Table of Contents

Background

OBJECTIVES

iNSIGHT was designed with two main objectives in mind:

- to facilitate students' learning about vision and vision science
- to facilitate students' learning about the process of "doing science"

iNSIGHT is the culmination of many years of research, teaching, and curriculum development on the part of the authors. *iNSIGHT* grew out of a series of laboratory exercises originally developed for teaching vision science to college- and graduate-level students. Since its original publication, *iNSIGHT* has been adopted for use at colleges around the world in psychology, biology, neuroscience, optometry, computer science, and various multi-disciplinary courses. The subject matter, and its form of presentation, has been selected based on this extensive classroom use. As a result, the exercises included in *iNSIGHT* have evolved (and improved) over time.

Objectives

People have a natural interest in visual phenomena. The proliferation and popularity of books and posters on visual illusions and 3D stereograms provides ample evidence of this widespread interest in visual phenomena. *iNSIGHT* capitalizes on this inherent interest, using it to attract students' attention and draw them into the study of vision. Each experiment and demonstration is based on a particular visual phenomenon. By exploring, manipulating, and measuring these phenomena, students learn about many aspects of vision and the human visual system and brain, including anatomy, physiology, and visual psychophysics (i.e., the science of measuring perception). In the process, students discover that perception is something that can be objectively measured, and the results can be subjected to the same type of rigorous analyses as those of the "hard" sciences.

Vision science is especially well suited to a computer/multimedia format of presentation. While many other areas of scientific investigation rely on the computer to teach through simulation, the teaching of vision science uses the computer for the "real thing." The experiments and demonstrations in *iNSIGHT* are *not* simulations. Vision scientists use the computer as their primary tool for conducting research, and *iNSIGHT* uses computer technology in the same way. The experiments in *iNSIGHT* are in most respects identical to experiments done by vision scientists (some are inspired by the authors' own research). The data sets that students obtain are not contrived or "canned," but generated by the students themselves. Acting as both experimenter and subject (subjects are usually referred to as "observers" by vision scientists), students carry out real investigations. By collecting, analyzing, and interpreting data, students learn about science first hand—the outcome of each experiment is not pre-determined.

iNSIGHT Philosophy

iNSIGHT is based on the *constructivist model* of learning—that students actively construct knowledge rather than passively absorbing it. The best way to accomplish this within the context of learning about science is for students to do real science, participating in the same activities and processes as those of real scientists. Students should be involved in exploration and manipulation, in higher-order thinking and problem solving, and in drawing conclusions and making inferences.

The design of *iNSIGHT* is consistent with the objectives outlined above:

- A limited number of topic areas within the general framework of vision science can be explored in detail by means of interactive demonstrations and experiments.
- Experiments are presented in the context of the "scientific method"— background research, formulating hypotheses, experimental design, data collection, data analysis and presentation, and reporting of findings.

- Students generate real data sets which they manipulate to construct an understanding of the underlying principles and processes.

About the Authors

John A. Baro, Ph.D.

Dr. Baro is Director of Software Development at Polyhedron Learning Media, Inc. where he is involved in the design and development of interactive multimedia instructional materials for K–16 math, science, and social studies education. Dr. Baro has also worked as a Senior Instructional Designer/Programmer at the NASA Classroom of the Future, and as a postdoctoral fellow and research associate at the University of Missouri–St. Louis. While at the University of Missouri, in collaboration with Dr. Stephen Lehmkuhle, he developed instructional software for teaching experimental psychology and vision science. He has published several articles and book chapters on vision science and educational technology.

Stephen Lehmkuhle, Ph.D.

Dr. Lehmkuhle is the Chancellor at the University of Minnesota Rochester. He has published over 40 articles and 5 book chapters in vision science. He has also co-authored one book and edited several other books on vision. Dr. Lehmkuhle has taught courses in vision that utilize interactive multimedia technology. These courses include topics in visual perception and binocular vision. He has co-authored several papers together with Dr. Baro on the use of interactive educational software in the classroom.

