-assessed codes	% Under-assessed codes
Simple	60%	30%	10%	49%	43%	8%
Intermediate	47,4%	17,3%	35,3%	49,5%	21,9%	28,6%
Complex	52,6%	33,3%	14,0%	41,1%	44,4%	14,4%
Total percentage	55%	27,0%	18,0%	47,0%	37,0%	16,0%

Table 4: Percentage of correct, over-assessed and under-assessed codes in Alpha and Beta

	Alpha Hospital (public-private hospital)		**Beta Hospital (public hospital)**	
	Value	*%*	*Value*	*%*
Bias²	177.76	**61.76%**	102.79	32.12%
Variance	110,08	38.24%	217.19	**67.88%**
Total error	287,84		319,98	
Chi-Square Test ($p < 0,005$) on bias-variance distribution with respect to total error: **Rejected H0**				

Table 5: Bias and Variance error components in Alpha and Beta hospitals

	Simple Scenarios*				**Intermediate Scenarios***				**Complex Scenarios****			
	Alpha Hospital		**Beta Hospital**		**Alpha Hospital**		**Beta Hospital**		**Alpha Hospital**		**Beta Hospital**	
	Value	***%***	***Value***	***%***	***Value***	***%***	***Value***	***%***	***Value***	***%***	***Value***	***%***
Bias²	38.51	**63.28**	21.41	35.39	9.51	26.15	26.36	**76.27**	4.21	30.33	2.42	21.79
Variance	22.34	36.72	39.09	**64.61**	26.85	**73.85**	8.20	23.73	9.67	**69.67**	8.69	**78.21**
Total Error	60.85		60.5		36.36		34.56		13.88		11.11	
Chi-Square Test ($p < 0,005$) on bias-variance distribution respect to total error: *__Rejected H0__ ($p < 0,005$) ** __Accepted HO__ ($p < 0,1$)												

Table 6: Bias and Variance components respectively in simple, intermediate and complex scenarios