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Provost's Learning Innovation Grant (PLIG) for 2019

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DEPARTMENT OF PSYCHOLOGY, COLLEGE OF LIBERAL ARTS
ROCHESTER INSTITUTE OF TECHNOLOGY

PROVOST'S LEARNING INNOVATION GRANT (PLIG) FOR 2019

FINAL REPORT

Esa Rantanen, Ph.D., CPE

August 29, 2020

Abstract

This grant allowed for a redesign of the PSYC 714 "Graduate Engineering Psychology" course, offered by the Department of Psychology about every two years since 2013, for online delivery. The grant was awarded on March 29, 2019. Full Project Plan report was submitted on Aug. 16, 2019. The majority of the course redesign work was completed during the fall semester 2019 (2191), including creation of several software programs to support the lab exercises designed for the course. The Preliminary Findings report was submitted on Jan. 10, 2020, and the PSYC 714 course was offered online in the spring semester of 2020 (2195) as a "pilot" of the redesign. The course ran successfully through the semester, and being online, was not impacted by the COVID-19 pandemic that resulted in closing of RIT's campus and moving of all classes online after the extended spring break on March 23, 2020. Other events related to this grant (Preliminary Findings Roundtable and PLIG Showcase) were canceled. The final report deadline was extended from August 21 to August 31, 2020. This document details the course design features and is meant for broad distribution and to serve as a model for other graduate courses that may be moved online at RIT. Moreover, the PSYC 714 course is required for the Advanced Certificate in Engineering Psychology (ENGPSY-ACT) at RIT. This documentation of the development of this course will hopefully allow two other required courses in the ENGPSY-ACT program be redesigned for online delivery. This would effectively make the entire ENGPSY-ACT an online program, as there already are several online graduate courses offered at RIT that may serve as electives in the program.

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1 Engineering Psychology

1.1 A Brief History

Engineering psychology evolved as a distinct discipline during and after World War II. Three forces may be identified behind this [1]. First, practical needs that arose from the accelerating advancement of technology, which was a direct result of the war effort.

Second, technological advancements were particularly pronounced in the aviation domain, where aircraft speed, capabilities, and complexity increased at an unprecedented rate. This resulted in unacceptable accident rates and loss of life before the pilots ever saw combat. It was no longer possible to fit the human to the machine through selection and training, but human capabilities and limitations had to be considered in the *design of the machines*.

Third, linguistic developments were brought about by the combined effort of both engineers and psychologists to address the novel human-machine interface problems. The role of the human operator was acknowledged as that of a system component and human behavior was described in similar terms as the systems they were interacting with. Thus terminology and concepts common in electrical and systems engineering (e.g., channel capacity, feedback, optimal control, etc.) replaced the stimulus-feedback language of behavioral psychology and further facilitated the integration of engineering and psychology for the design and evaluation of human-machine systems.

1.2 Terms and Definitions

To define engineering psychology as a discipline it is important to distinguish it from both psychology and engineering as well as from several other, closely related, disciplines. Although there is a relationship between applied psychology and engineering psychology, there is also an important difference: Where applied psychology seeks to control and influence people, the goal of engineering psychology is the design of a better machine. Although this at the time was a very non-traditional objective from the psychologists' point of view, psychology made substantial contribution to the design of machines: Knowledge of human variability and methods of dealing with it, factors engineers were not used to accounting for. Thus the role of the engineering psychologist in machine design is thus both that of a scientist, seeking knowledge of human behavior, capabilities, and limitations for engineers to use, and that of a technologist, actively participating in the design of human-machine systems [2].

Although engineering psychology shares the practical orientation with applied psychology, the methods employed in research of human-machine systems are primarily those of experimental psychology [3]. To differentiate engineering psychology from applied experimental psychology, then, one must again consider the specific domain of applications of engineering psychology, the human-machine systems. To further underscore the unique nature of engineering psychology, the discipline was accorded a divisional status (Division 21) by the American Psychological Association. The mission for Engineering Psychologists is defined by APA as "to promote research, development, application and evaluation of psychological principles relating human behavior to the characteristics, design and use of environments and systems within which people work and live" (American Psychological Association).

Engineering psychology differs from the closely related discipline of *human factors*, or *human factors engineering*, in two important aspects. On one hand, human factors is a much broader discipline which encompasses such diverse sub-disciplines as anthropometry and biomechanics [4]. The same is true for *ergonomics*, a term commonly used in Europe and essentially synonymous with human factors, as the discipline is referred to in the United States. Engineering psychology, true to its roots in psychology, is concerned predominantly with the information processing aspects of human performance. On the other hand, human factors can be seen as a purely applied discipline, while engineering psychology, albeit motivated by applications in human-machine systems design, is also concerned with more basic research [1]. The ultimate goal of human factors is to improve system design, not to seek understanding of human behavior, whereas "the aim of engineering psychology is not simply to compare two possible designs for a piece of equipment, but to specify the capacities and limitations of the human, from which the choice of the better design should be deducible directly" [5, p. 178].

The cognitive focus of engineering psychology has recently become increasingly pronounced. This reflects the shift of interest towards cognition in psychology in general but also the new demands increasingly complex systems place on the operators. The emphasis on cognition is today the main scientific force driving application efforts [6]. This fact is underlined by the emergence of such disciplines as *cognitive engineering* or *knowledge engineering*. These disciplines, however, are too young to have their own, fully developed, identity and they cannot be adequately distinguished from the more established engineering psychology.

Because the main area of application for engineering psychology is systems design and evaluation, a quantitative approach to the description of human behavior is imperative. These efforts have benefited substantially from the influence of the traditional engineering disciplines [2, 1]. In addition to the methods of experimental psychology, mathematical modeling is an essential tool used by engineering psychologists [7]. Extensive reviews of the various modeling approaches are provided by [8, 9, 10, 11].

2 Background of Course Redesign

2.1 Project Objectives

This project was aimed at developing and delivering an online graduate course, PSYC 714 "Graduate Engineering Psychology", which is part of an Advanced Certificate (AC) program, the Advanced Certificate in Engineering Psychology (ENGPSY-ACT). Thorough documentation of the development of this course is aimed at allowing two other required courses in the ENGPSY-ACT program (PSYC 712 "Graduate Cognition" and PSYC 715 "Graduate Perception") to be redesigned for online delivery as well. This would effectively make the entire ENGPSY ACT an online program, for there already are several online graduate courses offered at RIT that may serve as electives in the program.

2.2 The Problem

The ENGPSY-ACT was approved by Academic Senate on January 25, 2013. Since then, several graduates from the MS in Experimental Psychology (EXPSY-MS) have earned the AC as part of their regular MS curriculum. The ENGPSY-ACT was also designed to benefit students in other graduate programs at RIT, specifically in Industrial Engineering (ISEE-MS) and Human-Computer Interaction (HUMCOMP-MS), but also professionals working in industry who are unable to leave their jobs to enroll in a graduate program but would nevertheless like to burnish their credentials. However, very few people outside the EXPSYC-MS program have had access to it. The primary problem is scheduling. In particular, the three required courses have historically been scheduled in conflict with courses in the other graduate programs at RIT, and at times of the day when industry professionals are unable to come to campus to attend them.

2.3 Significance

Converting the entire ENGPSY-ACT program to online format would substantially improve its accessibility to students from diverse disciplines as well as to people outside RIT. The proposed project would also create a procedure and template for conversion of the other two required courses in the ENGPSY-ACT program, which would allow for the entire program be offered online. A redesign of a course that is part of a larger program will also allow for coordination of the contents of the courses in the program so that they are complementary and form a coherent whole. Finally, the course was redesigned to meet an external standard, that of the Core Competencies of the Board of Certification for Professional Ergonomics.

2.4 Integration with RIT Priorities

Online offering of the PSYC 714 course (as well as the PSYC 712 and 715 courses) is aligned with the RIT strategic goal to develop and execute new flexible course delivery models by offering more online options in graduate programs. A program such as the ENGPSY-ACT will serve as outreach to nontraditional students. This project may also serve as a first step in the process of making the ENGPSY-ACT part of RIT's MicroMasters program.

3 Course Development Plan

3.1 Creativity and Innovation

There are four aspects of the proposed course conversion that make it novel and innovative:

1. The course will maximize the affordances of its delivery medium, that is online using RIT's course management system myCourses. This is first and foremost a theoretical question, and as such it must be re-examined as data on student learning become available each time the course is offered.
2. The course contents reflect my research over past 8 years on the knowledge and skills expectations for new human factors/ergonomics (HF/E) professionals (engineering psychology is a subdiscipline of HF/E) [12, 13, 14, 15, 16, 17, 18].
3. The course contents were designed to meet an external standard, that of the Core Competencies as defined by the Board of Certification for Professional Ergonomics (BCPE). The goal is to develop the courses in the ENGPSY-ACT to meet the criteria for a professional certification by designing the courses according to the published core competencies to help students earn independent certification of their competence upon completing the 5 courses required for the ENGPSY-ACT. This course redesign was the first step towards that goal.
4. The research for and development of the engineering psychology course within the this project was extensively documented. This documentation is designed in such a way that it will serve as a handbook and a template for similar conversion of other courses, first the other two required courses in the ENGPSY-ACT program (PSYC 712 "Graduate Cognition" and PSYC 715 "Graduate Perception"), but conceivably also serving all the faculty at RIT who may wish to convert their courses into online format.