OVERVIEW

iNSIGHT activity modules can be divided into two general categories:

- **experiments**
- **interactive demonstrations.**

Overview

iNSIGHT activity modules can be divided into two general categories: **experiments** and interactive **demonstrations.** The Student Guide also provides some background information about the scientific process, methods of vision science, and anatomy and physiology of the brain and visual system.

Experiments and Demonstrations

Each **experiment** demonstrates a commonly-used psychophysical procedure (i.e., methods used to measure visual perception) in a subject area of interest to psychologists, physiologists, or vision scientists. These modules illustrate how perceptual and cognitive processes can be objectively measured and quantified. Students generate their own data, which they analyze and interpret; *the results are not simulated.* The data are summarized, graphed, and in some cases, subjected to statistical analysis. The data from some experiments can be combined across a number of students—in these instances appropriate procedures for analysis are suggested, and left to be carried out by students.

Each interactive **demonstration** illustrates a particular visual phenomenon and permits the student to manipulate the effect in various ways to gain a better understanding of these phenomena. Real-time manipulations and immediate feedback encourage “what if” exploration. Data sets are not generated by the demonstrations. However, the exercises in the *Student Guide* outline some suggested manipulations for students to try in order to facilitate assessment.

The following is a list of the experiments and demonstrations, along with a brief description of the content area of each:

About Science	**Background Information—Provides** background information about science and the scientific process. Topics include Hypothesis, Experiment, Data Analysis, Data Presentation, and Research Report.
About Vision	**Background Information—Provides** background information about vision and vision science. Topics include Light and Color, Measuring Vision, The Brain, The Visual System, and Color Vision.
Receptive Field Mapping	**Demonstration—This** is a demonstration of mapping the receptive fields of neurons in the visual system. Students play the role of a vision scientist trying to find the location and best stimulus for getting responses from individual visual cells.
Form and Motion	**Demonstration—The** visual system is well suited to extracting information about the structure and form of objects on the basis of motion. In this demonstration randomly-positioned dots, which contain no apparent structure when stationary, are animated to produce vivid perceptions of three-dimensional structures.
Illusions and Aftereffects	**Demonstration—Illusions** are fun and interesting to view, but more importantly they provide insights into how our visual system works. By discovering ways in which the visual system can be “fooled,” we can learn something about the way we see.
Spatial Vision	**Demonstration—Any** visual image can be mathematically broken down (by a process called Fourier analysis) into a number of basic components. By manipulating these components and then reassembling them, a variety of visual effects can be achieved. This process demonstrates how our visual system analyzes images and how different types of visual problems can affect our perception of shapes and edges.

