Mediterranean Archaeology and Archaeometry, Vol. 14, No 2, pp. 367-373

MATTERS ARISING

Critical Evaluation of the Paper by Fazio et al., "The mysterious coexistence of bloodstains and body image on the Shroud of Turin explained by a stochastic process".

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The paper by Fazio et al. (2014), claiming, among other things, that a stochastic process was involved in the production of the image on the Shroud of Turin, has major conceptual errors to the extent that its main claims are totally unsupported and even meaningless. Moreover, the authors are essentially presenting personal opinions disregarding the most fundamental scientific approach. In the following, I address separately the most important errors.

1) The term "stochastic process" is misused and misunderstood by the authors. A stochastic process is a **mathematical modeling** technique used in many scientific domains including computer science, biology, physics, chemistry, and more (Çinlar, 2013). For example, the Brownian motion of particles suspended in a fluid was first mathematically analysed using a stochastic process.

A stochastic process needs to have a description of its random variables, with their probability density function, but no such description is presented in that paper.

The only model we could try to infer from that paper is from the following two contradictory sentences (appearing near the end of the paper!): "Such damage on the fibrils, which depends on the intensity of the energy sources and their macroscopic effect (yellowing of fibrils), is purely probabilistic. In our hypothesis, the dependence of yellowing fibril density versus the distance is linear, [...]" (pp. 8-9).

These statements are contradictory: "is purely probabilistic" means that the probability density function is uniform, but that would be impossible because there is a clear image of a body on the Shroud whereas a uniform probability would create a uniform noisy image. On the other hand, if we accept that the "density versus the distance is linear", this would not be probabilistic, but deterministic. So we are left with a stochastic process that creates a noisy image.

Misunderstanding of what is a stochastic process can also be inferred from the following statement:

"In this case, what was the source of energy? This question is and will remain open because for a stochastic process, if two or more sources of energy are involved (which can well be the case for the Shroud images), it is not possible to know which one has triggered it." (p. 8)

This general statement is untrue because several clearly identifiable energy sources can be modeled using stochastic processes. In other words, the fact that a physical process is modeled using a stochastic process has no implication about the energy sources: among other things, they can be clearly identifiable.

In summary, for this first point, the authors are not describing a stochastic process, but are refering to a *putative random physical phenomenon* that would have created the image on the Shroud, which they **do not describe with any precision**.

2) The authors claim that a random physical phenomenon (what they call a "stochastic process") is involved based on the observation that some colored fibrils of a thread of the Shroud of Turin are mixed with uncolored ones. This property can be seen from photomicrographs taken by Mark Evans in 1978 and is usually described as the halftone property of the image on the Shroud. But that observation is unrelated to the conclusion that a "purely random" process is involved because, for example, if we photomicrograph a black and white printed newspaper, the halftone property can be seen and no "purely random" phenomenon is involved because a deterministic process created this print.

3) A major fundamental erroneous claim is made about stochatic processes: they would only be produced by low-energy sources. This is false because stochastic processes have been used to model high-energy physics phenomena for decades (Puri, 1970). This claim is made in the first paragraph of Section 2.3 of that paper:

"In the introduction, we have affirmed that both radiative and artistic forgery hypotheses must be discarded. Indeed, it is theoretically impossible for these mechanisms to produce a subtle body image on linen like we see on the Shroud with an unpredictable mix of fibrils (10-15 μ m each) that would be yellowed, along with some others that would preserve their background colour in a same region (Pellicori and Evans, 1981)."

First, radiation does produce phenomenon that appears random. As a matter of fact, some radiations are produced by non-deterministic physical phenomenon such as beta-decay, which produce beta radiation (i.e., high-energy electrons) that interacts non-deterministically with matter. Some high-energy electrons could modify the structure of a single fibril without affecting close-by ones in a thread. There is no connection between the fact that some fibrils are colored next to uncolored ones (i.e., halftone property) in a thread of the Shroud and whether the energy source is a (high-energy) radiation or not. Essentially, the authors are confusing high-energy radiation (e.g., gamma rays, beta-decay) with radiative effect due to large amount of energy.