These aspects of the course development are elaborated below.

3.2 Course Topics

The course covers the most fundamental topics of engineering psychology in multiple ways, through mini-lectures, reading assignments, online discussions, and lab exercises. The topics are:

1. Engineering psychology discipline
2. A model of human information processing
3. Cognitive task- and work analysis (CTA, CWA)
4. Signal Detection Theory (SDT) and Fuzzy SDT
5. Information theory
6. Models of attention
7. Spatial cognition, navigation
8. Manual control; discrete control (Fitts' Law) and continuous control
9. Augmented reality
10. Language and communications
11. Memory

12. Skills, Rules, and Knowledge (SRK) framework
13. Situation Awareness (SA)
14. Decision making, normative models
15. Information processing model of decision making
16. Naturalistic Decision Making (NDM)
17. Selection of action
18. Human error
19. Human Reliability Analysis
20. Multitasking and time-sharing
21. Mental Workload

3.3 Maximizing Affordances of Online Delivery

The working hypothesis in the development of this course is that an online course will occupy a place within a space (a tetrahedron) bounded by four primary learning methods at the vertices (see Fig. 1) and that given the affordances and constraints of the online format, an optimal point may be defined for the course. Hypothetically, although an online course will involve some lecturing (videos) and one-on-one mentoring with direct interactions with the instructor (online discussions), learning will be heavily weighted towards self- and group learning. Therefore, the course design should maximize the benefits afforded by these learning methods.

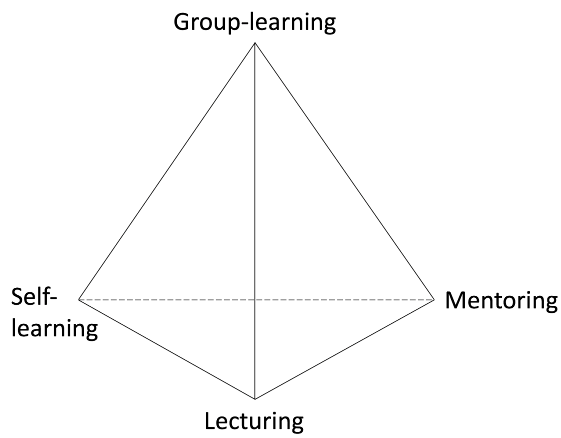

Figure 1. A hypothetical learning space with four main learning methods occupying the vertices of a tetrahedron, representing a learning space. Hypothetically, an optimal point for online learning may be found within this space.

There are two specific affordances of online format that were in the focus of the course redesign. First, because the course involves several lab exercises, it very well meets the definition of active learning. The labs require the students think through the theoretical underpinnings of each topic covered, test their understanding of the theory by selecting and manipulating appropriate independent variables and predicting the effect(s) on relevant dependent variables and measuring them. The labs also require development of the technical skills of experimental design, including control of extraneous variables, and data collection and analysis. Finally, the students will learn to communicate their findings in a clear and persuasive manner in lab reports. The challenge is to coach students to perform the labs and facilitate group learning through effective interactions with their classmates in an online environment. Second, writing skills are inherently important in an online course where most of the communication must happen asynchronously in writing [19]. With at least 7 short writing assignments (technical lab reports) the students will also work on a long paper assignment. which will have the format of a research proposal on a topic of their choice but relevant to the general course theme (engineering psychology) and based on their review of relevant literature [20].

3.4 Design for Periodic Redesign

As the knowledge and skills expectations for new HF/E professionals are constantly changing, tracking the trends in these in the workplace is an ongoing activity. Therefore the course design must accommodate periodic revisions to the knowledge and skills it is meant to impart to students. Such flexibility was a design criterion for this course, afforded by its modular structure.

3.5 External Standard

The course contents were designed to meet the Core Competencies as defined by the BCPE. The mission of the BCPE is to provide ergonomics certification to protect the public, the profession, and its professionals by assuring standards of competency and advocating the value of certification. There are two levels of certification, professional and associate, and three designations reflecting the certificant's primary area of competence. The associate level is seen as an optional, temporary, stepping stone to the professional level, and as such, and appropriate standard and criterion for the ENGPSY-ACT. In other words, the goal was to develop the courses in the ENGPSY-ACT to meet the criteria for a professional certification by designing the courses according to the published core competencies. Not only do such criteria provide external validation for the advanced certificate offered by RIT but also help students earn independent certification of their competence upon completing the 5 courses required for the ENGPSY-ACT.

The current BCPE core competencies are as follows, in three categories:

1. Analyze
    - 1.1. Conduct user research and/or assessment to identify, document, and prioritize requirements for individuals and groups to achieve their goals
    - 1.2. Identify and employ relevant organizational factors impacting individuals and groups interacting within an organization, to produce recommendations to enhance quality of work life, safety, effectiveness and efficiency
    - 1.3. Identify and measure the relevant physical, physiological and biomechanical aspects of individuals and groups performing their activities in their environments, with particular reference to health, safety, comfort and effectiveness and efficiency
    - 1.4. Identify cognitive, behavioral and social characteristics of individuals and groups that impact health, wellbeing, safety, performance, quality of life, attitudes, value belief systems, and motivation
    - 1.5. Identify and apply methods of evaluation of cognitive aspects of human-technology interfaces to reduce human error, optimize mental workload, and enhance health, comfort, safety, effectiveness and efficiency Identify and apply methods of evaluation of physical aspects of human-technology interfaces to reduce human error, optimize physical workload, and enhance health, comfort, safety, effectiveness and efficiency
    - 1.6. Identify and analyze training and educational aspects of human-technology interfaces to enhance health, comfort, safety, effectiveness and efficiency
2. Design
    - 2.1. Apply ergonomic principles and data appropriate to developing and fulfilling a set of requirements to achieve a safe, usable, effective, and efficient human centered design
    - 2.2. Design the hardware product, which includes functions, information displays, interactions, communication modalities etc., within the constraints and capabilities, and context to enable individuals and groups to accomplish a particular set of goals

2.3. Design the software product, which includes functions, information displays, interactions, communication modalities etc., within the constraints and capabilities of the hardware and the context to enable individuals and groups to accomplish a particular set of goals
2.4. Design tasks within human capabilities and limitations, and the workplace context to enable individuals and groups to accomplish a particular set of goals, and manage stress and fatigue
2.5. Design jobs using systematic procedures, principles, and techniques in developing and combining tasks into jobs to make them safe, efficient, effective, and motivating, to better utilize human capabilities, and manage stress and fatigue
2.6. Design the organization within human capabilities and limitations, and the social context to enable to accomplish a particular set of goals, and manage stress and fatigue
2.7. Design the environment, within human capabilities and limitations, and the wider context to enable to accomplish a particular set of goals, and manage human stress and fatigue
2.8. Design training and educational aspects of human-technology interfaces to enhance health, comfort, safety, effectiveness and efficiency

3. Integrate
    3.1. Implement and test products and related systems, for predictive, stable, reliable and effective outcomes
    3.2. Implement and test tasks and jobs and related systems, for predictive, stable, reliable and effective outcomes
    3.3. Implement and test organizations and related systems, for predictive, stable, reliable and effective outcomes
    3.4. Implement and test environments and related systems, for predictive, stable, reliable and effective outcomes
    3.5. Implement and test training and education materials to support effective and efficient individual, group, and organizational adoption of design.

Note that it will be impossible to provide the students *all* of the above competencies in just one semester. Nevertheless, the course design should be explicit on which competencies the student will receive training in, and to what extent. This project is also an experiment to test how well the core competencies, as presently articulated, serve educational purposes.

3.6 Lab Exercises

There are 7 lab exercises in the course, each requiring a formal, written, lab report submitted for grading. The labs allow for important *skills training* in three critical areas:

1. **Design of experiments** is a critical research skill. Ability to identify independent and dependent variables relevant to given theories is also critical to deeper understanding of the theories studied. By designing their own experiments, students are forced to think through the given theories and anticipate results predicted by them. Students are also required to analyze their results by relevant descriptive statistics and plots to visualize their data.
2. **Coding** is another critical skill students need to practice. The labs involve several ready-made experimental programs, written in PsychoPy (an open-source package for running experiments in Python), but students are required to change the code according to their desired experimental designs. This will provide them with practice in reading and understanding code and confidence in making changes to code to meet their needs. Students are also required to use R (a free software environment for statistical computing and graphics) to further practice writing code for statistical analysis.
3. **Writing** formal scientific reports is the third critical skill students need to practice. Students are required to report their lab results in a formal lab report prepared according to the American Psychological Association (APA) Publication Manual, 7th ed., using the LaTeX typesetting program. A LaTeX template for the lab reports is provided.

3.7 Lab Programs

Most of the lab exercises in this course have been programmed in Python, specifically, with PsychoPy (https:// www.psychopy.org), an open-source application for running a wide range of psychology experiments. The purpose of this requirement is twofold: (1) The program should allow running of the lab experiments with minimal coding experience (i.e., just following short, step-by-step, instructions) but also (2) allow students in the course to become familiar with programming experiments with Python and modify the experiment by writing some code on their own. The PsychoPy modules are therefore extensively commented and documented so as to serve a stand-alone introduction to Python programming to novices. The specific labs using PsychoPy programs are:

1. **Visual Search Lab**: The participants visually examine a computer display including a number of items as distracters and a target item, which may or may no be present on the display, and indicate with a keystroke whether they found the target item or not. The experimenter prepares several stimulus screens in advance, each containing some combination of the independent variables and with a unique identifier. The experimenter also determines a specific sequence of presentation of the stimulus screens. The independent variables (i.e., variables that the experimenter manipulates) are (1) type of object/character, (2) size of the character, (3) color of the character, (4) number of characters on screen, (5) spacing of the characters on screen, and (6) time the stimulus screen is displayed. The dependent variables (i.e., variables that will be measured in the experiment) are (1) he keystroke in response to presentation of the stimuli: Yes (target present) or No (target not present) and (2) the elapsed time from onset of the stimulus screen to the response, or response time (RT).