Stereograms	**Demonstration—Stereograms** create an illusion of depth because slightly different images are presented to each eye. They simulate the real-world situation in which each eye views the world from a slightly different position. Different types of stereograms, including random-element, line, and stereo photographs, are presented.
Color Vision Test	**Demonstration—This** is a simulation of a common clinical test for color vision disorders. Students arrange colored patches then analyze the results to identify color vision deficiencies.
Color Mixing	**Demonstration—This** is a demonstration of additive and subtractive color mixing, or the mixing of colored lights and colored pigments. The proportion of the primary colors in a color mixture can be adjusted to see the result. The position of a given color mixture can be plotted in a 3D color space.
Mach Bands	**Demonstration—Mach** bands are an illusion produced by the communication between neighboring cells in the retina. Because nearby cells can inhibit each others' responses (lateral inhibition), our perception of edges is enhanced. Students create grayscale images that produce Mach band effects.
Scaling Vision	**Experiment—A** magnitude estimation procedure is used to measure students' perception of the magnitude of different types of stimuli. Students make predictions based on conflicting theories and test their results against their predictions. A number of variables known to influence the results of a magnitude estimation procedure can be manipulated.
Measuring Illusions	**Experiment—A** Yes-No procedure combined with the method of limits are used to measure the size of a visual illusion. This provides the student with tools to experimentally determine the features of the stimulus that produce the illusion.
Global Precedence	**Experiment—A** reaction time procedure is used to measure different types of information processing by the visual system. This procedure demonstrates how the speed and sequence of visual processing can be measured, and shows the relative importance of different attributes of visual images (we see the forest before the trees).
Feature Analysis	**Experiment—A** reaction time procedure is used together with a visual search task to measure the speed of cognitive operations (visual and other "thought" processes). Some types of visual information are processed in parallel, while other types require focused attention and are processed serially. This experiment demonstrates the types of visual features that are processed serially and in parallel.
Depth Perception	**Experiment—A** magnitude estimation procedure is used to measure the apparent distance between a reference point and a figure that appears to be either in front of or behind it. The results illustrate the relation between the difference between the two eyes' views and the perception of depth.
Contrast Sensitivity	**Experiment—Method** of adjustment and forced choice procedures are used to measure the contrast sensitivity function. "Common sense" suggests that it is easier to see "big things" than it is to see "small things." This experiment demonstrates that common sense is not always correct.
Signal Detection	**Experiment—A** rating scale procedure is used to demonstrate basic concepts of signal detection theory—response criterion, d-prime, and ROC curves.

Content at a Glance

iNSIGHT activities cover a wide range of subject matter. The following table can be used as a quick reference to the primary content area(s) covered by each exercise.

	Difficulty Level*	Experiment/Demo	Biology	Anatomy/Physiolog	Physics	Science Methods	Art	Math
About Science	1					•		
About Vision	2			•	•	•		
Receptive Field Mapping	4	D	•	•		•		
Form and Motion	1	D	•	•				
Illusions and Aftereffects	2	D	•				•	
Spatial Vision	3	D	•		•		•	
Stereograms	2	D	•	•				
Color Vision Test	1	D	•	•				
Color Mixing	1	D		•	•		•	•
Mach Bands	3	D	•	•			•	
Scaling Vision	4	E	•		•	•		•
Measuring Illusions	1	E		•		•		•
Global Precedence	2	E		•		•		•
Feature Analysis	3	E		•		•		•
Depth Perception	2	E	•	•		•		•
Contrast Sensitivity	3	E	•	•		•		•
Signal Detection	4	E		•		•		•

*** Difficulty Level**

1 Easy

2 Moderate

3 Advanced

4 Very Advanced

Using iNSIGHT Exercises

iNSIGHT EXERCISES

iNSIGHT was designed to be used in two ways (although you can probably think of others):

- To support structured exercises, such as those provided in the *Student Guide* or designed by the instructor.
- To support independent exploration and student-designed experiments, such as science fair projects.

The exercises included in the *Student Guide* provide a structured approach to using *iNSIGHT.* Exercises pose questions or present theories and then provide guidelines for answering the questions or testing the theories. Instructions indicate how various parameters should be set, but the experiments and demonstrations are open ended to encourage student exploration. In the course of completing the exercises students learn about the scientific process, experimental design, hypothesis testing, data collection and analysis, and the presentation of scientific findings, as well as about the content area of the exercise.

iNSIGHT was also designed to provide the flexibility to support additional investigations proposed by both the teacher and students. Experiments and demonstrations provide extensive background information, references, and numerous options and parameter settings, which permits the investigation of a variety of experimental questions. While the exercises are meant to provide a solid, structured introduction to science, and vision science in particular, it is hoped that they will serve as starting points for student research projects. Besides answering existing questions, students should become aware that good scientific research generates new questions.