Second, artists can create the halftone effect by using the right physical phenomenon. The authors simply forgot that artists use physical phenomena to produce their artifacts, and that these physical phenomena could produce the halftone effect. The authors would have to prove that artists couldn't use any physical phenomenon that can produce a halftone effect, but this is not proven at all, and it is very hard to see how they could prove it.

So their main claim from the introduction is unproven.

4) Other claims are meaningless or physically impossible, such as

"For us, on the Shroud, there are latent body images [...] triggered by a little quantity of energy [...]. These effects are absent just when the energy is zero." (p. 3)

First, note the use of "For us" at the beginning of the claim, which is equivalent to "In our opinion". The authors appear to no longer try to support their claims, but propose their personal opinions: more on this point at (5) below.

Second, this is physically impossible because "energy zero" is a non-producible physical state in physics and "energy near zero" would imply that the Shroud was away from any source of energy, including the air (i.e., of course, the air, even at low temperature, has a nonzero energy). Are the authors implying that in the first century, the Shroud was put away in some vacum container away from Earth?

This claim is followed by: "Therefore, the hypothesis involving an artistic forgery or a miraculous event must be discarded."

Because the image is latent it cannot be an artistic forgery? An artist could have used chemical products that would take years to produce the complete image. There is no connection between latency of an image and some artistic production.

A miraculous event must be discarded? So the authors have proven that a miraculous event cannot create a latent image? Have the authors even defined what is a miraculous event in their paper? No. If a miraculous event is based on God's ability, why would he not be able to create a latent image? In a few words: their statement about a "miraculous event" that "must be discarded" is not false, it is meaningless.

5) In a scientific or scholarly paper, there is no place for personal diatribes such as this one:

"Here, it is necessary to add a comment: in spite of the vast amount of solid data obtained by different experiments and analysis done by blood chemists and medical or forensic experts, there are still self-styled scientists who denied such a fact, which is incredible, especially when we consider that this is one of the most unquestionable facts regarding the Shroud! These people should know that science has nothing to do with personal opinions." (p. 4)

Such a comment is useless because it does not refer to any specific publications, which the reader can analyze. Moreover, the sentence "These people should know that science has nothing to do with personal opinions" is very ironic because the authors themselves use four times the expression "In our opinions" to introduce major claims:

a) "In our opinion, this state of affairs is due to the fact that this cloth could be the authentic burial shroud of Jesus of Nazareth." (p. 2)

b) "In our opinion, it is necessary a new run of measurements, by radiocarbon dating, with an original sample." (p. 2)

c) "In our opinion, a non-stochastic process is unable to explain the formation of both body images (ventral and dorsal) that have the same physical and chemical characteristics as the ones that appear on the Shroud." (p. 6)

d) "In our opinion, the bloodstains formation was followed shortly thereafter by a transfer of a little quantity of energy that was released by the dead body in direction of both parts of the cloth (ventral and dorsal parts), which triggered a stochastic process that produced, after some time (e.g. a few decades), a yellowing of some fibrils on the cloth's surface." (p. 9)

Notice that (d) is in the conclusion and qualifies the main claims, which renders the entire paper a presentation of the authors' opinion. Therefore, they cannot claim, even by trying to create a new version of this paper, that what was intended to be presented used a scientific approach. Indeed, as the authors wrote "[...] science has nothing to do with personal opinions."

6) In summary, that paper not only makes claims that are unproven, but the arguments used are full of statements that are false, meaningless or physically impossible. Moreover, according to the conclusion itself, their main claims are a matter of their personal opinion.

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MATTERS ARISING – REPLY

Reply to Mario Latendresse concerning his skepticism regarding our hypothesis that the body image on the Shroud of Turin was yielded by a stochastic mechanism, By *G. Fazio[a,b], and G. Mandaglio[a,b,c*] (gmandaglio@unime.it)*

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We reply to the colleague Latendresse thinking that the various articles present in literature addressed to these questions (Fazio and Mandaglio, 2011, 2012 and 2014: Fanti, 2014; Fazio et al, 2014a; Fazio, 2013; Curciarello et al, 2012) have not been sufficiently clear to explain our model. Because of this, we will try in the following to describe our hypothesis in a simpler way.