2. **Signal Detection Lab**: The program allows students to experiment with the task of detecting a very small signal in a noisy context, and with most of the factors that affect human signal detection performance. The stimuli are visual, presented on a computer display in a tightly controlled manner. The basic image resembles a woven fabric. There are 5 different "fabric" patterns to choose from, differing in the density of the "weave" and corresponding difficulty of the task. The signal is a broken "thread" in the weave pattern. The primary independent variable to be manipulated is the size of the signal. The location of the signal on the screen may be manipulated from completely random to randomly placed in constant areas or varying size. The probability of signal in a given stimulus screen is manipulated by the experimenter from 0% (a signal is never present) to 100% (a signal is present on every screen). The time the stimulus screen is displayed is varied in 3 ways: (1) For a given time, in seconds and 1/100 s (e.g., for 3.75 s), (2) until response, after which the next stimulus screen is presented, and (3) after a separate keystroke. There is a knowledge-of-results (KoR) function (on or off). This function, when selected "on", shall display "correct" or "incorrect" text on the display after a response depending on the response. The number of trials (number of stimulus screens presented) shall be set by the experimenter. The participant responds with a key stroke if they detect a signal in the stimulus screen or not (a Y/N response). The elapsed time from the onset of the stimulus screen to the response key stroke shall be recorded to 1/100 s. The data recorded from the experiment are saved in a comma separated values (csv) file with the columns: (1) Trial number (a running number from the beginning of the experiment); (2) signal's presence (S = signal, N = no signal, or noise); (3) response (Y/N); (4) response time. This is the raw data file. Additionally, a separate data file shall be saved with summary results, in a table with rows for (1) Hit Rate (HR; the number of hits/total number of signals in the experiment), (2) False Alarm Rate (FAR; the number of false alarms/total number of signals in the experiment); (3) Correct Rejection Rate (CRR; the number of correct rejections/total number of noise, i.e., no signal, screens in the experiment); (4) Miss Rate (MR; number of misses/total number of signals in the experiment).

3. **Manual Control Lab**: This is a very elaborate lab program. The software requirements specifications (SRS) for the program are in Appendix E.

4 Redesigned Features of the Course

4.1 General Course Structure

The syllabus for the redesigned course is in Appendix A. The course has a regular weekly schedule, one major topic for each of the 14 weeks of a semester. Each week has roughly the same structure, following a funnel-like progress from very general to very specific. Each week has a very broad, introductory video lecture for a context for the week's topic as well as a handout highlighting the most important aspects of the week's topic. There are somewhat narrower reading assignments. Further narrowing the topic is an online discussion, where students respond to a specific prompt. Finally, a lab exercise allows students to design their own experiment to examine some aspect of the week's topic in great detail.

4.2 Reading Assignments

Reading assignments for each week include a chapter from the course textbook [21], a handout, and an original, seminal, journal article. The handouts provide relatively concise outlines of the most critical elements of the topics covered in the course as well as additional information that cannot be found in the other readings. A sample handout is in Appendix D.

4.3 Online Discussions

Weekly online discussions require students to respond to the prompts provided. The prompts are in Appendix B. Students are also expected to *discuss* the emerging topics and positions with their classmates beyond the given prompt, pressing for deeper thinking with questions or contradictions, and rising to the challenge to answer the questions or defend or correct their position when challenged. Students are also encouraged to use the weekly discussions to ask questions about their assignments (e.g., labs) and collaboratively solve any problems they may encounter.

4.4 Lab Exercises

The 7 lab exercises form the bulk of the work in the course. An example of detailed instructions for a lab are in Appendix C. Many of the labs involve running a simple experiment using software programs provided. Students are expected to design their own experiment by manipulating the independent variable(s) within the experimental program, written in PsychoPy (an open-source package for running experiments in Python), collecting data on their own performance ($N = 1$), analyzing the data using R (a free software environment for statistical computing and graphics), and presenting their results in a formal lab report. The lab assignments, each with a formal, written, lab report, are as follows:

1. **Task analysis**: Student choose a task they are familiar with and perform a task analysis on it using a particular a task analysis method.
2. **Visual search**: Students perform a visual search task under four experimental conditions to test a mathematical model of visual search time. This lab uses a software package developed specifically for this course.
3. **Signal Detection Theory**: The students empirically investigate the impact of various variables on signal detection performance. They calculate the percent of hits, misses, false alarms, and correct rejections, the sensitivity measure *d'* and the bias measure β, as well as plot results in various forms. This lab uses a software package developed specifically for this course.
4. **Information Theory**: The student will empirically investigate the impact of uncertainty on decision time and demonstrate the Hick-Hyman Law. They calculate the H_s values for each experimental condition and plot them against response time, fit a straight line to the data and calculate the straight line equation (linear regression), and evaluate the regression equation and goodness of fit. This lab uses a software package developed specifically for this course.

5. **Manual control**: The students empirically investigate the impact of various variables on their own performance in both discrete and continuous control. In the discrete control part, the students shall compute the Index of Difficulty (ID) for each of the experimental conditions and plot the average movement time (MT) as a function of ID. They shall also calculate the coefficients a and b in Fitts' law and compute the regression equation for all their data points to evaluate Fitts' law. In the continuous control part, the students will examine the effects of gain, time delay, and their interaction by plotting their results for visualization of the data and easy comparison of the effects of the experimental conditions. They will also examine the effects of control order on their performance in a similar manner. This lab uses a software package developed specifically for this course.

6. **Human Reliability Analysis (HRA)**: Students read a story of a medical error and reanalyze the accident using the data from the narrative on a dedicated software. This analysis software is already in existence and is ready for student use. In addition to the accident analysis, students also critically review of the HRA method and the software tool.

7. **Mental Workload**: Students choose a task that they have done before or are familiar enough with to perform the analysis and modify the task in some way to make the task more demanding (e.g., impose time pressure or stricter performance criteria). Students then perform the task, and immediately after the task assess their workload on the six scales of the NASA-TLX and calculate their total workload. This analysis may be done by "paper-and-pencil" and there are software tools available for it online.

4.5 Term Paper

The course project/term paper assignment spans the entire semester and requires students to write a minimum of 2,000-word essay that integrates the various topics and models in Engineering Psychology covered in this course into a coherent view of human (cognitive) capabilities and limitations to be applied to the design of things. In other words, the purpose of the term paper is to allow the students to form a holistic view of both human capabilities and the engineering psychology discipline.

5 Summary

The design of the course maps the course topics to the course calendar (weekly), the BCPE core competencies, and the lab exercises. Multiple objectives (declarative knowledge, writing, critical thinking and creativity, and research methods, data analysis, and modeling) are practiced in each week of the course on each of the course topics. The course topics are also mapped to the the course itself. The final lab assignment asks students to reflect on their own workload in doing the assigned tasks in the course.

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A Appendix: Syllabus

Department of Psychology, College of Liberal Arts
Rochester Institute of Technology

PSYC 714—Graduate Engineering Psychology

SYLLABUS

Prof. Rantanen, Spring Semester 2021 (2205)

August 29, 2020

This syllabus is subject to change during the semester. Please see myCourses for up-to-date information about course schedule, readings, and assignments.

1 Course Information

1.1 Meeting Time and Place

Online (https://mycourses.rit.edu/)

1.2 Instructor Information

Name: Esa M. Rantanen, Ph.D.
Office: Eastman Hall (EAS)–2353.
Office hours: By myCourses discussion topic "General Course Questions", email, and in exceptional cases via Zoom teleconferencing (scheduled by email).
Email: esa.rantanen@rit.edu, **tel.** (585) 475-4412.

1.3 Course Texts

1. Wickens, C. D., Hollands, J. G., Banbury, S., & Parasuraman, R. (2013). *Engineering Psychology and Human Performance*, 4th Ed. Pearson. ISBN: 978-0-205-01560

2. *Publication Manual of the American Psychological Association*, 6th ed. (2010). Washington, DC: APA. ISBN: 978-1433805615

3. Original articles will be assigned for supplementary readings on most of the topics covered in this class. Please see myCourses website for reading assignments and PDF copies of the papers.

1.4 Course Description

In this course the students will learn to recognize the integrated (systems) nature of Engineering Psychology, the centrality of human beings in systems design, and to use information from the topics covered and the available knowledge base to adapt the environment to people. This course will cover several fundamental models of human information processing in the context of human-system interactions. The models include the Signal Detection Theory, Information Theory, theories of attention, both normative and naturalistic decision-making models, Control Theory, and the Lens Model of Brunswick. Most topics include readings in addition to the course text as well as a lab exercise with a detailed lab report. **Prerequisite:** Instructor approval; no co-requisites.

