JOURNAL OF FORENSIC SCIENCES

J Forensic Sci, July 2011, Vol. 56, No. 4
doi: 10.1111/j.1556-4029.2011.01714.x
Available online at: onlinelibrary.wiley.com

PAPER

GENERAL

Ira Helsloot,[1] *Ph.D. and Jelle Groenendaal,*[1] *M.Sc.*

Naturalistic Decision Making in Forensic Science: Toward a Better Understanding of Decision Making by Forensic Team Leaders

ABSTRACT: This study uses the naturalistic decision-making (NDM) perspective to examine how Dutch forensic team leaders (i.e., the officers in charge of criminal forensic research from the crime scene until the use of laboratory assistance) make decisions in real-life settings and identifies the contextual factors that might influence those decisions. First, a focus group interview was conducted to identify four NDM mechanisms in day-to-day forensic decision making. Second, a serious game was conducted to examine the influence of three of these contextual mechanisms. The results uncovered that forensic team leaders (i) were attracted to obtain further information when more information was initially made available, (ii) were likely to devote more attention to emotionally charged cases, and (iii) used not only forensic evidence in the decision making but also tactical, unverified information of the police inquiry. Interestingly, the measured contextual influences did not deviate significantly from a control group of laypeople.

KEYWORDS: forensic science, naturalistic decision making, recognition-primed decision making, image theory, contextual bias

Considerable effort has been devoted to understanding the influence of psychological factors on forensic decision making. Currently, it is believed that decision making in the forensic sciences is affected by a variety of contextual factors that may influence the decision outcome (1–4). However, little attention has been paid to how forensic team leaders (i.e., the officers in charge of the forensic research of a crime from the crime scene until the use of laboratory assistance) assess and use information in real-life environments.

In the Netherlands, a widely publicized mistrial of an alleged child rapist and murderer, the 2000 Schiedammerpark murder, initiated a national project for improving forensic research and other aspects of criminal investigation and prosecution (5). This project included a special course for forensic team leaders and crime scene advisors (a crime scene advisor is a higher educated employee of the National Forensic Institute of the Netherlands who advises forensic team leaders working for regional police forces on complex crime scene investigations) developed by the Police Academy of the Netherlands. This course incorporated a 2 day module focusing on the "process aspects" of forensic research. This module was developed by one of the authors based on the input of experienced forensic team leaders and the body of knowledge called naturalistic decision making (NDM), which studies the way experts make decisions in real-life environments characterized by uncertainty, time pressure, and high stakes.

More precisely, NDM has been defined as "how experienced people, working as individuals or groups in dynamic, uncertain, and often fast paced environments, indentify and assess their situation, make decisions and take actions whose consequences are meaningful to them and to the larger organization in which they operate" (6, p. 5,7). Because the environment in which forensic team leaders operate can also be characterized by uncertainty (contradictory or ambiguous information), time pressure (e.g., high work load and performance indicators), and high stakes (determining the outcome of a criminal lawsuit and handling media pressure), NDM may be valuable in the study of decision making by forensic team leaders.

In the following section, we will provide a brief review of the recent literature on decision making in forensic science. In the third section, we will describe some general theories about human decision making and provide an overview of the basic properties of NDM. In the fourth section, we will outline three central NDM models using examples from the focus group interview. In the fifth section, we will describe the methodology of the serious game and its results. In the final section, we will discuss these results and provide recommendations for practitioners.

Decision-making Studies in Forensic Science

The central aim of forensic science is to equip forensic researchers with the best possible tools to solve crimes. Hence, the way in which forensic researchers deal with information and reach conclusions is an important aspect of forensic science.

Research on how forensic researchers make decisions and how this decision making can be improved has traditionally been based on rational choice theories (RCT; see [8,9] for examples of recent research using this perspective). According to RCT, decision making should be "rational" (i.e., decision makers should aim to make the best possible decision by calculating the likely advantages and disadvantages of each option before choosing the best action). This

[1]Free University Amsterdam, Faculty of Social Sciences, Department of Public Administration, De Boelelaan 1081, 1081 HV Amsterdam, the Netherlands.

Received 29 Jan. 2010; and in revised form 16 April 2010; accepted 17 April 2010.

process involves gathering all necessary information and generating a range of decision-making options and then choosing the best option by evaluating the advantages and disadvantages of every possible outcome (10,11).

