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Surgeon's Performance: An Analogy with Aircraft Pilot's Challenges

Ephraim Suhir[1] and Inna Bedny[2]

[1]Portland State University, Portland, OR 97220, USA
[2]United Parcel Service, Parsippany, NJ 07054, USA

ABSTRACT

There is an obvious analogy between the challenges that an aircraft pilot has to cope with when fulfilling his long-term mission or when encountering an abnormal situation, and the challenges that a surgeon faces during his "mission", a surgery, which is always a highly challenging and sometimes unpredictable effort. In this paper we indicate the need for quantifying the role of the Human Factors in making a surgical procedure less risky and to consider the analogy of this effort with the aircraft pilot challenges. These challenges have been addressed and modeled in a number of recent publications. Systemic-Structural Activity Theory is applicable to the improvement of efficiency and reliability of the highly challenging types of human activity. Future work should include experimental and statistical verifications of the validity and fruitfulness of the suggested modeling approach, as well as development of the appropriate auxiliary experimental and modeling methodologies and test vehicles.

Keywords: Surgeon's performance, Pilot's performance, Modeling, Human-non-failure

INTRODUCTION

Kao and Thomas seem to be the first ones who paid attention to an obvious analogy between the challenges that an aircraft pilot has to cope with when fulfilling his/her long-term mission or when encountering a short-term abnormal situation, and the challenges that a surgeon faces during his/her "mission", a surgical operation, which is always a highly challenging effort. This analogy could be considered from the point of view of what is identified today as human-system-integration/interaction (HSI) field.

Systemic-Structural Activity Theory (SSAT) is applicable to the analysis and improvement of the efficiency and reliability of the highly challenging types of human activity.

The objective of this paper is to indicate the need for quantifying the role of the Human Factors (HF) in making a surgical operation less risky and to indicate that the consideration of the analogy of this effort with the aircraft pilot challenges, which have been addressed and modeled in a number of recent publications, could be helpful. The paper uses a simplified double-exponential-probability-distribution function (DEPDF) to make our point and to "bring down to earth" the more general model for the probability of the human-non-failure (HnF).

By predicting this probability and making it adequate for a particular surgeon's task performance, one could put various "educated guesses" and "gut feelings" about the instrumentation and human reliability during the fulfillment of the surgical mission on a really "reliable" quantified foundation. Plenty of additional, both analytical and computer simulation-based modeling, as well as experimental and clinical and statistical work should be done to "reduce them to practice". The general idea is the need for quantifying, in one way or another, the numerous challenges that a surgeon faces in his/hers never-routine activity, in which the analogy with the pilot's performance might be helpful.

LITERATURE REVIEW

We use here a simplified double-exponential-probability-distribution function (DEPDF) to make our point and to "bring down to earth" the more general (Suhir, 2021) model for the probability of the human-non-failure (HnF). By predicting this probability and making it adequate for a particular surgical application, one could strive to predict instrumental and human reliability during the fulfillment of the surgical mission on a quantified foundation.

Kao and Thomas (2008) seem to be the first ones who paid attention to this analogy that could be viewed today as part of what is identified as human-system-integration/interaction (HSI). This extraordinarily broad field includes the role of human performance in various psychological and ergonomic tasks in general (Suhir, Karwowski, and Bedny, I., 2021, Suhir, and Paul, 2021,Suhir, 2020, Hollnagel, 1993, Taatgen, 2002, Lehto and Buck, 2008, Gluck and Pew, 2005) and critical aspects of human interaction with an intelligent system in particular: predictive modeling (PM), computer and analytical based simulations (Suhir, 2014, 2016, 2017); vehicular engineering, such as aerospace (Suhir, 2013, 2019, Suhir and Yi, 2017), automotive, railway, and maritime; medical electronics (Cain, 2007); and, of course, all kind of the human-in-the loop (HITL) and human factor (HF) related activities, attributes and challenges. The outcome of these activities is due, first of all, to the short-term mental (cognitive) workload (MWL) (Suhir 2019) and, mostly to the long-term, human capacity factor (HCF) (Suhir, 2017, 2013, 2019, Suhir, Yi, 2017, Cain, 2007, Suhir, 2019). Probabilistic predictive modeling (PPM) enables evaluating, improving, assuring and ultimately, if possible and appropriate, even specifying the acceptable (adequate and never-zero) probability of failure of a HITL mission or a situation, when the reliability of the equipment/instrumentation, the performance of the human-in-control (the pilot or the surgeon) and the response of the object-of-control (the air or spacecraft, not to mention the patient undergoing surgery), and the interfaces of these and other uncertainties (Tversky and Kahneman, 1974) contribute jointly to the outcome of the undertaking of importance.

DISCUSSION

Probabilistic Predictive Modeling

The probabilistic predictive modeling (PPM) concept was introduced first in reliability physics (Suhir, 2021), and then applied to quantify the role of

the human factor (HF) in ergonomics (HFE) (Kao and Thomas, 2008). The concept is based upon the recognition of the facts that

1) neither system reliability nor human performance are completely certain;
2) the difference between a highly reliable and an insufficiently reliable system or technology and human performance is "merely" in the level of their never-zero probability of failure;
3) the reliable performance cannot be assured, if it is not quantified;
4) such a quantification should be preferably done on the probabilistic basis (Suhir, Karwowski, Bedny, I., 2021).