This course is also *required* for the **Advanced Certificate in Engineering Psychology**. For more information about the advanced certificate, please see
`http://www.rit.edu/cla/psychology/advanced-certificates/engineering-psychology`.

2 Course Mechanics

This course is a pilot for an online version of the Graduate Engineering Psychology course. The course materials will be delivered online and maximize the affordances of its delivery medium (i.e., online using RIT's course management system myCourses). Although an online course appears to offer slightly more flexibility than a traditional course taught in a classroom, we must necessarily follow a strict weekly schedule in this class; a week begins at 0000 on Mondays and ends at 2400 on Sundays. Due dates of all assignments are consistent with this schedule and will appear in myCourses calendar. This class schedule should allow you to plan your work this semester and anticipate activities in this class. This is a demanding class for all its participants, not least for me. Therefore, please, do not be late with your assignments, for there will be new assignments immediately afterwards.

Each week of the course has three elements:

1. Assigned readings and a video mini-lecture on the week's topics;
2. Online discussion in response to the assigned readings, a discussion prompt, and other participants' posts;
3. A lab exercise with a formal report submitted at the completion of the lab.

2.1 Readings

We will cover most of the Wickens et al. (2013) textbook in this course with chapters from it assigned for each week (*Note:* we do not read it strictly in order, however). Additionally, I have prepared brief introductory video lectures for you and somewhat more detailed handouts about the most important aspects of the weekly topics. We will also read several original articles throughout the course. It is very important that you read *all* assigned materials *prior* to the week they are associated with so that you have time to participate in the online discussion and apply what you learn from the readings in your lab exercises.

2.2 Weekly Discussion Schedule

Weekly discussion topics open on Monday mornings (at 0000) and close on Sundays at midnight (at 2400). Discussion prompts will be provided and you are also expected to *discuss* the emerging topics and positions with your classmates. Your contributions to these discussions will be graded individually. I wish to emphasize the importance of *discussion.* You must respond also to your classmates' (or mine, as it may happen) inputs; do not just agree, but press for deeper thinking with questions or contradictions, and if you are being questioned or contradicted, rise to the challenge to answer the questions or defend or correct your position in your own subsequent post.

2.3 Lab Assignments

There will be several lab assignments with detailed written reports to be submitted afterwards. Many of the labs involve running a simple experiment using software programs available at myCourses and running yourself as a subject ($N = 1$). You are expected to design your own experiment by manipulating the intependent variable(s) within the experimental program, written in PsychoPy (an open-source package for running experiments in Python), collecting data on your own performance, analyzing the data using R (a free software environment for statistical computing and graphics), and presenting your results in a formal lab report prepared according to the American Psychological Association (APA) Publication Manual, 7th ed., using the LaTeX typesetting program. Detailed instructions and a LaTeX template for the lab reports are provided in myCourses.

2.4 Course Project

The course project/term paper assignment will span the entire semester and require you to write a minimum 2,000-word essay that integrates the various topics and models in Engineering Psychology covered in this course into a coherent view of human (cognitive) capabilities and limitations to be applied to the design of things. Detailed instructions for the term paper are provided in myCourses.

3 Learning Outcomes

In addition to knowledge of the subject matter (Engineering Psychology), this course has been designed to provide the students with education and practice with several essential tasks and *skills* they would be expected to be able to perform as early career human factors/ergonomics professionals at the level of the Board of Certification in Professional Ergonomics (BCPE) professional certification. For more information about the BCPE and the certification examination, see `http://www.bcpe.org`. Therefore, the students should learn to:

1. Identify and apply methods of evaluation of cognitive aspects of human-technology interfaces to reduce human error, optimize mental workload, and enhance health, comfort, safety, effectiveness, and efficiency;
2. Identify theories and models of human performance applicable to design of hardware and software products and tasks and task environments, including functions, information displays, interactions, communication modalities etc., within the system and human constraints and capabilities and task context to enable individuals and groups to accomplish a particular set of goals;
3. Evaluate and redesign existing products and related systems, for predictive, stable, reliable and effective human and system performance.

Additionally, students should learn to :

4. Critically read and evaluate different materials from different sources and integrate their contents in a systematic and coherent manner in a term paper;
5. Communicate effectively and clearly articulate their understanding of different topics by participating in online discussions;
6. Write clearly and concisely about complex topics in lab reports;
7. Work with different software tools to get their work done in a professional and effective manner, in particular with Python, R, and LaTeX

4 Course Policies

4.1 Academic Accommodations

RIT is committed to providing academic adjustments to students with disabilities. If you would like to request adjustments such as special seating or testing modifications due to a disability, please contact the Disability Services Office. It is located in the Student Alumni Union, Room 1150; the website is `www.rit.edu/dso`. After you receive adjustment approval, it is imperative that you see me during office hours so that we can work out whatever arrangement is necessary.

4.2 Academic Integrity

As an institution of higher learning, RIT expects students to behave honestly and ethically at all times, especially when submitting work for evaluation in conjunction with any course or degree requirement. The Department of Psychology encourages all students to become familiar with the RIT Honor Code and with RIT's Academic Integrity Policy; please review them here:

RIT Honor Code: `https://www.rit.edu/academicaffairs/policiesmanual/p030`
RIT Academic Integrity Policy: `https://www.rit.edu/academicaffairs/policiesmanual/d080`

4.3 Absences

Please review RIT's official policy on attendance (RIT Governance Policy D4.0, Section I.B) `https://www.rit.edu/academicaffairs/policiesmanual/d040`. If a student needs to miss class, there are mutual responsibilities for students and faculty:

1. It is the student's responsibility to notify the faculty member in advance of the planned absence.

2. With advance notice of the planned absence, it is the faculty member's responsibility to ensure that the student can fulfill all class assignments and expectations without penalty or bias.

Given that this is an online course, absences do not have a similar impact as in-class courses. However, although the asynchronous mode of the course affords some flexibility, a week is a very short time and you should not fall behind with your assignments.

5 Expectations and Grading

Because this is an online class, active class participation is expected. Participation in online discussions will be graded weekly both by frequency (i.e., how often do you offer to answer a question or an original insight to the topic at hand, or ask a question) and substance (i.e., how well your questions, answers, and comments reflect your reading and understanding of the assigned materials).

5.1 Weekly Online Discussions

This is where most of the activity in this course will take place. I will provide a discussion prompt and expect you to respond to it. The criteria for weekly discussions are as follows:

1. Contributions are directly relevant to the topic of the week and follow the instructions given

2. The posts make a substantial contribution to the discussion, i.e., introduce a new and original point of view to the topic at hand
3. References are made to weekly readings to demonstrate that you have read and understood them and to relate your posts to them
4. You support your contributions by evidence; that is, make sure you accurately reference all your sources (e.g., include links in your post for online sources) so that others may follow upon them. You should look up other references in addition to the assigned readings. *Note*: Sharing personal experiences is essential to this course, but you should put them in the context by referencing assigned readings of other resources.
5. Discuss the topic, i.e., respond to your classmates' posts by asking questions about them or challenging what they have to say. *Note*: This item also has a timeliness component: You cannot *discuss* the topics with your classmates and have them discuss what you had to say if you get to the discussion too late!

5.2 Lab Reports

Grading criteria for labs exercises and term paper will be included in these assignments.

5.3 Lab Reports

Grading criteria for labs exercises and term paper will be included in these assignments.

5.4 Grading Scheme

The grading scheme for these course components is as follows:

Course Component	Proportion of Course Grade
Online discussions	30%
Lab Reports	40%
Term Paper/Course Project	30%
Total	100%

The letter grade distribution reflects the new refined grading system (i.e., "plus/minus grading" scheme) adopted by RIT this academic year:

Percent Score	Letter Grade	Points toward GPA
93.00–100.0	A	4.00
90.00–92.99	A-	3.67
87.00–89.99	B+	3.33
83.00–86.99	B	3.00
80.00–82.99	B-	2.67
77.00–79.99	C+	2.33
73.00–76.99	C	2.00
70.00–72.99	C-	1.67
60.00–69.99	D	1.00
< 60.00	F	0.00

6 Tentative Course Schedule

The weekly coverage might change as it depends on the progress of the class. Similarly, the assignment and due dates are only approximate and detailed instructions with exact due dates for each assignment will be provided in myCourses. The chapters and page numbers refer to the course text (Wickens, Hollands, Banbury, & Parasuraman, 2013). The reference numbers pertain to supplemental readings. Note that reading assignments will be specified for each week in greater detail in myCourses. Make sure that you check myCourses regularly for current reading and discussion assignments for each week.

Week	Dates	Topics, Readings, Labs
1		Introductions, Engineering Psychology discipline (Ch. 1, pp. 1–6) [1]
2		Cognitive task- and work analysis (CTA, CWA) [2]; Lab#1 assigned
3		Attention and visual search (Ch. 3); Lab#2 assigned
4		Signal Detection Theory (SDT) (Ch. 2, pp. 8–31); Fuzzy SDT [3]; Lab#1 due; Lab#3 assigned
5		Information theory (Ch. 2, pp. 32–47). Lab#2 due; Lab#4 assigned
6		Models of attention (Ch. 4, [4, 5]); Lab#3 due
7		Control (Ch. 5, pp. 145–149); Lab#4 due; Lab#5 assigned
8		Skills, Rules, and Knowledge (SRK) framework [6]
9		Situation Awareness (SA) (ch. 7, pp. 214–220, [7])
10		Decision making (Ch. 8, pp. 245–278, [8]); Lab#5 due
11		Human error (Ch. 9, pp. 284–315; [9])
12		Human Reliability Analysis (ch. 9, pp. 315–320); Lab#6 assigned
13		Multitasking and time-sharing (ch. 10)
14		Mental Workload (Ch. 11, [10]); Lab#6 due; Lab#7 assigned (due at the time of the Final Exam)

7 Supplementary Readings

All supplementary readings will be provided as PDF copies in the myCourses website, under the “Content” tab. Note that the readings list below and in the above course schedule is incomplete. Additional readings will be assigned as necessary to gain the required competence on the course topics. Please refer to myCourses regularly for up-to-date reading assignments and PDF copies of the readings.