However, behavioral analyses of everyday decision making have uncovered some serious problems regarding the prescriptive use of RCT. These fundamental problems with the everyday use of RCT were introduced in the 1960s by Nobel Prize winner Herbert Simon (12). He described the concept of "bounded rationality" in human decision making, an idea that contradicts the basic tenets of RCT. Simon stressed that people make choices based on their interpretation of the situation and that this interpretation is a simplification of reality "bounded" by cognitive limitations. Simon also argued that, contrary to the assumptions of RCT, alternative outcomes are not "given" but have to be "found" in a discovery process that costs time and money. Thus, Simon (12) asserted that humans cannot consider a range of options in daily practice but instead must choose the first *satisfactory* option rather than seek the *best* solution.

Many scholars since Simon have provided support for the hypothesis that decision makers do not decide following pure RCT methods (13). Two main research streams on decision making in general have emerged.

The first research stream implicitly considers RCT to be an ideal method of decision making, thus investigating deviations from RCT standards or, as they are usually called, "decision biases." In a classic article, Tversky and Kahneman (14) found that people's probability judgments deviated from the normative RCT standards in systematic ways. They discovered that people rely on a limited number of heuristic principles that reduce complex tasks to simpler judgmental operations. These heuristics lead to systematic errors (14). For a thorough discussion of decision biases and heuristics, we recommend the Patel et al. review (15).

The second research stream, NDM, takes as a starting point how experts make everyday decisions. Being an expert implies that the professional environment judges them to make the most optimal decisions in day-to-day settings. This research stream is aimed at identifying the rare occasions in which their decision making is flawed and can be incrementally improved (6,7).

Focusing on forensic science, since 2000, it appears that the decision bias approach is dominant in the literature (16). Special attention has been paid to how different methods of presenting information affect decision making in forensic laboratories. Dror and Rosenthal (4), for instance, found that fingerprint experts judged re-presented stimuli differently when extraneous, contextual information was added. Similarly, Langenburg et al. (3) reported that the decision outcome of fingerprint specialists, both novice and experienced, can be influenced by contextual information about the evidence. In an experimental study, three of five fingerprint examiners changed their initial identification decision when the same fingerprint was submitted in a different and emotionally charged context (17). In a related study, Dror et al. (18) demonstrated that subliminal messages and emotion both influenced the decision outcome when the fingerprints to be matched were ambiguous. The scholarly debate on whether deviation effects exist still lingers, fueled by studies reporting that contextual information does *not* affect the decision outcome. Hall and Player (19), for instance, presented the same fingerprint in two different criminal contexts and found that the context had no significant effect on the final decision made by the fingerprint examiners. However, this study has been criticized for its methodological flaws (20,21).

In this article, we follow the second stream and use the NDM perspective to look into how forensic team leaders deal with "real-life" decisions in daily practice.

Naturalistic Decision Making by Forensic Team Leaders

To discover whether NDM models are applicable to forensic team leaders and, if so, which models are relevant, a focus group interview was held. Focus groups are considered a useful method of data collection when relatively little is known about the phenomenon of interest (22,23). As recommend by NDM scholars (24), we used the focus group interview to broaden our understanding of forensic decision making by team leaders, encouraging them to brainstorm NDM-like decisions that occur in forensic science. The participants in the focus group interview were nine experienced forensic team leaders (average experience of 11 years). In the first stage of the discussion, we introduced a total of six NDM models that might be appropriate to the participants. In the second stage, the participants discussed whether they recognized these models in their daily practice of forensic decision making. One of the authors acted as moderator for the group, posing questions, and sustaining the discussion, while a second observer made notes. The focus group interview took about 110 min. No questionnaire was used.

The participants generated several examples that represented three of the six NDM models: recognition-primed decision making (RPD), image theory, and explanation-based decision-making theory. For the most part, the other models were not recognized and will thus not be discussed in this article. Apart from the presented NDM models, a new mechanism that influenced the participants' decisions was identified: the availability of information motivated the search for additional information. In the following sections, each model/mechanism recognized by the participants will be briefly described and illustrated with examples provided during the focus group interview.

Recognition-Primed Decision Making

The RPD model is a prominent model of NDM that was originally based on the observations and retrospective accounts of fire commanders (7,25). Initially, Klein and Calderwood (25) designed this research to gain a better understanding of how fire commanders handled time pressure and uncertainty. The results revealed that, in most cases, experienced fire commanders did not compare options when choosing a course of action; instead, they performed the first action that came to their minds. Klein and Calderwood (25) found that experienced decision makers—when operating under conditions with time pressure and extreme uncertainty—were able to recognize cue patterns signaling a particular type of problem quickly. As Orasanu (26) showed, this fast recognition triggers the retrieval of a response previously associated with a similar cue pattern, leading to a successful resolution. Consequentially, experienced decision makers are able to make effective decisions almost instantaneously. This mechanism is most likely to occur when both experience and time pressure are high. As previously stated, decision making based on recognition does not guarantee that experts will find the "optimal" solution or strategy, but it does make sure that they will find an effective one.