Experiments and Hypotheses

Because one of the objectives of *iNSIGHT* is to teach about the process of "doing science," the implementation of the exercises built around experiments deserves special attention. These exercises were designed to give students exposure to and experience with all aspects of the scientific process, including doing background research, forming hypotheses, experimental design, data collection, data analysis, data presentation, and the preparation of written and/or oral research reports. Of these, probably the most important aspect of the scientific process, and the cornerstone of modern science, is hypothesis testing. Well-designed experiments, and good research in general, grow from the hypothesis.

It is therefore important to stress the significance of the hypothesis in the research process. After reading the various background materials and before beginning each experiment, students should be encouraged to formulate a hypothesis, and they should be provided guidance in exactly what makes a good hypothesis.

The following are some suggestions to guide students in the formulation and evaluation of hypotheses:

- The hypothesis should clearly and succinctly state the question(s) that the experiment is designed to address and at least one predicted outcome.
- The question should be phrased in terms of the underlying process that is being measured, and the prediction should be phrased in terms of the experimental procedure used to measure that process. This distinction is important because in measuring perception we can only use indirect measurement techniques and must infer from their outcome what is "really" going on in the brain.
- The question must be asked in such a way that the answer can be inferred from the measurement technique that is used in the experiment.

Teachers—Try This

Try the **Global Precedence** experiment as an example—read the **Background** information, formulate an hypothesis, collect data, and examine the results. After reviewing the **Background** information, students should understand in general that the brain processes different types of visual information at different rates. In particular, they should know that the brain processes information about big things (overall shape and form—the global properties of an image) faster than information about small things (fine details—the local properties of an image). Students should also understand that the reaction time procedure is a method used by vision scientists to (indirectly) measure the speed at which the brain processes information. The hypothesis should therefore include a statement of the problem in terms of the known differences in the brain's processing speed and the expected outcome in terms

of reaction times. For example, "It is known that the brain processes information about the global properties of a stimulus before it processes information about the local properties of a stimulus. Therefore, reaction times, which reflect processing speed in the brain, should be shorter when observers respond to the large, composite letters than when they respond to the small, component letters."

Working in Groups

The experiments in *iNSIGHT* have been designed so that students may complete them individually, in small groups, or as a class. However, as is true with respect to the collection of virtually any type of data, the more you have the better (statistically speaking, that is). One possibility is to have students work in groups of three or four. Work could then be divided up among the members of each group. For example, one member might be responsible for becoming familiar with the background information, one for becoming familiar with the procedure and program operation, one for the data analysis, and one for the presentation of the data. All members of the groups would act as observers, and they might work together in formulating the hypothesis and preparing (and participating in) a group oral presentation.

Combining Data (Advanced)

If data from several observers are combined, *raw data should not be used* to generate the descriptive statistics (e.g., means). This will control for variability within individual observer's responses and for large differences between observers. To generate group statistics, use the means provided by the experimental modules for each condition in the experiment (or calculate new means if conditions are combined) to calculate group means for each condition. For example, if there were two experimental conditions, A and B, and 10 observers, you would use the means for each of the observers to calculate group means for conditions A and B. In other words, you would end up with Mean A and Mean B, each of which is the mean of 10 values. It is also recommended that the standard errors be calculated for the group. *You cannot take an average of standard errors.* Students can calculate this statistic themselves (it is relatively straight- forward, and the formula is provided in **About Science: Data Analysis)**, or this statistic can be calculated for them.

Student Evaluation

In addition to providing structure for student investigations, the exercises provide a means of monitoring and assessing student performance. Activities built on demonstrations guide the student through a series of manipulations, each of which is followed by questions or instructions that require a written response by the student. For activities built on experiments students can use the questions included in the exercises in one of three ways:

- The questions can be answered individually as they would be in a demonstration exercise.

- The questions can be used as a guide or outline for the preparation of a written research report. Guidelines for preparing a written research report are included in **About Science: Research Report.**
- The questions can be used as a guide or outline for the preparation of an oral presentation. Guidelines for preparing an oral presentation are included in **About Science: Research Report.**