Ergonomics Laboratory Exercises

Timothy Joseph Gallwey
Leonard William O'Sullivan

CRC Press
Taylor & Francis Group

Ergonomics Laboratory Exercises

Ergonomics Laboratory Exercises

Timothy Joseph Gallwey
Leonard William O'Sullivan

CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **informa** business

Cover: An example of Leonardo da Vinci's flying machine made to his drawings by the Science Museum, London, and donated to the University of Limerick by Dr. Tony Ryan of Guinness Peat Aviation. It hangs in the Atrium of the Foundation Building and raises such ergonomics issues as: body dimensions, layout of controls, perception and vision, learning, physiology, and the ability to perform physical work.

CRC Press
Taylor & Francis Group
6000 Broken Sound Parkway NW, Suite 300
Boca Raton, FL 33487-2742

Version Date: 20110715

International Standard Book Number-13: 978-1-4200-6737-8 (eBook - PDF)

Visit the Taylor & Francis Web site at
http://www.taylorandfrancis.com

and the CRC Press Web site at
http://www.crcpress.com

Contents

Preface

This book provides a series of exercises for the laboratory work aspect of the formation of professional ergonomists as evaluated by CREE (Centre for Registration of European Ergonomists) according to HETPEP (Harmonising Education and Training Programmes for Ergonomics Professionals). CREE evaluates applicants from European Union (EU) ergonomics societies to register as a European Ergonomist (EurErg) according to HETPEP criteria, and to demonstrate their professional competence, in order to facilitate movement within the countries of the EU.

HETPEP specifies that the education component must be supplemented by "Laboratory exercises, [which] are in addition to the … [classroom] hours and are an integral component from the beginning of the education period … . [They] should prepare the student for later training and experience … [and] should comprise approximately 30 to 35 day-parts (3 hours each) that should total about 100 hours during the academic period." But the concept of "laboratory work" in ergonomics appears to be confused, or is at least unclear, for significant numbers of people.

Ergonomics is not a pure science like physics, chemistry, or experimental psychology. Ergonomics knowledge is not sought for the fundamental purpose of understanding how something works, what its laws are, or which theories are the most valid. That is the pursuit of science and, although ergonomics has a science basis, the essence of the profession is to use the findings of science to solve problems in the here and now. It is an applied science like engineering. Stokes (1997) has illustrated this point with a two-dimensional array of fundamental understanding versus consideration of use, where high understanding and low consideration of use is labelled as the Bohr quadrant, and the reverse is the Edison quadrant. He points out how high understanding from basic research led to solid state devices but now high considerations of use require the improvement of the performance of these devices which in turn requires further basic research. Likewise, ergonomists need to combine high understanding of the scientific basics with high considerations of use or application, which he classifies as Pasteur's quadrant. That is where we must aim.

Ergonomics cannot be learned out of a book. It must be learned by doing, with an applications-oriented ethos. It requires "hands-on" learning, where students see major aspects of relevant scientific phenomena for themselves, gain experience in how to collect data on them, and learn how to apply them. It is well known that active learning is much more effective than passive learning (e.g., see Czaja and Drury, 1981). Traditionally, this point has been demonstrated in office work and factory jobs, but it also applies in academia. Laboratory work in its general sense is the best way for students to receive active learning in an academic course. But they also need to learn about the safeguards required for obtaining valid and reliable data, they need to learn how to interpret its meaning, and they need to learn how to devise solutions to real world problems.

To some people "laboratory work" appears to be synonymous with people in white coats, using sophisticated and expensive high-tech equipment to collect highly accurate data on complex activities under tightly controlled conditions. That is one of the meanings used here, but it also includes what is sometimes called practical work, or practicals, or praxis, or *Ubung* in German, or practicum elsewhere, that is, practice or practical exercises. But these wider terms are also used at times in other contexts to refer to gaining general practical experience of working in industry, so their usage could lead to confusion. At the risk of telling people what they know already, it is first of all necessary to establish the essential nature of the type of work that is expected to be undertaken. We define "laboratory work" as an investigation with the following characteristics:

- An activity is performed to achieve a specific end (e.g., assemble parts).
- The performance is observed in a scientific manner (i.e., with some controls).
- Data are collected on that performance (probably with "scientific instruments").
- The data are analysed by scientific methods (e.g., mathematical statistics).
- The results are compared with those published in the scientific literature.
- A scientific report is drawn up that gives conclusions and recommendations.