The participants in the focus group generated many examples of RPD. According to the participants, the first impressions of a forensic research team lead almost automatically to decisions regarding the tactics and methods of forensic research. The participants claimed that these decisions usually prove correct because they quickly generate as much supporting forensic evidence as possible. When asked for specifics, however, most participants provided examples in which the first impression proved incorrect. One of the participants described the following situation:

> I was engaged in research on a devastating fire in a large store. A team member found some cigarette butts in a garbage container located at the back of the store. Therefore, we concluded immediately that the cigarette butts could have caused a smouldering fire. After more thorough research of the garbage container, we concluded that there was no evidence to assume that the fire was intentionally produced. Afterwards, however, a second opinion revealed that the fire most likely started in electronic equipment in the front of the store and almost certainly not in the garbage container.

In this example, the immediate identification of the probable cause of the fire is an obvious example of a decision based on recognition; the forensic researcher had seen numerous fires started by cigarette butts left in garbage containers. Unfortunately, because of the quick discovery of the cigarette butts, other causes were excluded and thus not systematically researched. No attention was given to the front of the store. Because of time constraints, the participant declared that he had simply not considered any other option. His "excuse" reveals the influence of time pressure characteristic of a forensic team leader; all participants in this and later sessions stressed that, under normal daily conditions, there is no time to eliminate all the possible causes of a fire.

Image Theory

The image theory (27–29) assumes that human decision making is based on the values, personal principles, and strategies (labeled as "images") of the decision maker. According to the image theory, decisions are made based on whether they fit the personal values, goals, and strategies of the decision maker (11). The personal values or principles of the decision maker reflect a belief in how things should be and how people ought to behave, involving concepts like honor, ethics, ideals, justice, loyalty, and truth. In addition to values, the decision maker has an agenda of goals to achieve, goals that are driven by both personal values and the environment. According to Beach and Mitchell (29), goals can be concrete events (finding fingerprints) or more abstract states (being a good employee). The last image, strategy, contains a plan for reaching the goal. This plan comes from past experience (doing what worked before) but can be adjusted depending on the (expected) situation. According to Beach and Mitchell (29), the compatibility of a decision with the "images" of the decision maker is the most important criterion in the decision-making process. In the literature on forensic science, the image theory is reflected in the above-mentioned research on the influence of emotions on fingerprint identification. In the context of the present study, we view the image theory as a mechanism that influences the decisions of forensic team leaders.

The participants of the focus group interview recalled several cases in which emotions may have influenced their decision-making process. Two illustrative examples:

> When I investigate what appears to be the accidental death of a young child in his own home, I feel uneasy and want to fulfil my tasks as quickly as possible. This is especially true when the family of the child is still at the crime-scene.

> I honestly believe that we—forensic team leaders—pay much more attention to child murders than to the murder of prostitutes. And I am sure there are no "rational" grounds to legitimate these preferences. Moreover, I think that media-pressure and the public and political opinions are really pressing these days.

Explanation-based Decision Making

The explanation-based decision-making model was originally developed by Pennington and Hastie (30,31) to explain juror decision making but has since been applied to many domains. The model assumes that decision makers construct a "story" or causal representation of the available facts (from different sources of information) and then base their decisions on the constructed narrative. According to Pennington and Hastie (30), decision making involves matching the "constructed stories" and "constructed choice" sets. Because the construction of choice sets is specifically concerned with binary decision making based on the constructed story (like the guilty or not guilty decision of jurors), only the first stage is relevant for this study. When forensic scientists construct stories, they build a narrative based on the evidence (facts, statements), their knowledge of similar events (e.g., "best practices" from the professional community), and their knowledge of story structure (e.g., understanding that human behavior is goal oriented). This process results in several narrative representations of the evidences that include causal relationships (31). The decision maker chooses the story that best explains all available evidence and seems the most coherent. Apart from the effect of the image theory on the story builder, this process is in accordance with RCT. However, this process is prone to error because decision makers try to fit new information into the existing narrative rather than asking whether this information challenges the constructed story.

