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Hazard and Risk Assessment and Perception in the Analysis of Cultural Heritage

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Abstract – **The concept of "risk" and how its meaning is related to that of other concepts such as "danger", "hazard", "safety" and "uncertainty" has been studied for almost a century. When risk is involved, human decisions are conditioned by the different perception and elaboration of the relevant information connected to the choice process. For example, positive and negative feedback about past risk taking can affect future risk taking. People who are led to believe they are very competent at decision making see more opportunities in a risky choice and take more risks, while those led to believe they are not very competent see more threats and take fewer risks.**
During the preparation of an experiment on samples of cultural relevance, a deeper awareness of these concepts should be taken into consideration, as well as an informed knowledge of the mechanisms of decision making in presence of a possible damage.

I. INTRODUCTION

The study of samples in cultural heritage artifacts and micro-samples benefits from diagnostic techniques based on novel, often intense radiation sources, such as synchrotrons, free electron lasers, ion-beam accelerators and lasers. While most of the corresponding conventional techniques are classified as non-destructive, investigation with photons or charged particles entails a number of fundamental processes that may induce changes in materials. These changes depend on irradiation parameters, chemical, physical and morphological properties of materials, and environmental factors. In some cases, radiation-induced damage may be detected by visual inspection. When it is not, irradiation may still lead to atomic and molecular changes resulting in immediate or delayed alteration and bias of future analyses [1].
The knowledge of analysis-induced alteration mechanisms, however, is not sufficient to prevent risky situation. The perception of risk and hazard is ruled by subjective elaborations that must be taken into account. After a concise review of typical alterations induced by X-ray or charged particles, we will describe these psychological mechanisms and suggest some methods to limit their effect.

II. ANALYTICAL INDUCED DAMAGES TO ANCIENT MATERIALS

Researchers using SRμXCT (Synchrotron Radiation micro-tomography) report color changes in ancient teeth during submicron scanning [2]. This effect (see figure 1), related to the hydroxyapatite crystals, rather than to the organic component, are visible indicators of ionization (i.e. chemical change) and therefore of potential physical damage [3].

Fig. 1. Color change in an ancient tooth under X-ray irradiation

While Tafforeau says that these effects are reversible [2], Richards found several cases of irreversible damage [3]. Another case of irradiation damage is reported by Boistel [4], who found deformation of the inner ear of a frog during a high-resolution tomography at ESRF. The close-knit coexistence of organic and mineral components in the biological tissue may be linked to the dramatic increase of radiation dosage sensitivity.

The first authors to refer to the use of X-rays applied to ancient DNA (aDNA) consider this field of techniques as destructive [5-6], since they can increase the fragmentation of the endogenous DNA. Others simply suggest to "avoid further damage to specimens by preventing X-ray exposure to the specimens and maintaining specimens at the same temperature they were excavated" [7].
Other authors investigated the effect of typical clinical CT X-ray energies on the possibility to extract and amplify aDNA from bone [8]. Their results suggest again that, in general, radiation exposure fragments DNA, thereby decreasing the amount that is amplifiable. More recently, other authors found no quantifiable degradation of DNA strands length under standard X-ray exposure during a desktop scanner microCT analysis [9].
There are also data about the energy range 7-150 eV, corresponding to the range of energies typically involved in the efficient production of DNA single-strand and double-strand breaks [10], but this range is usually filtered out during tomographic acquisistions. More reports on this subjects can be found in the works of Fujii [11], Hiller [12], and Holton [13].
In general, further research is required to elucidate the degree to which radiation fragments DNA in archaeological specimens.
Some authors consider desktop scanner microCT as a non-destructive study prior to radiocarbon dating, but do not discuss this argument [14]. There is no scientific reason to say that in general there could be x-ray damage related to RC dating. If we consider thermoluminescence as a dating technique, scientists used to think that X-rays analyses were not a problem for this technique, but a continuous increase in X-ray absorption by samples is starting to alarm. Presently, no experimental data are avallabile.
An additional consideration: different setups of the same technique induce different X-ray dose absorbed by the samples: in the case of X-ray tomography, for example, clinical CT, desktop scanners, sub-micron and micron-level CT, monochromatic and wide-bandpass synchrotron beamlines are characterized by radically different parameters.

III. RISK PERCEPTION

The concept of “risk” and how its meaning is related to that of other concepts such as “danger”, “hazard”, “safety” and “uncertainty” has been studied for almost a century [15]. Maybe the most appropriate suggestion about the semantical difference between “risk” and “danger” has been given by the sociologist Niklas Luhmann [16]: “risk” refers to potential failure loss as a consequence of a decision, while “danger” is a potential loss resulting from something external. Another important concept to consider is the so called “risk factor”, which is the probability of something happening multiplied by the resulting cost or the benefit if it does. When risk is involved, human decisions are conditioned by the different perception and elaboration of the relevant information connected to the choice process. For example, positive and negative feedback about past risk taking can affect future risk taking. In an experiment, people who were led to believe they are very competent at decision making saw more opportunities in a risky choice and took more risks, while those led to believe they were not very competent saw more threats and took fewer risks [17].

During the preparation of an experiment on samples of historical and cultural importance, a deeper awareness of these concepts should be taken into consideration, as well as an informed knowledge of the mechanisms of decision making in presence of a possible damage to the sample under analysis.