Such investigations include the traditional sophisticated laboratory work but, in this document, we also include simpler investigations such as stopwatch studies, and pencil-and-paper exercises. The bulk of the work is likely to be performed on campus, with data collected on tasks performed by the course participants, in the classroom or the laboratory, under conditions not as tightly controlled as in proper research work. But, provided the characteristics of the previous paragraph apply, they will satisfy our definition.

Students should experience the inherent variability of the data collection process, and learn how to limit the amount of variability in their data by good experimental design and practice. They should have to write scientific reports on the work in order to obtain first-hand exposure to the process of analysis, comparison, inference, deduction, and drawing of conclusions. It should include consulting current scientific journals to ensure exposure to the latest findings, and it should usually also require the use of sophisticated statistical analysis.

Classroom work should be supplemented by field type studies. Preferably the students should investigate real work sites, with real employees, who perform real tasks, in real jobs, in a nonacademic establishment. But it is also possible to perform such studies on campus. They should expose students to the difficulties of doing such work, explore techniques for getting reliable and repeatable data at such sites, and develop skills in dealing with people in the workplace. The work should include data collection and analysis followed by a formal written report similar to those required for the other investigations. It will usually be done on a teamwork basis so it will enhance the skills needed for working in a team.

For some subject matter seminars, essays, tutorials, or self-work assignments are more appropriate mechanisms to support the lecture material. Hence, some material is provided to meet these needs. While the emphasis is on the relevance of the material to real world issues of ergonomics, the stress must be on understanding the fundamental principles involved and how they relate to relevant theoretical issues.

Part of the aim is to take a holistic approach so as to develop a systems view. But the laboratory work is not just an academic exercise. In many situations the state of ergonomics knowledge is insufficient to provide the basis for acceptable and sound solutions. So practitioners need to be able to collect their own data in an accurate and reliable fashion. That needs a good grounding in laboratory work.

Finally, the process helps to sharpen the students' critical reading of the scientific literature. It should help them to tease out reasons for differences in results, and to deduce appropriate measures to adapt reported results to their needs. It should help them to select the most appropriate methods and results in devising their solutions to the problems they address. It should also engender in them a respect and a desire for scientific rigour.

Czaja, S.J. and Drury, C.G., 1981, Aging and pretraining in industrial inspection, *Human Factors*, 23, 485–494.

Stokes, D.E., 1997, *Pasteur's Quadrant: Basic Science and Technological Innovation*, Brookings Institution Press, Washington, D.C.

The contents of this book are supported by additional material which is available from the CRC Web site: www.crcpress.com. This includes a list of possible equipment vendors.

Under the menu Electronic Products (located on the left side of the screen), click on Downloads & Updates. A list of books in alphabetical order with Web downloads will appear. Locate this book by a search, or scroll down to it. After clicking on the book title, a brief summary of the book will appear. Go to the bottom of this screen and click on the hyperlinked "Download" that is in a zip file.

Or you can go directly to the Web download site, which is http://www.crcpress.com/e_products/downloads/download.asp?cat_no=67362.

Acknowledgments

Some of the exercises detailed in this document owe a debt to the former ergonomics staff of the University of Birmingham (especially Dr. Ben Davies and Prof. Nigel Corlett), and a heavy debt to the State University of New York at Buffalo (Prof. Colin Drury). Their contributions are gratefully acknowledged and hopefully these are well referenced, but inevitably there are probably some topics and ideas that have not been referenced sufficiently. We ask for their forbearance. However, all errors and deficiencies are the responsibility of the authors.

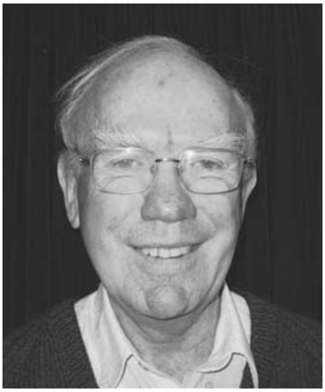
Many students have contributed ideas and improvements over the years to the work detailed in these experiments. Important contributions have come from specific graduate assistants in the universities in Buffalo, Windsor (Ontario), and Limerick. But a significant contribution has also been made by all course students through demonstrating deficiencies in wording and procedures, and these have been extremely valuable in refining the work.