A team leader reported an interesting example of this error-producing phenomenon during the focus group interview:

> I remember a case in which a defendant was convicted by the forensic evidence of my team. He was accused of arson in a garage neighbouring his own. There was a lot of circumstantial evidence; however, the forensic evidence was decisive. At the first trial, we had shown that the fire was raised through a small hole just above the apparent starting place of the fire—in the wall of the suspect's own garage. Afterwards, during his appeal, a second researcher revealed that the hole was not made by the suspect, but by a damage expert hired by the insurance company to investigate the damage to the garages. This person had visited the crime scene on the day before we arrived and started our investigation. He, of course, used that spot for making the hole because it was the place where the damage caused by the fire was most extensive.

This example shows (along with the probable combined effects of time pressure and a "petty crime effect," that is the underestimation of petty crimes by professionals) how easily evidence can be arranged into a suitable, but fallacious, story of the events.

The Availability of Information as Motivation for Obtaining More Information

During our discussion with the participants in the focus group interview, we discovered another mechanism that could influence their decision making. Predictably, the pressure to come up with irrefutable forensic evidence in high-profile cases leads to a thorough investigation, producing a large quantity of information but also a large number of information gaps or seemingly contradictory pieces of information. These gaps and contradictions require an

even larger research capacity. When discussing a few of these cases, the participants concluded that the forensic research should have been stopped earlier because the resulting information would clearly not affect the trial outcome. Looking back on the cases, the forensic team leaders involved with the cases agreed with this assessment. From these examples, we concluded that, when a large amount of information is available, the perceived goal of forensic research becomes distorted: instead of viewing the information as evidence directed toward an impending trial, the forensic team leaders are motivated to fill in information gaps.

> One of the cases discussed was a well-publicized environmental scandal in the Netherlands. After a devastating fire, it became clear that the ATF waste-processing factory in Drachten did not follow environmental regulations. The smoke from the fire thus contained a great number of toxic substances that polluted the surrounding area for some kilometres. The forensic and tactical inquiries resulted in a dossier of more than a thousand pages. However, much of the forensic research on the origin and spread of the fire proved, as could be predicted, to be useless during the trial.

As previously mentioned, we used the results of the focus group interview to develop a course that aimed to make forensic team leaders aware of their non-RCT decision processes. As an introduction to this course, we conducted a "serious game" to help the participants recognize the effect of three of the four previously discussed contextual factors on their own decision making. The concept serious game refers to the use of simulation techniques to research aspects of reality.

Description of the Serious Game

The serious game requires the participants to make a sequence of choices regarding the distribution of a forensic team between two and, later, three crimes. These choices are based on information that arrives in multiple pieces, imitating the forensic research process.

Participants

In the above-mentioned course, the serious game was used as a starting point for a discussion on the influence of contextual factors in everyday decision making. The participants in the serious game were forensic team leaders and crime scene advisors who were attending the course "process aspects of forensic research" at the Police Academy of the Netherlands between 2005 and 2008. During these years, the serious game was conducted five times on a total of 98 forensic researchers with an average of 5.5 years experience in forensic research.

In investigating whether the results of the serious game were unique to forensic team leaders, the serious game was also conducted in 2008 with 46 public administration students at the Free University.

Design of the Serious Game in Detail

Three cases were presented to the participants: Micro Electric, Renkum Murder, and Happy Slapping. Each case consisted of two versions, A and B. In the serious game, three contextual biases were introduced in either the A or B version. These biases included the presence of tactical "gossip" (i.e., unverified information from the police inquiry), a difference in the amount of forensic information available, and the presence of a highly emotional context. In each case, these biases were introduced as follows:

- *The Micro Electric* case deals with a fire in a retail store. In the B version, extraneous information explicitly classified as the "thoughts" of a police detective was added to the police inquiry (*RPD: presence of tactical "gossip"*).
- *The Renkum Murder* case deals with a family murder. In both versions, the defendant pleads guilty; however, the participants were supplied with more detailed information in the A version (*information as a motivation for seeking more information*).
- *The Happy Slapping* case deals with a murder. In the A version, a criminal was murdered; in the B version, a child was murdered (*image theory: highly emotional context*).

The complete case descriptions are presented in the Appendix.

Procedure

Participants were randomly separated into two groups, group A and group B. Every 5 min, groups A and B received one or more fiches (i.e., a written piece of information, see Appendix) regarding the three cases (one fiche for each case) to simulate the fragmented information flow that characterizes naturalistic environments (32). After 15 and 30 min, the groups had to make a decision about the distribution of their team between two and, later, three cases. Distribution decisions were made with a 100% capacity and 5% intervals. Each group had to decide what percentage of the team would be distributed to each case based on the available information about the cases. The groups did not know that they each received different information about the cases. The groups wrote the team distribution on a piece of paper that was handed to the instructor. The participants were explicitly asked to make their decisions using only *forensic* information. After 30 min, the results were presented and discussed.