References

[1] H. W. Hendrick. Good ergonomics is good economics. In *Proceedings of the Human Factors and Ergonomics Society 40th Annual Meeting*, 1996.

[2] G. Lintern. The foundations and pragmatics of cognitive work analysis: A systematic approach to design of large-scale information systems. http://www. cognitivesystemsdesign.net/home.html, 2009.

[3] R. Parasuraman, A. J. Masalonis, and P. A. Hancock. Fuzzy signal detection theory: Basic postulates and formulas for analyzing human and machine performance. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, 42(4):636–659, 2000.

[4] C. D. Wickens. Multiple resources and performance prediction. *Theoretical issues in ergonomics science*, 3(2):159–177, 2002.

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[6] J. Rasmussen. Skills, rules, and knowledge; signals, signs, and symbols, and other distinctions in human performance models. *IEEE Transactions on Systems, Man and Cybernetics*, (3):257–266, 1983.

[7] M. R. Endsley. Toward a theory of situation awareness in dynamic systems. *Human Factors*, 37:32–64, 1995.

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[9] D. A. Norman. Categorization of action slips. *Psychological review*, 88(1):1–15, 1981.

[10] K. C. Hendy, J. Liao, and P. Milgram. Combining time and intensity effects in assessing operator information-processing load. *Human Factors*, 39(1):30–47, 2007.

B Appendix: Online Discussion Prompts

Week 1

Please refer to Ch. 1 in the course text and the handout and the Hendrick article in the Content area. How would you recommend that practitioners and researchers inside the Engineering Psychology discipline (i.e., the engineering psychologists) relate to professionals in myriad other disciplines? Your practical suggestions should reflect your understanding of disciplinary boundaries in general as well as current trends in them. Although you are just beginning this course and cannot be expected to know much about Engineering Psychology, you may use your current level of knowledge as a frame of reference as you think about this assignment.

Week 2

In psychology, and in particular Engineering Psychology, the point of much research is about "getting inside someone's head". In Engineering Psychology people of interest are often expert operators doing very difficult jobs that engineering psychologists try to make easier by design. Often the only way of "getting inside someone's head" is to ask the person what and how they think and how they do their jobs in an interview. While this topic would warrant a semester-long course all on itself, I think that we can at least gain some appreciation of its power and challenges through a weeklong exercise that I also hope will be interesting and fun to you. Hence, please do the following: (1) Read the Hoffman, Crandall, and Shadbolt (1998) article about Critical Decision Method in the Content area. You may also want to watch YouTube videos of your favorite interviewers to learn from their techniques. (2) Think of someone you would like to interview about some critical incident or an important decision in their past. This person could be someone you are presently living with (e.g., a parent), but you can of course conduct the interview by phone of via email, too (email interviews are good as they automatically produce a transcript for later analysis). Press your interviewees until they reveal something you did not know before and provide enough detail for you to understand how and why they behaved the way they did in the situation you discussed. Take good notes! (3) Share your challenges (e.g., what questions to ask, and how) and any particular techniques you find successful in this discussion topic with your classmates.

Week 3

Please think of a personal experience related to visual search (e.g., when driving, or trying to find an item on a mile-long aisle in a grocery store). Discuss why the search task may have been easy, or hard. If easy, what made it easy? If hard, how would you redesign the task and/or the target to make the task easier? Analyze and discuss also you classmates' examples!

Week 4

Please discuss the utility of the Signal Detection Theory (SDT) in engineering psychology in general by coming up with a specific example of a tasks or tasks that could be examined by the SDT. Be very specific about the task (refer to Week 2 topic on task analysis), how you would collect the data on hits and false alarms, and what the d' and β would tell you about the participants' performance. Remember that you should have discussions with each other, so ask questions and offer constructive criticism on your classmates' examples!

Week 5

Show how the Signal Detection Theory (SDT) and Shannon's Theory of Communication, a.k.a. Information Theory, are related. To tackle this question you would need to do much of your own research beyond the assigned readings and think pretty hard about it. This is a very challenging assignment, so please work on it together in this week's discussion!

Week 6

Please think of a personal experience related to attention and tell it in the context of the models you learned about in this week's readings. For example, you might tell about a time when you were successful at multi-tasking, or doing many things at once, or perhaps when you were not, and when your deficit in attentional resources caused you miss something crucial, or some simple errors that could be labeled attentional slips. Whatever you decide to tell about, please be analytical, and show very clearly how the models you learned about this week could explain your story, or how your story might refute a model.

Week 7

Please think of a personal experience with manual control, either a good one, where you were really "in control" and never made any errors, or a bad one, where control was very hard or where you frequently make errors. Analyze your example experience in terms of control theory, and discuss the factors affecting your (good or poor) performance: Index of difficulty (if your example is about discrete control), system stability, feedback, time delays, control order, and gain. If your your example is a "good bad one", offer design suggestions to help with the control.

Week 8

Please read the handout on dual processes and the Rasmussen (1983) paper on the SRK framework. Give an example of some activity you have been engaged in this week and analyze it in terms of this week's theories. What control mode were you in when performing the task or doing the activity (automatic or controlled, system 1 or 2, or skill-, or rule-, or knowledge-based)? Did your behavior/performance match the theoretical characteristics of the control mode you identified? How? Was the control mode appropriate for the activity/task, or would your performance been better had you been in a different control mode? Or did you perhaps shift between control modes?

Week 9

As before, please read the assigned materials (Endsley, 2015, and my handout) first, before contributing to this topic. After you think you have a reasonable understanding about the construct of situation awareness (SA), please describe two (2) cases from your own experience: One should be a good example of a good SA and how it helped you perform well in your example situation, and another a good bad example about a time when your SA was poor and how it hurt your performance or got you in a trouble in some way. Please be very analytical in your description of these cases and list all the factors that you think either helped you to gain and maintain a good SA or prevented you from having sufficient SA for your task.

Week 10

For this week's discussion, please offer personal examples about decisions you have made. These may be big (such as what college to attend, or what car to buy), or small (what to eat for dinner, or what to wear on any given day), or split-second decisions (maneuvering your car to avoid a fender-bender or how to score in some game), or anything in between or outside these examples. The key to this discussion is to provide much detail about both the circumstances and your own state at the time the decision was made (e.g., under time- or other pressure, being tired or unprepared, &c.) and analyze your example by the Kahneman and Klein (2009) article and my handout. Please offer your help in analysis of your classmates' examples, too!

Week 11

Please describe errors you have made recently, so that all the details are still fresh in your memory. The errors can range from very simple such as forgetting to attend a telecon to more serious ones, perhaps made in a homework assignment or spending good money on a bad purchase. Please analyze your error as deeply as you can (to find a root cause for it). Given the context of your error, how would you go about quantifying your reliability in relevant tasks?

Week 12

Please use my handout, the seminal Weick (1987) paper, and the FRAM website for references, and discuss how you might apply the Safety II thinking in your own everyday "operations" in your everyday lives. If you think presently along the lines of Safety I, describe that, too, but then speculate how you might move to the Safety II direction. This is pretty headache-inducing stuff, so I expect to see many questions and a lively discussion on the topic and your examples!

Week 13

"Multitasking makes you stupid" was the title of the original article in *The Wall Street Journal* on February 27, 2003, and it has been repeated innumerable times since then. What is your experience with multitasking? Make sure you differentiate between multitasking and time-sharing, and identify the factors that make each successful, or not. Please offer your help in analysis of your classmates' examples, too!

Week 14

For this week's discussion, please reflect on the tasks you have been required to perform in this course and answer the following questions: (1) What were the primary drivers of workload in this course? (2) what strategies did you employ to manage your workload and avoid overload situations? and (3) what impact did your workload in this course have in your performance in it?

C Appendix: Sample Lab and Term Paper Instructions

Department of Psychology, College of Liberal Arts
Rochester Institute of Technology

PSYC 714—Graduate Engineering Psychology

LAB#2 INSTRUCTIONS: VISUAL SEARCH

Prof. Rantanen

August 29, 2020

1 Goals

There are several goals for this lab exercise; you should learn to:

1. Understand the utility of mathematical modeling of human performance;
2. Design an experiment to test models against empirical data;
3. Understand computer code (Python) to create experiments;
4. Perform statistical analyses of experimental results using R;
5. Write clear and concise reports on experiments in the APA style [1] and using the LaTeX typesetting program.