Considerable contributions have come from authors such as Sanders and McCormick, Mundel, Barnes, and Konz and these have been acknowledged wherever we have been conscious of it. However, there are probably instances where their ideas and contributions, and those of others, have been absorbed to the extent that we are no longer conscious of them, and we hope for their forbearance and that of their publishers.

We offer a special thanks to the publishing staff — Richard Steele in the UK, Cindy Carelli, Amber Donley, and Gail Renard in the US — for their help in all the activities of producing a book.

We owe a particular debt to John Collins, who did the drawings that supplement this text to assist users in carrying out the exercises detailed here.

About the Authors



Timothy Gallwey has degrees in engineering and ergonomics. After 10 years in heavy engineering and the automobile industry, he moved to academia in Canada and then Ireland where he established a master's degree program in ergonomics at the University of Limerick and started the Irish Ergonomics Society. He was actively involved in the creation of the Centre for the Registration of European Ergonomists and led its first course accreditation. His research is mainly in musculoskeletal disorders, and he has been a partner in EU projects in this area. Currently, he is an independent ergonomics consultant.

Leonard O'Sullivan has a bachelor's degree in materials and construction and a master's and Ph.D. in ergonomics. He joined the University of Limerick as a lecturer in the Department of Manufacturing and Operations Engineering in 2003, where he lectures in industrial and product design ergonomics. His main interests are in musculoskeletal disorders, and he has been involved in several European Commission funded ergonomics research projects.

1 Report Writing

Important parts of the academic process, and the development of a deep understanding of ergonomics, are the analysis of data and the writing of scientific reports. The process of reading and dissecting various sources of information, breaking them up into distinct pieces, and reassembling them into a series of sound, cohesive points is one of the most challenging intellectual tasks. It is also one of the best means of developing a good understanding of the material and of helping students to learn how to organise data to make a scientific case or argument. For these reasons, the whole process of laboratory work would be incomplete without having to write up the work in a professional, scientific manner; therefore, it is an important part of these exercises.

Obviously, the requirements and styles of employers differ from each other and from those of scientific journals, just as the requirements of scientific journals differ, and hence it is impossible to provide guidance on what is needed by each. However there are general issues that have to be addressed, and these have been incorporated into a set of requirements for laboratory reports. In some cases, the work may not warrant a lengthy report, especially where a deep theoretical issue is not being examined; some employers actually prefer a shorter, more succinct style. For this reason three report styles are presented. Accompanying the short report-style document is a sheet for comments that can be ringed where appropriate to indicate particular shortcomings. Students, especially in the early stages of such studies, often have only a hazy idea of what is expected of them. To clarify this aspect, marking schemes with questions and pointers are discussed as well. To ensure that correct scientific notation is used, and correct formatting of the document, additional detail is provided on report presentation.

The HETPEP (Harmonising Education and Training Programmes for Ergonomics Professionals) document requires a final piece of project work to integrate study material and to provide particular depth in one area; this has its own special writing-up requirements. Writing laboratory reports in the style provided gives the students good training in how to construct such a final document, but a separate guide is provided for the style and structure of the project or thesis report. The requirements of different institutions will probably not be the same as that given here, but the general form of these documents has been developed over several years and should therefore match most of the requirements of most employers and publications.

Because ergonomics students come from a variety of scientific and engineering backgrounds, they may be accustomed to different conventions and report structures. This may be particularly apparent in different approaches to notation and the designation of units. The conventions used here are those largely accepted by most journals devoted to ergonomics, and employ SI units.

The analysis aspects of these experiments require a good ability with statistics, more than that obtained in an introductory course. Students should have had exposure to a thorough course in the more advanced aspects of the design of experiments. In particular, an understanding is needed of the issues associated with mixed-model designs and expected mean squares in the analysis of variance (ANOVA), and the process of transforming variables to meet the normality requirement of ANOVA. Around 40 hours of lectures is expected. The importance of having this background becomes particularly noticeable in project/thesis work. Serious problems can arise with both design and analysis if these areas are not well understood and implemented. Hence, many of the experiments incorporate particular emphases on these issues. The authors have worked with SPSS (Statistical Package for the Social Sciences; www.SPSS.com), as reflected in some of the material, but any one of the well known computer packages will be suitable.