Serious Game Results

The results of the distribution decisions at 15 and 30 min are presented in Table 1. In Table 2, we listed the results of the control group. These results showed that contextual variables dramatically influenced the decision making of forensic researchers.

TABLE 1—*Team distribution in %.*

	Group A			Group B		
	Renkum	Micro Electric	Happy Slapping	Renkum	Micro Electric	Happy Slapping
Experiment 1 (N = 18)						
t:15	70	30		50	50	
t:30	35	15	50	20	10	70
Experiment 2 (N = 16)						
t:15	75	25		55	45	
t:30	45	15	40	20	15	65
Experiment 3 (N = 23)						
t:15	70	30		50	50	
t:30	40	15	45	20	10	70
Experiment 4 (N = 22)						
t:15	80	20		50	50	
t:30	40	10	50	15	15	70
Experiment 5 (N = 19)						
t:15	75	25		45	55	
t:30	40	15	45	15	10	75

t:*x* = distribution made after *x* minutes.

TABLE 2—*Team distribution in % of control group.*

	Group A			Group B		
	Renkum	Micro Electric	Happy Slapping	Renkum	Micro Electric	Happy Slapping
Control group I (N = 20)						
t:15	80	20		60	40	
t:30	40	10	50	0	30	70
Control group II (N = 26)						
t:15	65	35		75	25	
t:30	50	35	15	0	20	80

t:*x* = distribution made after *x* minutes.

The most obvious difference between groups A and B occurred in the Happy Slapping case. Members of group B invested more effort into the child murder case than group A members invested in the ex-criminal murder case *although all participants claimed that they made their decisions using only forensic information.*

In the Micro Electric fire case, we introduced tactical information to the participants in group B. The results showed that, in the first 15 min of the game, the B groups were taking into account the unverified statement of a witness who believed that the fire was set to earn money from the insurance company. Compared to the A groups, the B groups spent significantly more time on the case. Once again, however, *all participants claimed that they made their decisions using only forensic information.*

In the Renkum murder case, both groups received information that the defendant pleads guilty. However, the suspect's confession did not explain the precise way the cover-up arson was started. The A groups were provided with much more "raw" information about the cause of the fire. This information was briefly summarized for group B by giving them the following statement: "However, some details about the fire starting do not match the fire damage." As a result, the A groups decided to spend about 20% more time on the case relative to the B groups.

In the discussion held afterward, the participants did not believe that their decisions were affected by these contextual factors. Both groups demanded insight into each other's fiches to ensure that there were no forensic differences between them.

Unexpectedly, the results of the control group were almost similar. The NDM mechanisms that influenced the decision making of experienced forensic team leaders similarly influenced the decision making of public administration students.

General Discussion

The results of the serious game revealed that NDM is an accurate description of how forensic researchers approach and assess decisions in naturalistic environments.

The results showed that providing the groups with a larger amount of information motivated further information gathering. In the Renkum Murder case, the groups that were provided with more information also "asked" for significantly more research capacity. Because the results of the forensic team leaders in the Renkum Murder case are largely identical to the results of the control group, we propose that the motivation to gather more information when more information is provided is experience independent. However, having more information is not always better or, in other words, more information does not automatically lead to better decision outcomes. In a study on confidence in psychologists, Oskamp (33) found that the accuracy of the decision outcome did not increase significantly as information increased; however, confidence increased steadily and significantly.

Our results also indicated that emotion is a contextual factor that affects forensic team leaders. The results of the Happy Slapping case revealed that, while the evidence in a murder case is a driving principle in establishing priorities, personal values can also play an important role in the decision-making process. This result is in line with prior research studying the affect of emotional environments on decision making (18,19). Pyrek (34), in particular, stressed that people's reaction to harm and their need to resolve harm are partially motivated "by their desire to see justice done." The Happy Slapping case might indicate that the desire to see justice done is stronger—even for forensic professionals—when the case is perceived as more tragic.

In addition, the results showed that forensic team leaders give primacy to tactical information in the decision-making process. The fact that the participants in group B used the tactical "gossip" in the Micro Electric case is consistent with both the RPD model and the story-building model. We found that the tactical information (in the B version) was quickly recognized as a way to relieve time pressure (RPD). It was also used in the reasoning process according to the explanation-based decision-making theory; the tactical information was recognized as a reasonable explanation of the fire and was used to build a coherent story from the evidence. This finding is in accordance with prior research (2,3) but also extends previous theories by suggesting that, even when the evidence is indisputably poor, forensic team leaders feel compelled to use it. This result supports the conclusions of Koppl (35), who observed that forensic scientists are sensitive to what he called "information pollution"; researchers tend to draw conclusions based on irrelevant, nonverified information that is usually provided by witness testimony or police inquiry. Regretfully, the usual "masking" technique recommended by for example Saks et al. (1) will not be effective for forensic team leaders as their work cannot be separated from the crime scene and the presence of its contextual factors.