Let's use an example. In an irradiated population, it is possible to observe stochastic and deterministic effects. Both effects respect characteristic laws depending, in these cases, on the absorbed dose from the interested population.

To high dose, the effects in the population are deterministic:

i) They only appear when a threshold-dose is reached.
ii) When the above dose is surpassed, the effects will affect every person, also considering the individual variability.
iii) The latency is short (a few days or weeks); in a few case, the effects can late.
iv) The seriousness of the effects increases if the absorbed dose is higher.

Therefore, for this kind of process, we can affirm that:

1) The probability of an event to occur is 1.
2) The seriousness of the effects on the population increases with the absorbed dose.

On the contrary, when the absorbed dose is low, the effects on the irradiated population are stochastic:

a) Here, a threshold-dose does not exist; the effects are absent only when the absorbed dose is equal to zero.
b) The effects have a probabilistic character.
c) The frequency of appearance increases if the absorbed dose is higher.
d) The effects appear years or decades later.
e) The seriousness of the above effects do not increase if the absorbed dose is higher.
f) These effects are indistinguishable from the ones induced by other causes.
g) The above affirmations are demonstrated by radiologic experiments and by the epidemiological evidence.

In conclusion, for the stochastic processes:

A) The probability of an event to occur is a function of the absorbed dose.

B) The seriousness of the effects is independent of the absorbed dose.

It should be noted that a stochastic distribution of ill people can also be observed when we analyze a population living in an environment where a faint pollution is present, due to chemical substances. Obviously, we will have the same kind of distribution for a weak presence of pollution that includes not only a physical nature but also a chemical nature. In this last case, for an ill person, it's impossible to know if the origin of the illness is due to the action of one or the other or of both sources. However, these effects are noticeable only when the sample of ill people reached a minimal number.

In the case of the Shroud, we decided to focus our attention on the discontinuous distribution of yellowed fibrils (each fibril having a thickness of 10-15 microns) in the body image regions (i.e. frontal and dorsal images). This "population" is many numerous (Fazio et al, 2014b) and we think that stochastic effects can be observed.

In the end, the above mentioned effects always imply some kind of chemical modifications: for the affected persons, unfortunately, they concern tumors while for the Shroud fibrils, they represent oxidation and/or dehydration that yield an increase in the optical density.

For the frontal part of the Shroud body image, there is a correlation between the image intensity and the cloth-body distance. Recently, we have deduced that such a correlation also exists in the dorsal part of the Shroud body image (Fazio and Mandaglio, 2008). With this state of affairs, we know the distribution of the transferred energy in all the regions where both frontal and dorsal images are present.

In details, for the I(z) and also E(z) correlation, there are two different results that exist in the scientific literature. The first result (Jackson et al, 1984) is a linear function, the second one (Fanti, 2010) is an exponential function. In the first case, the probability to yellow a fibril has a linear trend and in the other, the probability possesses an exponential trend. To understand these effects, the existence of a correlation, able to describe the absorbed energy from the linen as function of the position on the cloth, is necessary.

On the Turin Shroud, the highest fibrils density (or image intensity) is located in the areas of cloth-body contact and decreases when the cloth-body distance increases, while the absorbed energy also decreases. Besides, the optical density of these fibrils is roughly the same, with possible slight differences due to the individual natural variability among the fibrils. This distribution of the yellowed fibrils (i.e. the ones that yield the image, which are mixed together with the uncolored fibrils) agrees with the affirmations made in the A) and B) items. Therefore, such a distribution can be described has being stochastic.

However, it is very difficult to resolve the question regarding the image formation at microscopic level. Indeed, it would probably be necessary to find the source (or sources) of the weak energy that was (were) able to trigger the image formation process. On this particular subject, we invite the colleague Latendresse to read our recent paper (Fazio and Mandaglio, 2014).