2 Resources

1. These instructions (below) and Ch. 3 from the textbook [2]
2. Download and install PsychoPy on your computer from here: `https://www.psychopy.org`
3. From PsychoPy, open the `VisualSearch2.py` file in myCourses and inspect the code. You may change the code according to your experimental design;
4. You may download R from `https://www.r-project.org`. You may also want to download an R editor; for example, the integrated development environment RStudio is available from RIT' managed software center. See my handouts in myCourses for a primer on R. For additional help, see very useful examples (with R code) here:
`http://www.cookbook-r.com/Graphs/Plotting_means_and_error_bars_(ggplot2)/`
5. Download a copy of LaTeX from `https://www.latex-project.org` and a LaTeX editor. RIT's Managed Software Center has MacTex available; you may also consider a nice integrated development environment for LaTeX, called TeXstudio, available here: `https://www.texstudio.org`. For a very good source of a wealth of LaTeX-related advice, see `https://en.wikibooks.org/wiki/LaTeX` (it is searchable).
6. Python (and PsychoPy), R, and LaTeX are free and open-source, with a broad following. Hence, for any questions you may have about these tools, you may simply Google them. You will find hundreds if not thousands tutorials, discussion forums, and documentation. It is also very likely that you will find code for your question online that you may simply copy and paste and lightly edit for your needs.

3 Instructions

1. The *serial* visual search model may be expressed as the following equation:

$$T = \frac{NI}{2} \tag{1}$$

   where $T =$ the search time, $N =$ the number of elements in the search field, $I =$ the average time it takes to inspect one element and decide whether it is the target or not. The right side of the equation is divided by 2 because, on the average, the target is found after half of the elements in the search field have been inspected (i.e., sometimes, by chance, the target is the first element inspected, sometimes the last).

2. To test the model, design an experiment with three independent variables, each with 2 levels (a $2 \times 2 \times 2$ experiment). The independent variables should be

   (a) Type of task, (1) easy or (2) hard. In an easy task the target should be easily distinguishable from the distracters (i.e., it should "pop out" when the search field is inspected) for *parallel* search; in the hard condition the target should be very much like the distracters so that each element needs to be individually inspected to determine if it is a target or not (a *serial* search).

   (b) Presence of target. In half of the trials the target should be (1) present in the search field, in half (2) absent. In the latter and hard condition it will be necessary to inspect all elements in the search field before you may determine that the target was indeed absent.

   (c) The number of distracters, (1) many and (2) few. In the many condition there should be twice as many distracters as in the few condition.

   The dependent variable is search time. Please make *predictions* on how the above manipulations would manifest themselves in the data, *if* the model were correct, or, what would you need to see in your data to falsify the model.

3. Run several trials (I will leave it up to you to determine how many trials you need to run) in each of the 8 conditions the experimental design necessitates. You only need to use yourself as a participant ($N = 1$). Note that you need to create 8 copies of the program code, one for each condition.

4. Analyze your data using R. I recommend a line plot with the number of distracters (few, many) on the x-axis and a line each for the remaining 4 conditions. Visual analysis should suffice for this assignment (i.e., you may draw your conclusions from your data plot).

5. Prepare a formal lab report using the template provided in myCourses –> Content –> Resources. You will need to download a copy of LaTeX from `https://www.latex-project.org` and a LaTeX editor. RIT's Managed Software Center has MacTex available; you may also consider a nice integrated development environment for LaTeX, called TeXstudio, available here: `https://www.texstudio.org`

4 Deadline

The complete lab report is due in a designated dropbox folder in myCourses on [date, time].

References

[1] APA. *Publication Manual of the American Psychological Association*. American Psychological Association, 6th edition, 2010.

[2] C. D. Wickens, J. G. Hollands, S. Banbury, and R. Parasuraman. *Engineering Psychology and Human Performance*. Pearson, 4th edition, 2013.

Term Paper Instructions and Template

Your Name
PSYC.714.01—Graduate Engineering Psychology
Prof. Rantanen, Semester, Year
Rochester Institute of Technology

Abstract

This instructions for term papers is also an example of a paper using the LaTeX apa6.cls document class to typeset manuscripts according to the American Psychological Association (APA) Publication Manual, 6th edition. It takes advantage of the LaTeX typesetting program and is modified from an example by Athanassios Protopapas and William Revelle. The abstract should be max. 100 words and convey four points: (1) why is the problem interesting, (2) what (modeling) approach you chose to address it, (3) what does your model look like, and (4) how it might work? Note: This example abstract is exactly 100 words long.

General Guidelines

A term paper is the required main deliverable for this course, worth 30% of the final course grade. For writing in general, refer to the American Psychological Association (APA) Publication Manual (6th Ed.). This manual not only gives detailed instructions for organizing and formatting your papers, but also serves as an excellent reference for English grammar, punctuation, and spelling of words, as well as for general precision, clarity, smoothness, and economy of expression (APA, 2010). You are expected to make extensive use of this resource in preparation of your papers.

The main requirement for you is to write a logical, argumentative, and *integrative* essay on human performance models that we have learned about in this course. The goal of your essay is to *show* how the different models we have learned about "hang together", or that the different models merely look at the same organism (i.e., the human) from different angles rather than having substantive differences in themselves. In other words, focus on commonalities between the models rather than differences. I hope that you will find this assignment both appropriately challenging and helpful in your learning about Engineering Psychology in this course!

In addition to the above, here are some further specifications for the papers:

Paper Structure

Headings and Subheadings

Make extensive use of headings and subheadings to organize your paper and to make its structure plain to the reader. As you plan your paper, it is a good idea to outline it using the APA heading structure. Thus the outline will provide subheadings for the final paper, and the writing becomes merely "filling in the blanks" between subheadings.

References

Your paper must be extensively referenced. Make use of the textbook and its extensive reference list as well as the papers we have read in the class to find additional material. I expect you "to follow the evidence to wherever it may lead" by looking up research that supports your thesis/model. Pay close attention to the validity and reliability of your references; citations of Wikipedia articles or websites are *not* acceptable. Material accessed online should come from reputable scientific journals.

Paper Length

The paper should be at a minimum 2,000 words long (that is about 4 pages, single-spaced) total. This is very short, so make sure you will do much *thinking* as there is not much writing. Follow the APA Publication Manual and this handout for formatting.

General Writing Guidelines

For general guidelines for writing style, see ch. 3 in the APA Publication Manual (6th ed.). Remember, "Complexity is the first refuge of a scoundrel". Do not be a scoundrel. Do not give any reason for anybody to even suspect that you might be a scoundrel. The first three steps to avoiding such suspicion are:

1. Make sure that all the terms you use are clear and unambiguous, and define all terms that are not, or that may not be familiar to your readers;

2. Show that all your premises are true; and

3. Make sure that your reasoning is all logically valid.

You might also heed Albert Jay Nock's three-point editorial policy in your writing (as I will, in my grading!): "The first one... is that you must have a point. Second, you must make it out. The third one is that you must make it out in eighteen-carat, impeccable, idiomatic English."

Grading

Grading criteria include clearly expressed understanding of the topic and the specifications for this assignment, clear and unambiguous formulation of the thesis, well-reasoned synthesis of the reviewed literature in support of the thesis, overall logic of the argument, and correct grammar and spelling (proofread, proofread, proofread!).

References

APA. (2010). *Publication manual of the american psychological association* (6th ed.). American Psychological Association.

D Appendix: Sample Handout

DEPARTMENT OF PSYCHOLOGY, COLLEGE OF LIBERAL ARTS
ROCHESTER INSTITUTE OF TECHNOLOGY

PSYC 714—GRADUATE ENGINEERING PSYCHOLOGY

HANDOUT: INFORMATION THEORY

PROF. RANTANEN

August 29, 2020

1 Background

Information theory originally referred to the Mathematical Theory of Communication by Claude E. Shannon [1] (April 30, 1916–February 24, 2001). Shannon developed his theory to to find fundamental limits on signal processing operations such as compressing data and on reliably storing and communicating data.

We speak about human cognition as an information processing system. However, that begs the question "what is information?" Shannon's theory defines information as reduction of uncertainty. We can also quantify information by the number of true/false questions required to learn a new fact, or *bits* of information.

For example, imagine it is September in 2000, George W. Bush and Al Gore are running for president, and I somehow can foresee the outcome of the election; what would you need to ask me to also know the outcome? You could ask "Did Al Gore win?" to which I would respond "no" and you would know that Bush won. You asked *one* question and received one *bit* of infomation (it works the same way if you had asked "Did George Bush win?").

Another example: Imagine it is March in 2000, the Republican and Democratic primaries are yet to be held and we have four candidates, Gore and Bradley are vying for nomination for Democratic nomination, and Bush and McCain for Republican candidacy. I still claim to know the final election outcome. Now you need to ask two questions; first, "Will the winner of the election be a Democrat?" (no), and "Did Bush win" (yes). Two questions gave you *two bits* of information.

Note that in the above examples assume that all events are equally likely. If you had asked about the presidential election of 2004, when Barack Obama was leading in the polls throughout, me predicting Obama's victory over McCain would have given you *less* than one bit of information; you might have guessed the outcome yourself. On the other hand, say, in January of 2016 if I had predicted Donald Trump's election over Hillary Clinton, that would have provided you with more that one bit of information because Trump's victory was so unlikely (nobody could believe it even after the election!).