In all three cases, the respondents believed that they were making purely rational decisions, and several respondents initially refused to accept the results. These results indicate that the participants were largely unaware that contextual factors were influencing their decisions. Courses like the one we presented may increase awareness of these factors; however, we did not measure whether attending this course decreased the participants' vulnerability to these mechanisms.

Finally, our results showed that the factors influencing the decision making of the control group were almost identical to factors influencing the forensic experts. On the one hand, this result is not surprising because these mechanisms stem from other domains and have thus proven to be broadly applicable. On the other hand, we expected that a professional would be less influenced by emotions than a layperson, an assumption that proved incorrect. This result may reflect the fact the forensic team leaders are controlled by district attorneys, who unquestionably incorporate the "popular voice" in their decision-making process. There is thus no corrective mechanism within the professional hierarchy to counter the effect of emotions.

Limitations

Admittedly, our results are preliminary, and more research is necessary to understand fully the everyday decision making of forensic team leaders and other forensic experts. While our research design provides the first insight into the decision-making processes of forensic experts, the following caveats should be noted:

- In the serious game, we measured group scores. Although we have seen no indications of group dynamics, our results may be influenced by group pressures, such as groupthink (36) and, consequently, be less reliable.
- The participants in the serious game had to make decisions regarding simplified cases; more research (i.e., participatory research) is needed to validate the findings of the serious game.

Recommendations

Overall, we believe that experienced forensic team leaders make effective and efficient decisions. Even when the time pressure and the stakes are high, experienced team leaders are able to operate effectively because of NDM-like mechanisms. Furthermore, it would naïve to believe that forensic decision makers, who deal with time constraints and a limited research capacity, make purely rational decisions. In few circumstances, however, interventions are imperative to decrease the likelihood of subjective decision making. Based on our research, we offer two practical recommendations for forensic team leaders and their advisors.

Our first recommendation is to make forensic team leaders aware that contextual factors have the potential to influence their decision making. Serious games can be used to make the members of forensic teams more aware of contextual and personal factors that influence the decision outcome (see also [35]). If someone wants to overcome these biases, he or she must first be aware of their existence.

Our second recommendation is to present a devil's advocate perspective in every suitable investigation. A peer review can function as a devil's advocate, identifying potentially irrational decision making. Peer reviews may be organized informally, as a regular part of a team meeting, or formally by appointing a dedicated official in high-profile cases.

These recommendations are in accordance with the official policy in the Netherlands following the 2000 Schiedammerpark murder (see [5]). However, this policy was specifically aimed at preventing the effect of group dynamics (i.e., tunnel vision). We would argue, therefore, that this policy has broader implications.

Conclusion

This article aimed to broaden our understanding of decision making by forensic team leaders. By applying NDM theories to forensic decision making, we have identified four mechanisms that influence the decisions of forensic team leaders. First, our results uncovered a previously unnamed mechanism that motivates forensic scientists to obtain further information when more information is initially made available. Second, consistent with prior research, we also found that forensic decision makers devote more attention to emotionally charged cases. This finding suggests that forensic decision making is not only directed by rational evidence but also influenced by the personal values of the decision maker. Third, our results revealed that forensic scientists use tactical, unverified information in the decision-making process. Fourth, if a decision maker operating under tight time constraints is confronted with a decision that matches prior experience or the first impression of the evidence, that decision alternative is likely to be chosen.

In most cases, these mechanisms help forensic researchers to make effective and efficient decisions. In a few cases, however, these mechanisms may negatively influence the decision outcome and decision-making process. We were surprised by our results, but more surprised by the strong denial and disbelief of the participants when the results of the serious game were presented. It appeared that insights into "real-life" decision making have not penetrated deeply into the forensic science community. Therefore, we not only suggest introducing devil's advocate perspectives and serious games but also education that includes "real-life" decision-making courses to enhance the self-awareness of the forensic science community.