IV. RISK MANAGEMENT PROCESS

While people working in the many different forms of risk management always have the same goal, to provide a sound basis for decisions on whether risks are acceptable and, if necessary, obtain reliable information how they can be dealt with, there are many different definitions of risk and of the risk management process elements and many different versions of the process to be followed. The ISO 31000:2009 standard [18, 19] provides internationally recognized sound principles for a simple and effective risk management process. This standard is based on five steps schematically illustrated in figure 2

Step 1: Identify the Risk. The team uncovers, recognizes and describes all the risks that might affect the project or its outcomes. There are several techniques that can be used to find project risks. During this step it can be useful to prepare a Project Risk Register [20].
Step 2: Analyze the risk. Once risks are identified, the likelihood and consequence of each risk should be determined. It is important to develop an understanding of the nature of the risk and its potential to affect project goals and objectives. This information is also an input to the Project Risk Register.
Step 3: Evaluate or Rank the Risk. The risk should be evaluated and ranked by determining the risk magnitude, which is the combination of likelihood and consequence (figure 3), making decisions about whether the risk is acceptable or whether it is serious enough to warrant treatment. These risk rankings are also added to the Project Risk Register.
Step 4: Treat the Risk. This is also referred to as Risk Response Planning. During this step the highest ranked risks are assessed and a plan is set out to treat or

modify these risks to achieve acceptable risk levels. Aim of this step is to minimize the probability of the negative risks as well as enhancing the opportunities. Creating risk mitigation strategies, preventive plans and contingency plans in this step, and adding the risk treatment measures for the highest ranking or most serious risks to the Project Risk Register.

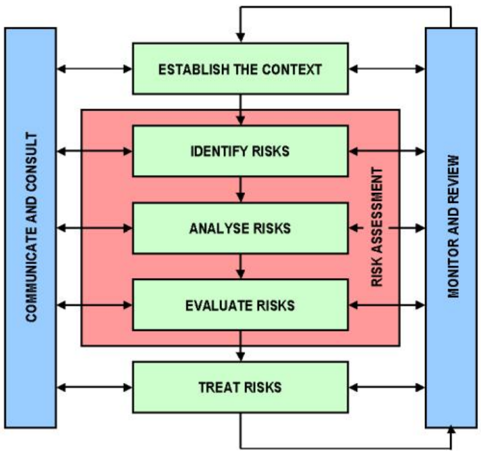

Fig. 2. ISO 31000 Risk Management Process

Step 5: Monitor and Review the risk. This is the step where the Project Risk Register is finalised and used to monitor, track and review risks.

V. THE PROJECT RISK REGISTER

The Project Risk Register is in general a handy tool to add structure and consistency to any project risk management process. There are many different tools that can act as risk registers, from commercial software packages to simple Excel spreadsheets. The effectiveness of these tools depends on their implementation and the organisation's culture. A typical Project Risk Register contains 12 key elements divided in the four areas related to the described steps. Elements 1 to 3 record the results of the Risk Identification phase.

1. Risk Category – This is the moment when the risk is categorized. Does it fall under the category of scope, time, cost, resources, environmental, or another key category? Using these categories helps tease out likely risks and groups them into relevant categories for future reference.

2. Risk Description – A brief description of the potential risk. For example it can be related to the kind of instrument used in the experiment ot the environment where the analysis is conducted.

3. Risk ID – In more formal environments, such as industry, this is a unique identification number used to identify and track the risk in the risk register.

HAZARD RISK ASSESSMENT MATRIX

	Hazard Categories			
	1	2	3	4
Frequency of Occurrence	Catastrophic	Critical	Serious	Minor
(A) Frequent	1A	2A	3A	4A
(B) Probable	1B	2B	3B	4B
(C) Occasional	1C	2C	3C	4C
(D) Remote	1D	2D	3D	4D
(E) Improbable	1E	2E	3E	4E

Unacceptable High Medium Low

Fig. 3. Hard Risk Assessment Matrix

Elements 4 to 6 record the results of the Risk Analysis phase.

4. Project Impact – A description of the potential impact on the project as a result of the risk**.**

5. Likelihood – The estimated likelihood or probability that the risk will occur at some point and become a project issue. This can be qualitative: high, medium, or low; but it can also be quantitative if enough information is available.

6. Consequence – The potential consequence or impact of the risk if it did become a project issue. For a project, for example, time is a fixed constraint, and so any risk that has the potential to significantly delay the project schedule has a "High" consequence.

Elements 7 and 8 record the outcomes of the Risk Evaluation phase.

7. Risk Rank – This is the magnitude or the level of the risk. It is a combination of likelihood and consequence (figure 3).

8. Risk Trigger – What are the triggers that would indicate the need to implement contingency plans?

The last four elements record the outcomes of the Risk Treatment phase**.**

9. Prevention Plan – This is an action plan to prevent the risk from occurring.

10. Contingency Plan – This is an action plan to address the risk if it does occur.

11. Risk Owner – This is the person responsible for managing the risk and implementing the Prevention or Contingency Plans. Different stakeholders, such members of the experimental team, the Project Manager and the sample owner, can all be risk owners.

12. Residual Risk – This is the risk that remains after treatment is carried out. After treatment, we should assess the residual risk level as "Low."

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