There are several factors affecting the amount of information transmitted:

1. Number of events;
2. Probability of events;
3. Sequential constraints and contex; and
4. Redundancy

2 Some Formulas

We can quantify information conveyed in each case with a set of a few simple formulas, all sharing the same form and base 2 logarithm. If your calculator does not have base 2 logarithm, it is handy to recall some basic properties of logarithms:

$$\log_a b = x \Leftrightarrow a^x = b \tag{1}$$

and

$$\log_a x = \frac{\log_b x}{\log_b a} \tag{2}$$

For example,

$$\log_2 x = \frac{\log_1 0x}{\log_1 0a} = \frac{\ln x}{\ln a} \tag{3}$$

Information conveyed by a stimulus is calculated by the formula

$$H_s = \log_2 N \tag{4}$$

where *N* is the number of *equiprobable* events. Since *rare* event convey *more* information than expected or common events, information conveyed by a stimulus event *i* is calculated by the formula

$$H_s = \log_2 \left(\frac{1}{P_i} \right) \tag{5}$$

The *average* information conveyed by a number of stimuli is calculated thus:

$$H_{ave} = \sum_{i=1}^{n} P_i \left[\log_2 \left(\frac{1}{P_i} \right) \right] \tag{6}$$

In a series of stimuli, for example, ABABABABABAB, $P(A) = P(B) = 0.5$. What is the next letter in the sequence? What is the probability it is an A? How much information does that convey? Not much, for it is fairly obvious that the next letter will be an A, given the regularity of the sequence. Such context can be accounted for in calculation of information conveyed by a stimulus thus:

$$H_s = \log_2 \left(\frac{1}{P_i|X} \right) \tag{7}$$

Changes of stimulus probabilities reduce the amount of information conveyed. This is known as *redundancy*. For example, there are 26 letters in the English alphabet; $\log_2 26 = 4.7$ bits. Can you read this:

"I cxn rxplxe xvexy txirx lextex of x sextexce xitx an x, anx yox stxll xan xanxge xo rxax xt–ix wixh sxme xifxicxltx."

Sure, that was not too hard! In the English language not all letters and letter sequences are equally likely. On average, the English language has about 1.5 bits/letter in the alphabet and therefore

$$\%redundancy = \left[1 - \left(\frac{H_{ave}}{H_{max}} \right) \right] 100 = [1 - (1.5/4.7)]100 = 68\%$$

3 The Channel Concept

The concept of an information transmission *channel* is a very important one. The original idea is Shannon's, but others (e.g., Paul Fitts) have applied it to human information processing by looking at human as an information channel with some limited capacity. Two important measures are the *channel capacity*, which is defined as the amount of information transmitted from a stimulus to a response and measured in unit of bits, and *bandwidth*, which is defined as the speed of information transmission and measures in bits/s.

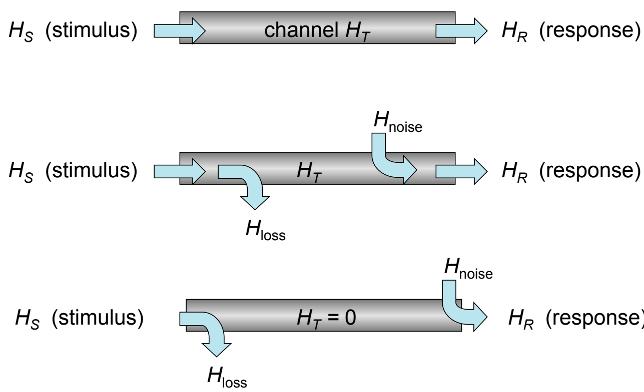

Figure 1. The channel concept in information theory. Information transmission is degraded by both loss of information and entry of noise to the channel..

A particular application of the information theory is in absolute judgment tasks (see pp. 32–34 in our course text) [2]. Consider the following results of human performance in different absolute judgment tasks:

Task	Channel Capacity	Number of Choices
Pitch:	2.5 bits	5.6
Loudness:	1.9 bits	3.7
Points on Line:	3.2 bits	9.5
Brightness:	2.3 bits	5.0

Note the 2.3 to 3.2 bit range over several studies that corresponds to 5 to 9 choices = 7 ± 2 choices. The 7 ± 2 is also knows as a magical number! [3]

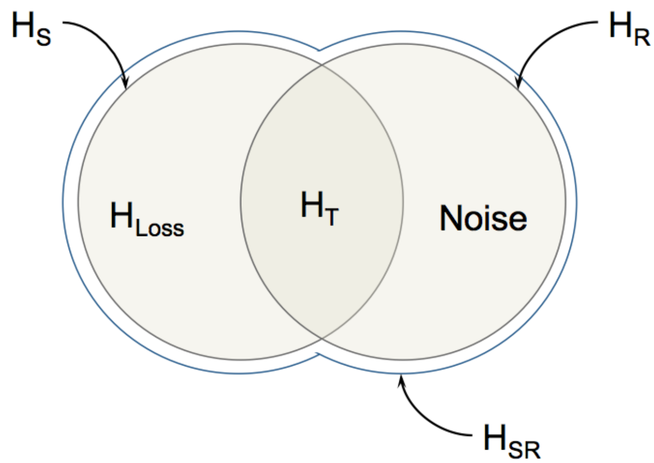

Figure 2. Information transmission in a Venn diagram.

4 Confusion Matrices

A very useful application of the information theory is *confusion matrices*. Consider an example of air traffic control (ATC) communications, or ATC communications vs. pilot responses (communication errors). There is a direct stimulus–response mapping, i.e., stimulus S (ATC communication) should elicit a response R from the pilot, or S1 $\rightarrow$ R1, S2 $\rightarrow$ R2, S3 $\rightarrow$ R3, etc. In Figure 3 ATC communications A, B, C... match pilot responses A, B, C... If there is a mismatch, that is a communication error. To calculate the information transmitted, or the goodness of the channel, follow these steps:

What the pilot responded (r)

What the ATC said (s)	A	B	C	D	E	Σ
A	19				1	20
B		8	2	8	2	20
C	2		15		3	20
D		10		10		20
E	6		2	2	10	20
Σ	27	18	19	20	16	**100**
p_j	0.27	0.18	0.19	0.20	0.16	(P_i = .2)

Figure 3. A confusion matrix of a hypothetical air–ground voice radio communication experiment.

1. Construct a confusion matrix (Fig. 3).
2. Compute H_S :$\mathrm{H}_S = \sum p_i \log_2 \left(\frac{1}{p_i}\right) = 1.0 \log_2 5 = 2.32$ bits

3. Compute H_R :$\mathrm{H}_R = \sum p_j \log_2\left(\frac{1}{p_j}\right) = 0.27\log_2(1/0.27) + 0.18\log_2(1/0.18) + .. + 0.16\log_2(1/0.16) =$ 2.28 bits

4. Compute H_{S+R} :$\mathrm{H}_{S+R} = \sum p_i j \log_2\left(\frac{1}{p_i j}\right) = 0.19\log_2(1/0.19) + 0.01\log_2(1/0.01) + .. + 0.1\log_2(1/0.1) =$ 3.47 bits

5. Compute H_T :$\mathrm{H}_T = H_S + H_R H_{S+R} = 2.32 + 2.283.47 = 1.13$ bits

6. Compute H_N :$\mathrm{H}_N = H_R H_T = 2.281.13 = 1.15$ bits

7. Compute H_L:$\mathrm{H}_L = H_S H_T = 2.321.13 = 1.19$ bits

8. Finally, compute H_T/H_S :$\mathrm{H}_T/H_S = 1.13/2.32 = .49 = 49\%$

References

[1] C. E. Shannon. A mathematical theory of communication. *The Bell System Technical Journal*, 27:379—423, 1948.

[2] C. D. Wickens, J. G. Hollands, R. Parasuraman, and S. Banbury. *Engineering Psychology and Human Performance*. Pearson, 4th edition, 2012.

[3] G. A. Miller. The magical number seven, plus or minus two: some limits on our capacity for processing information. *Psychological Review*, 63(2):81–97, 1956.

E Appendix: Sample Software Requirements Specifications for the Manual Control Lab

DEPARTMENT OF PSYCHOLOGY, COLLEGE OF LIBERAL ARTS
ROCHESTER INSTITUTE OF TECHNOLOGY

SOFTWARE REQUIREMENTS SPECIFICATIONS (SRS)

MANUAL CONTROL LAB

PROF. RANTANEN

Version 0.0, October 14, 2019

1 Purpose of the Program

This program is to serve as a basis for the Manual Control Lab (MCL) in the PSYC 714 "Graduate Engineering Psychology" course and other human factors courses. Towards this end, a number of tasks that will be part of the MCL lab are described, as well as the input and output variables relevant to each task. The MCL program shall be constructed around these tasks so that students can run them as mini-experiments, themselves serving as subjects.

2 Glossary of Terms

3 General Requirements

3.1 Program Platform and Hardware Requirements

The MCL program shall run on PsychoPy and be platform-independent, It shall also be self-contained, that is, not dependent on any libraries etc. specific to the particular computer it is being run on. Ideally, the program should be contained entirely in a folder that can be simply copied to the hard drives of students' own computers.

3.2 Interface for Setting Input Variables and Selecting Output Variables

The interface for setting input variables and selecting output variables shall open in a separate window and contain a list of variables, each with a window in which the desired value can be entered. See below for an example:

```
Target Width (W) _ . _  mm
Amplitude (A) _ . _  mm
Gain _ . _
```

The output options shall appear in the same window, possibly accompanied by "radio buttons" allowing the user select the desired output. The input and output variables will be defined separately for each task below.