1.1 SHORT LABORATORY REPORTS

Report writing is an important part of any job and a difficult discipline that needs to be learned and practiced. Short reports are limited to a maximum of six pages, and should be carried out according to the following format, incorporating also the requirements specified in Section 1.3, Report Presentation.

First Page (10% of Marks)

Concept Examined: This constitutes the top half. It is not a description or summary of what was done, but rather a brief expose or essay on the underlying theme or concept studied in your labwork. Certain aspects of ergonomics relate directly to the topic of the lab and so provide the basis for the work performed. Describe them. The treatment must be conceptual and general and end in a sentence stating the concept, principle, or idea examined.

Method: The bottom half of the page is this section. It must give sufficient detail that someone else will be able to repeat what was done. Minutiae of benches, etc., for example, are not relevant but information on apparatus used, procedure, and type of person used is relevant, provided that they may have affected the results achieved. It will help you or others if or when the work has to be repeated.

Second Page (15% of Marks)

Results: The top one third or so is this section. It must describe in words what information came to light from the work. Do not try to explain it or refute its validity, etc., here. Just state in words and with some data what was found, especially findings that run counter to expectations.

Discussion: The middle third of the page is this section. This is not a rehash or summary. Here, consider the quality of the experimental work, its validity, possible reasons for unexpected results, and what could have been done differently.

Conclusions: This is the last third of the page. It must consist of a series of numbered one-line or two-line statements of what the work revealed. Do not leave the reader wondering what to make of it all. The statements must relate to what was done, and must be supported by the data. Do not indulge in general, unsubstantiated speculation.

Last Four Pages (35% of Marks)

A set of appendices is given here. These consist of such items as tables of data collected, graphs, process charts or flow diagrams, sketch of the workplace, sample calculations, etc.

Writing Style (20% of Marks)

Correct grammar, spelling, and sentence construction must be used. What was done must be written in the past tense; by the time the report is written, it will be history. Avoid padding, waffling, and irrelevant statements. It must be written in the third person, that is, do not use "I" or "we" or "you" but rather "It was found that …". Telegraphic or military style is also not acceptable such as "Timed by stopwatch". Sentences must contain a finite, transitive verb.

Understanding of Concepts (20% of Marks)

The report must demonstrate that the student(s) understands the concept(s) involved, the techniques used, the meaning and relevance of the results obtained, and their implications.

1.2 SHORT LAB REPORT GRADING COMMENTS

Student(s)____Lab Group_____
Lab Topic____

Concept examined: waffle, summary, too short, too long, extraneous info, something other than concept, does not stand alone.

Method: summary, lacks detail, waffle, not a method, describes the wrong thing, contains material of other sections, incomplete.

Results: data not presented, discussion, incomplete, missing, what was achieved?, waffle, method/procedure, complaints, says nothing, merely refers elsewhere, data table put here, little or no link to the concept(s), not described verbally, wrongly stated.

Discussion: results, summary, rehash of results, points missed out, waffle, complaints, missed out altogether, method, little relevance.

Conclusions: not numbered statements, incomplete, missing, not related to the data, what did you get?, waffle, complaints, missed out, not justified by data, summary, wrong, against the data.

Tables: badly drawn, wrong labelling, units omitted, data omitted, one or more not included, values wrong or wrong data, not labelled.

Figures: wrongly drawn, wrongly labelled, info omitted, axes wrong, one or more not included, legend omitted, units wrong or omitted, label omitted, dimensioning problems.

Format: units wrong or not SI, pages wrong way round, report structure wrong, work asked for not done, too long, too short, headings wrong, wrong page order, not printed on one side of page only, not typed or printed, Discussion or Results text in appendices, correct sheets not used, sheets submitted not originals.

Writing: bad spelling, errors not corrected, bad grammar, faulty punctuation, wrong tenses, non-sentences, sentences not flowing, mixed singular and plural, telegraphic, not third person, use of abbreviations, padding, unclear.

Understanding: inadequate, wrong, missed the point, unclear.