References

1. Saks MJ, Risinger DM, Rosenthal R, Tompson WC. Context effects in forensic science: a review and application of the science of science to crime laboratory practice in the United States. Sci Justice 2003;43(2):77–90.
2. Dror IE, Charlton D. Why experts make errors. J Foren Ident 2006;56(4):600–12.
3. Langenburg G, Champod C, Wertheim P. Testing for potential contextual bias effects during the verification stage of the ACE-V methodology when conducting fingerprint comparisons. J Forensic Sci 2009;54(3):571–81.
4. Dror IE, Rosenthal R. Meta-analytically quantifying the reliability and biasability of forensic experts. J Forensic Sci 2008;53(4):900–3.
5. Openbaar Ministerie, Politie en Nederlands Forensisch Instituut [The Public Prosecutions Service, Police and the Netherlands Forensic Institute]. Versterking opsporing en vervolging [Enhancing investigation and prosecution, author's translation]. Parliamentary documentation: 2005; HTK 30 300 VI, no. 32.
6. Zsambok CE, Klein G, editors. Naturalistic decision making. Mahwah, NJ: Lawrence Erlbaum Associates, 1997.
7. Lipshitz R, Klein G, Carroll JS. Introduction to the special issue. Naturalistic decision making and organizational decision making: exploring the intersections. Organ Stud 2005;27(7):917–23.
8. Biedermann A, Bozza S, Taroni F. Decision theoretic properties of forensic identification: underlying logic and argumentative implications. Forensic Sci Int 2008;177:120–32.
9. Taroni F, Bozza S, Bernard M, Champod C. Value of DNA tests: a decision perspective. J Forensic Sci 2007;52(1):31–9.
10. Elliott T. Expert decision-making in naturalistic environments: a summary of research. Edingburgh, Australia: DSTO Systems Sciences Laboratory, 2005.
11. Morrell K. Decision making and business ethics: the implications of using image theory in preference to rational choice. J Bus Ethics 2004;50(3):239–52.
12. Simon HA. A behavioral model of rational choice. Q J Econ 1955;69(1):99–118.
13. Klein GA. Naturalistic decision making. Hum Factors 2008;50(3):456–60.
14. Tversky A, Kahneman D. Judgement under uncertainty: heuristics and biases. Science 1974;185:1124–31.
15. Patel VL, Kaufman DR, Arocha JF. Emerging paradigms of cognition in medical decision making. J Biomed Inform 2002;35(1):52–75.
16. Thompson WC, Cole SA. Psychological aspects of forensic identification evidence. In: Constanzo M, Krauss D, Pezdek K, editors. Expert psychological testimony for the courts. New-York, NY: Lawrence Erlbaum & Associates, 2006;31–68.
17. Dror IE, Charlton D, Peron AE. Contextual information renders experts vulnerable to making erroneous identifications. Forensic Sci Int 2006;156:74–8.
18. Dror IE, Péron AE, Hind SL, Charlton D. When emotions get the better of us: the effect of contextual top-down processing on matching fingerprints. Appl Cognitive Psych 2005;19(6):799–809.
19. Hall LJ, Player E. Will the introduction of an emotional context affect fingerprint analysis and decision-making? Forensic Sci Int 2008;181:36–9.
20. Dror IE. On proper research and understanding of the interplay between bias and decision outcomes. Forensic Sci Int 2009;191(1):17–8.
21. Saks M, Concerning LJ, Hall E. Player "Will the introduction of an emotional context affect fingerprint analysis and decision-making?" Forensic Sci Int 2009;191:36–9.
22. Wilkinson SH, Joffe L, Yardley L. Qualitative data collection: interviews and focus groups. In: Marks DF, Yardley L, editors. Research methods for clinical and health psychology. London, UK: Sage, 2004;39–55.
23. Stewart DW, Shamdasani PN. Focus groups; theory and practice. Newbury Park, London, UK: Sage, 1990.

24. Carroll JS, Hatakenaka S, Rudolph JW. Naturalistic decision making and organizational learning in nuclear power plants: negotiating meaning between managers and problem investigation teams. Organ Stud 2006;27(5):1037–57.
25. Klein GA, Calderwood R. Decision models: some lessons from the field. IEEE Trans Syst Man Cybern 1991;21(5):1018–25.
26. Orasanu J. Crew collaboration in space: a naturalistic decision-making perspective. Aviat Space Environ Med 2005;76(6):154–63.
27. Beach LR. Image theory: decision making in personal and organizational contexts. Chichester, UK: Wiley, 1990.
28. Beach LR. Broadening the definition of decision making: the role of prochoice screening of options. Psychol Sci 1993;4(4):215–20.
29. Beach LR, Mitchell TR. Image theory: theoretical and empirical foundations. Mahwah, NJ: Lawrence Erlbaum Associates, 1998.
30. Pennington N, Hastie R. Explaining the evidence: tests of the story model for juror decision making. J Pers Soc Psychol 1993;62(2):189–206.
31. Pennington N, Hastie R. Reasoning in explanation-based decision making. Cognition 1993;49:123–63.
32. Montgomery H, Lipshitz R, Brehmer B. How professionals make decisions. Mahwah, NJ: Lawrence Erlbaum Associates, 2005.
33. Oskamp S. Overconfidence in case-study judgments. J Consult Psychol 1965;29(3):261–5.
34. Pyrek K. Forensic science under siege. San Diego, CA: Elsevier Academic Press, 2007.
35. Koppl G. How to improve forensic science. Eur J Law Econ 2005;20(3):255–86.
36. McCauley C. The nature of social influence in groupthink: compliance and internalization. J Pers Soc Psychol 1989;57(2):250–60.