3.3 Saving Settings

Once the settings (input and output variables) have been selected, the user shall have the option to save them under user-specified names. For example, on the settings window there could be an option for "save settings as," which would open another window allowing the instructor define a name for the settings (for example, "Part 1A") and place the settings in a menu for the students to choose from.

3.4 Saving Outputs

The output data from each experiment shall be saved in a separate file as comma-separated values (csv) text. These files shall be named by the user; for example, after an experiment a window should open prompting the user to "Save data as" and allowing a filename to be entered. See Appendix for a format example.

3.5 Notation and Other Remarks

The notation used in this specifications document shall be used also in the program code and user interfaces. This includes variable names, units, and mathematical symbols where applicable.
This document describes only a subset of possible tasks. The program should therefore be constructed in a modular fashion allowing for easy modifications in the source code, addition of tasks, and addition of both input and output variables. The code shall also be extensively commented and documented to facilitate future modifications.

4 Requirements for Discrete Control (Fitts' Law) Task

4.1 Task Description

This task demonstrates the Fitts' Law. The subjects move a cursor into a target box using a mouse (see Fig. **??** below). The cursor shall move only along the x-axis.

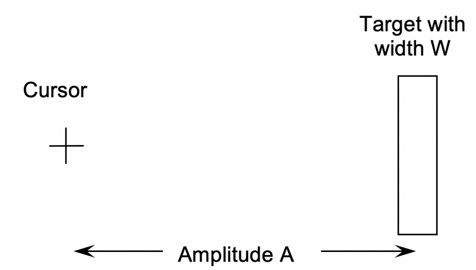

Figure 1. Fitts' task. The participant will move the cursor into the box using a mouse or some other input device (trackpad, trackball, joystick.

4.2 Constants

4.2.1 Cursor

The cursor shall be a cross, vertically centered on the screen, and only move horizontally. The height and width of the cursor shall be 10 mm and the line weight 1.0 points.

4.2.2 Target

The target shall be a rectangle with a constant height of 50 mm and width as specified in the input variables. The target shall be vertically centered and the cursor and the target equidistant from their respective edges of the screen.

4.3 Input Variables

4.3.1 Target Width W

Target width (W) shall determine the width of the target in mm and be determined to the accuracy of 0.1 mm or equivalent in pixels.

4.3.2 Amplitude A

Amplitude (A) shall be the distance from the center of the cursor to the middle edge of the target rectangle. The unit of A is mm and it shall be determined to the accuracy of 0.1 mm or equivalent in pixels.

4.3.3 Gain

Gain shall determine the ratio of the input device movement (i.e., mouse) and the corresponding movement of the cursor on the screen. The default value of gain shall be 1.

4.3.4 Time Delay

Time delay shall be in seconds to the accuracy of 0.1 s, and determine the time elapsed from the movement of the input device to the corresponding movement of the cursor. The default time delay shall be 0.

4.3.5 Control Order

Control order shall allow for selection between position (0-order) control, velocity (1st order) control, and acceleration (2nd order) control.

4.3.6 Target Capture Criterion

Target capture criterion shall be defined in terms of time (in seconds to the accuracy of 0.1 s) and be the time the center of the cursor must stay inside the boundaries of the target for output to be created, as well as by velocity, which shall be 0. The algorithm for target capture shall therefore be

```
IF cursor velocity = 0
AND cursor is inside target
AND cursor has been inside target > target capture criterion time
THEN target capture
Movement Time = Movement Time - target capture criterion time
```

4.3.7 Trial Timeout

Trial timeout shall be defined in seconds to the accuracy of 1 s; it determines the time the program waits for the input device movement and successful target capture before advancing to the next trial.

4.3.8 Number of Trials

The number of trials shall define the number of successful target captures in an experimental block. Between the trials and after each successful target capture the program shall return the cursor to its initial position as determined by the amplitude value.

4.3.9 Stimulus-Response (S-R) Compatibility

This variable shall determine the compatibility of the mouse movement and the cursor movement on the screen and be defined in degrees to the clockwise direction. Two distinct conditions shall be created: $enumerate$

Movement Rotation. For example, 0 rotation means that the cursor movement matches the mouse movement: if the mouse is moved right, the cursor shall move right; 90-degree rotation means that when the mouse is moved right the cursor shall move down on the screen; a 180-degree rotation means that the cursor moves to the opposite direction from the mouse movement.

Screen Rotation. This option simply rotates the screen clockwise by the specified amount.

4.4 Output Variables

4.4.1 Movement Time MT

The only output variable for this task is movement time (MT) and it is defined as the time elapsed from the initiation of input device movement to entry into the target according to the target capture criterion defined in the previous section. MT shall be measured to the accuracy of one millisecond (0.001 s)

5 Requirements for Continuous Control Order Demonstration

5.1 Task Description

This task shall allow the subjects to “play” with different control orders. Three cursors shall appear simultaneously on the computer screen, one exhibiting position control (0-order) characteristics, one velocity control (1st order) characteristics, and one acceleration control (2nd order) characteristics. All three cursors shall move simultaneously in response to the movement of a mouse. The subjects’ task is simply to move the cursor away from the line at the center of the screen and return it back to the center, allowing them to experiment with different control techniques. A schematic of the screen appears below:

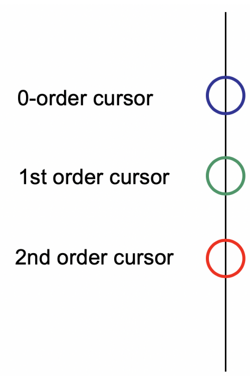

Figure 2. Control order demonstration. All cursors respond simultaneously to control input, but have different order of control; from top to bottom: position control, velocity control, and acceleration control.

5.2 Constants

A thin (0.5 pt) line shall mark the center and starting point for the demonstration. The cursors shall be circles, color-coded according to the control order they represent, 10 mm in diameter. Gain and time delay for the demonstration shall be set by the instructor/administrator.

5.3 Input and Output Variables

Since this task is only a demonstration, no input or output variables will be defined. In addition to the mouse movement to control the cursors, two additional controls are necessary: A left mouse-click shall return the cursors to the reference line, and a specified key (e.g., Esc) shall end the demo and return the program to the main menu.

6 Requirements for Continuous Control: Compensatory Tracking

6.1 Task Description

This task shall allow the students to experiment on a compensatory tracking task with various levels of the input variables. The task is to keep the cursor center inside the target box. In the compensatory tracking task the target shall be fixed in the center of the screen and the cursor move in response to both external disturbances and control inputs. Below is a schematic of the task:

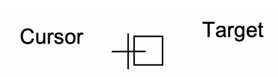

Figure 3. A schematic of a compensatory tracking task.

6.2 Constants

The following elements shall be constant on the display:

6.2.1 Cursor

The cursor shall be a cross, vertically centered on the screen, and only move horizontally. The height and width of the cursor shall be 10 mm and the line weight 1.0 points.

6.2.2 Predictor

The predictor shall be identical to the cursor but of different and lighter color (e.g., gray). The predictor shall be available in the 2nd order condition.

6.3 Input Variables

6.3.1 Control Order

Control order shall allow for selection between position (0-order) control, velocity (1st order) control, and acceleration (2nd order) control, as well as a presence of a 1st order predictor in the 2nd order condition.

6.3.2 Gain

Gain shall determine the ratio of the input device movement (i.e., mouse) and the corresponding movement of the cursor on the screen. The default value of gain shall be 1.

6.3.3 Time Delay

Time delay shall be in seconds to the accuracy of 0.1 s, and determine the time elapsed from the movement of the input device to the corresponding movement of the cursor. The default time delay shall be 0.

6.3.4 Number of Axis

The number of axis shall be 1 or 2, where 1 refers to cursor and target movements only along the x-axis and 2 to target and cursor movements along both x- and y-axis.

6.3.5 Disturbances

Disturbances shall be based on a set of frequencies in each input and bandwidth as selected by the user, according to the following table:

Table 1. *Disturbances based on a set of frequencies in each input and bandwidth as selected by the user.*

	Frequency (Amplitude)		
High Bandwidth (1.0 Hz)	0.30 (50%)	0.70 (30%)	1.00 (10%)
Medium Bandwidth (0.5 Hz)	0.20 (50%)	0.30 (30%)	0.50 (10%)
Low Bandwidth (0.1 Hz)	0.07 (50%)	0.11 (30%)	0.20 (10%)

Amplitude refers to the percentage of the screen width.

6.3.6 Sampling Rate

Sampling rate refers to the frequency the output variables are measured. It shall be defined in Hertz (Hz), or samples per second.

6.3.7 Trial Duration

Trial duration shall be defined in seconds.

6.4 Output Variables

6.4.1 Root Mean Square Error

Tracking error shall be measured from the center of the cursor to the center of the target. Error shall be measured at the rate specified in 4.3.6. The program shall compute the Root Mean Square Error (RMSE) at the end of each trial.

6.4.2 Time History

6.4.3 Bode Plot

6.4.4 Spectral Analysis

7 Requirements for Continuous Control: Pursuit Tracking

7.1 Task Description

This task shall be identical to that in 4, except that the disturbances shall act on the target and the cursor shall move only as controlled by the subject.

7.2 Constants

These shall be the same as in 6.2.

7.3 Input Variables

These shall be the same as in 6.3.

7.4 Output Variables

These shall be the same as in 6.4.

8 Clarifications

9 Functional and Non-Functional Specifications