HFE Specialists Could Benefit from Understanding the Analogy in Question

There is an obvious analogy between the challenges that an aircraft pilot has to cope with when fulfilling his/hers long-term mission or when encountering a short-term off-normal situation (Suhir, 2021, Kao, Thomas, 2008, Suhir, Karwowski and Bedny, I., 2021), and the challenges that a surgeon faces during his/hers "mission" - a surgery, which is often a short but a highly challenging effort. While there are also fundamental differences, the overlap relates mostly to error minimization (Suhir and Paul, 2021). Kao and Thomas paid attention to this analogy back in 2008.

Objective is to Minimize the Risk of a Surgical Procedure Through Modeling its Outcome

Our objective is to indicate the need for quantifying the role of the HF, specifically, the surgeon's human capacity factor (HCF), in making a surgery less risky. The con-sideration of the analogy of this effort with the aircraft pilot's challenges that has been addressed in several recent publications (Suhir, 2021, Kao, Thomas, 2008, Suhir, Karwowski and Bedny, I., 2021) could be helpful when attempting to predict the probability of the surgical operation outcome.

Surgical Training and Working Memory Issues

Some major issues with surgical training and performance reliability (Alexander, Langub and Rosen, 2014, Joseph. Campbell and Johnson, 1999, Hyun, Lee, Kim, Tong and Park, 2013) are viewed as follows:

1) The most commonly used formula for the surgical training is "Watch it, Do it, Teach it (WDT)". Such method puts the emphasis on memorization and using working memory. Such an extensive memory workload negatively affects human performance in unexpected and/or stressful conditions;
2) Multimedia computer aided and robot-assisted surgeries could improve the out-come of complex surgical procedures

Our Simplified Double-Exponential-Probability-Distribution Function (DEPDF) Model

To make our point and to "bring down to earth "the more general and more comprehensive predictive models considered in several earlier publications

(Suhir, 2021), a simplified double exponential probability distribution function (DEPDF) for the probability of the human non-failure, when performing a particular mission or encountering an extraordinary situation is as follows:

$$P(F, G) = P_0 \exp\left[\left(1 - \frac{G^2}{G_0^2}\right)\exp\left(1 - \frac{F^2}{F_0^2}\right)\right]$$

In this equation G_0 is the ordinary (low level, nonrandom) mental (cognitive) workload (MWL), F_0 is the (also non-random) level of the human qualifications identified by his human capacity factor (HCF) and quantified by the HCF level, G and F are random and possibly high-level MWLs and HCFs occurring in actual flight or surgery conditions. As evident from the above governing equation, P_0 is the probability of the human non-failure in ordinary MWL conditions, when $G = G_0$. Indeed, at normal MWL level ($G = G_0$) or at exceptionally high HCF level ($F \to \infty$) the probability of the human-non-failure is close to "one". This probability in off-normal conditions is always lower than in normal conditions, and this intuitively obvious fact is quantified by the introduced equation. If the MWL is extraordinarily high, the human will inevitably fail, no matter how high his/her HCF is, and this intuitively obvious fact is also quantified by the introduced governing equation.

A Pilot or a Surgeon does not have to be a Superman or a Superwoman to be Successful

The calculated data based on the introduced equation shows also that the increase in the human capacity ratio F/F_0 and/or in the mental workload ratio G/G_0 above 3.0 has a minor effect on the probability of non-failure. This means particularly that a professional does not have to be trained to cope with an extraordinarily high MWL. He/she does not have to be a superman or a superwoman to successfully cope with a very high MWL level, but still has to possess adequate qualifications and experience (reflected by the level of his/her HCF), and should be trained in his/her profession to an extent that, when there is a need, he/she would be able to cope with an elevated mental workload by up to a factor of 3.0 higher than in the normal mental workload conditions. In other words, his/her human capacity factor in extraordinary situations (and the situations that a surgeon has to cope with are always "extraordinary") should be at least by a factor of up to 3.0 higher than what is expected of a person of "ordinary skills in the art" or of a highly qualified individual in normal MWL conditions.

Systemic Structural Activity Theory (SSAT) and Human Performance Reliability

Systemic-Structural Activity Theory (SSAT) (Bedny, G. and Bedny I., 2018, Bedny, G., 2015) views human activity as a complicated structure that unfold in time.

It offers multiple measures of task complexity. Here we just want to mention one measure that reflects memory workload because it is important in the context of this paper.

T_{wm} quantifies the time for retaining current information in the working memory within the time T for the entire task performance.

Fraction of time for retaining current information in working memory in the time for the entire task performance is calculated as

$$N_{wm} = T_{wm}/T$$

In the authors' opinion, reduction of the memory workload during the performance of surgical procedures would improve the reliability and efficiency of such a procedure and reduce the stress on medical personnel.

FUTURE DEVELOPMENT AND CONCLUSIONS

The authors do not claim, of course, that all the i's are dotted and all the t's are crossed by the taken simplified approach.

Plenty of additional, both analytical and computer simulation-based modeling, as well as experimental and clinical and statistical work should be done to "reduce to practice" the general idea of the need for quantifying, in one way or another, the numerous challenges that a surgeon faces in his/hers never-routine activity, in which the analogy with the pilot's performance might be helpful.

Surgeons' tasks are unique because they include high precision motor actions, constant memory workload and decision making. Such combination makes activity of this type extremely complex. Complexity and reliability of task performance are interdependent characteristics. An increase in task complexity often result in a de-crease of reliability of its performance.

A surgeon has to work reliable under stress and when facing the work overload.

Future work should include experimental and statistical verification of the validity and fruitfulness of the suggested modeling approach, as well as development of the appropriate auxiliary experimental and modeling methodologies and test vehicles.

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