Sample calculations: omitted, wrong, incomplete, too extensive, too brief.

Critique: omitted, wrong, incomplete, sketchy, on the wrong topic, improvements not outlined, did not need the lab to show what has been presented.

1.3 REPORT PRESENTATION

Cover sheet: This consists of a declaration sheet that it is the author's own work; sources are fully acknowledged and signed (by all, in the case of group work) prior to submission.

Paper and usage: The report must be on A4 paper or similar size, using one side only, with 2 cm margins.

Text: must be typed or printed in 12 point.

Orientation of sheets: Normally it will be "portrait", however, for some tables and figures, it will have to be turned through 90 degrees (i.e., "landscape"). In the latter case the bottom of the table or figure must lie by the right hand edge of the report when it is laid out open on the desk.

Tables: Must be labelled descriptively across the top (e.g., "**Table XX.** Times for operators to perform each combination of conditions"). Rows and columns must be labelled for the variable represented and (in brackets) the unit of measure. *Note:* the quotation marks indicate the exact type of wording to be used but must not be included in your report.

Figures: Consist of all diagrams, graphs, charts, pictures, photographs, drawings, sketches, etc., and they must be labelled across the bottom (e.g., "**Figure YY.** Mean time of each group for each condition"). Axes of graphs must be labelled for the variable represented with (in brackets, see below) the unit of measure. Where a graph has more than one set of points there must be a legend to identify each set, and it is still called a "figure" and not referred to as a "graph".

Plotting: Individual lines on a graph must be labelled separately or the plotted points differentially identified (e.g., by using circles for one, triangles for another, and so on with a legend to identify each). Use metric (1, 5, 10 mm) paper or a computer package such as Microsoft EXCEL. The independent variable (i.e., what is altered deliberately [e.g., task difficulty]) must be along the horizontal axis and the dependent variable (i.e., what is measured for the results; e.g., time) must be along the vertical axis.

Units and notation: Must always conform to the Systeme Internationale (SI) and no others may appear in the report (e.g., masses must be in kilograms [kg], weights and forces in Newtons [N], lengths in metres [m] and millimetres [mm], velocities in metres per second [m/s], and times in seconds [s] usually but also in centiminutes [cmin], minutes [min] and hours [h] on occasions, but do not mix them such as seconds and minutes for the same quantity).

Binding: Must be such that pages can be read easily without having to dismantle the report. Where larger sheets are used (e.g., A3) bind the left-hand edge and fold in from the right to clear the binding, or staple the top left-hand corner, fold at the centre of the page, and then fold back or clip off the top right-hand corner.

Format: Ensure that the text is justified both sides, leave a blank line between paragraphs, use single spacing for lab reports, and one-and-a-half or double spacing for projects and theses.

1.4 LONG LABORATORY REPORTS

Construct the report as specified below, written in your own words. Mode of presentation and marking requirements are defined separately. As a general guide, see *Ergonomics* or *Human Factors* journals.

1. Introduction (15% of Marks)

It must review previous work in a critical fashion (i.e., main findings, limitations, contradictions of others, etc.) and explain the concept or theme studied in the lab-work, and justify doing it. It is not a preface, description, or a summary. At the start it must describe the problem in general terms especially in an ergonomics context. Then it should lead on to specific documentation that has been published on the concept, compare and contrast findings, methods, etc., and lead in a funnel shape to a particular topic examined. It should finish in a single sentence stating the exact concept or hypothesis or problem examined in the lab work. Do not say "The purpose of this laboratory was ..." and do not describe here what was done. Just state at the end, in general terms and briefly, the issue that was examined. Divide it into appropriate sections and subsections (e.g., 1.1, 1.1.1, etc.). Total length is to be one page or 300 words (5 letters = 1 word).

2. Method (8% of Marks)

Divide this into appropriate sections and subsections (e.g., 2.1, 2.1.1, etc.) about participants, apparatus, stimuli, design of experiment, procedure, and so on. It must give enough detail for somebody else to repeat it exactly elsewhere. But only include those things that are relevant to the method of investigating the question at hand, that is, might have a bearing on the results obtained. Specific lengthy details should be given in tables, quoting the appropriate labels. It must have appropriate subheadings and paragraphs. The length of the narrative part is one page or 300 words.