Now, as one can see, in the article of Latendresse, there is an important call to seriously consider the photomicrograph taken by Mark Evans in 1978. In Fig. 1, we show the photomicrograph of a portion of the nose region. In this particular area (which is most probably an area where there was a direct-contact between the cloth and the Shroud man's corpse), there are visible bundles of colored fibrils next to bundles of uncolored

fibrils. For some researchers, such a complex distribution of yellowed fibrils excludes *de facto* an image formation scenario involving a stochastic process. Indeed, they though this particular kind of distribution represents a random distribution of single yellowed fibrils.

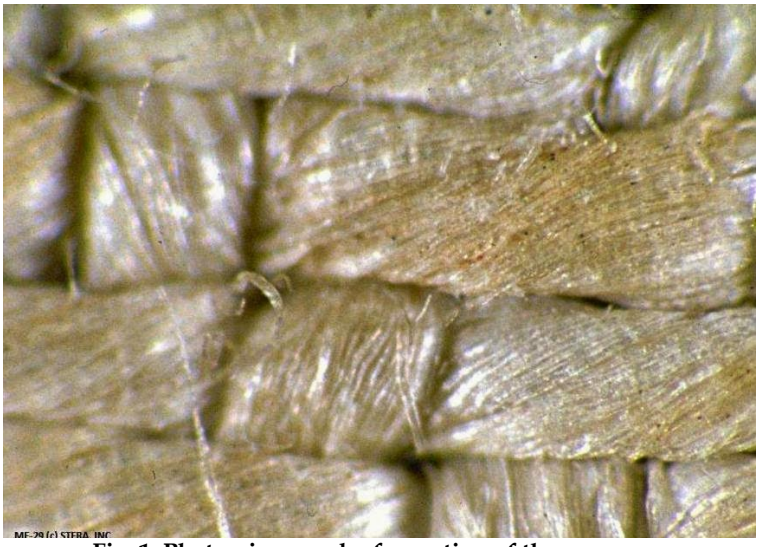

Fig. 1. Photomicrograph of a portion of the nose area

We answer that the stochastic characteristics can be present with single fibrils, bundles of fibrils or both, randomly distributed. In fact, it is only necessary that the analyzed distribution agrees with the affirmations labeled in the A) and B) items. Even more, we can state that the kinds of discontinuous distributions that we just mentioned are the only ones that can fit with a process that would be stochastic. In other words, to be in line with the characteristic described in the A) and B) items, it is necessary that the yellowed fibrils are showing a discontinuous distribution made of bundles of yellowed fibrils and/or of groups of yellowed fibrils and/or of single yellowed fibrils.

Therefore, in order to have a stochastic effect associated with the Shroud image formation, it is necessary that the image intensity is expressed by the density of the yellowed fibrils and that their optical density is the same for all the yellowed fibrils (while taking into account the natural differences that can exist among them).

One last consideration. To explain the mix of yellowed and uncolored fibrils in all the regions of the body image, we have two possibilities: to accept the action of a stochastic process (because it takes into account the discontinuous distribution of the colored fibrils responsible for the image) or to affirms that every fibrils and bundles of fibrils composing the image (i.e. those that eventually became yellowed) were arranged in advance in such a way that a change in the optical density of these threads could happened during the cloth body interaction, which would have eventually yielded the image that we still see on the cloth.

In conclusion, we believe in this kind of process (i.e. the stochastic one) that can offer a viable solution for the image formation. However, if someone can scientifically prove that such a process is not able to explain one or many of the numerous characteristics of the Shroud body image, we will simply reject our hypothesis. Nevertheless, in the pre-

sent state of our knowledge concerning the Shroud body image, we believe that such a discrepancy still needs to be properly proven and independently confirmed.

NOTE

A last consideration on the use of expressions, as "In our opinion" or "For us", present in (Fazio et al, 2014b): the colleague Latendresse should know that these particular sentence still need to be scientifically confirmed. Therefore, other opinions and hypotheses exist regarding them. So, in this context and to be correct, it was important to use these expressions in order to let the readers to know that other possibilities exist outside the conclusion or hypotheses we propose.

ACKNOWLEDGEMENTS

The authors wish to thank Yannick Clément for the improvement in the English language of this paper.

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