Additional information and reprint requests:
Ira Helsloot, Ph.D.
Professor of Crisis Management and the Politics of Safety
Free University Amsterdam, Faculty of Social Sciences
Department of Public Administration
De Boelelaan 1081
1081 HV Amsterdam
the Netherlands
E-mail: i.helsloot@fsw.vu.nl

Appendix

Case descriptions

	Group A	Group B
Micro Electric		
$T = 0$	A mobile phone shop, carpet store, and a small administrative office are all located in one building. The shop is located on the ground floor, the carpet store and administration office on the second floor. Unfortunately, the building was burned out	Ibid
	The fire was reported to the fire brigade by an employee of the administrative office at 9:13 PM	Ibid
	When the fire brigade arrived, all the entrance doors were closed (locked with roll doors)	Ibid
	A detective reports to the forensic researcher that he visited the phone shop 2 weeks ago. It was a mess inside the shop	A police officer reported to a forensic researcher that he thinks the owner of the carpet store is involved in the case. He believes the owner seeks to earn money from the fire insurance because the police officer heard from someone that the carpet store is almost bankrupt
$T = 15$	Decision	Decision
	A detective found cigarette butts in a half-burned dust bin at the ground floor (located at the entrance of the shop)	Ibid
	The owner of the shop declares that he left the shop at about 6:45 PM. Just before the owner left the shop, he placed the dust bin inside the shop to prevent vandalism Around 7:10 PM, the owner was called by a security agent; the burglar alarm had detected ''something'' When the owner arrived, the whole building was already burned	Ibid
	The safety center journal showed that the alarm was switched on at 6:45 PM About 7:06 PM, the alarm detected a possible burglar. The owner was called at 7:09 PM	Ibid
	A phone shop employee declares that the central heating switch (located in the meter cupboard) sometimes sparked	Ibid
$T = 30$	Decision	Decision

Appendix—*Continued.*

	Group A	Group B
Renkum Murder		
$T = 0$	A man is accused of strangling his wife and children. The bodies were burned in the home to cover the evidence	Ibid
$T = 15$	Decision	Decision
	The suspect confesses to the murder of his wife and children. The suspect also confesses to the arson. The confession supports the pathological and forensic evidence. However, some details about the fire starting do not match the fire damage Laboratory research (with a spectrograph) revealed some traces of titanium and zinc at the crime scene	The suspect confesses to the murder of his wife and children. The suspect also confesses to the arson. The confession supports the pathological and forensic evidence. However, some details about the fire-raising do not match the fire damage
	The suspect declares that he started the fire at about 5:40 AM. The suspect called emergency services at 6:29 AM. The suspect confesses to the murder of his wife and children as well as the arson	No information
	The fire brigade arrived at the crime scene at 6:41 AM. The fire was extinguished in 3 min. The fire fighters reported an odd white smoke while they extinguished the fire	No information
	Only a small area (where the bodies of the wife and children were found) in the bedroom was damaged by the fire A researcher found soot in a V-shape. The V-shape suggests that the fire was extinguished in an early stage of development. This finding is in accordance with the discovery of un-melted plastic furniture. However, the fire damage on the window frame suggests that the fire burned for more than 1 h	No information
$T = 30$	Decision	Decision
Happy Slapping		
$T = 15$	Behind a skip located in the ''Red Light District'' (Amsterdam, Holland), the police found the murdered body of a 33-year-old ex-criminal. His police record includes drug dealing, robberies, and violence	Behind a skip located in the ''Red Light District'' (Amsterdam, Holland), the police found the murdered body of a 16-year-old boy. The boy was on a school trip in Amsterdam but lost his group. His parents and the school informed the police that the boy was missing
$T = 30$	Decision	Decision