Demonstrations of Thresholds, Weber's Law, and Stimulus Discriminability

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Courses in sensation and perception, cognition, experimental psychology, and introductory psychology may include the topic of psychophysical methods, or at least its central issues. For example, the notion of a threshold is important in many areas of perceptual investigation (Laming, 1986) and even in some areas outside perception (Baird & Noma, 1978; Grossberg & Grant, 1978; Wegener, 1982). Likewise, the ability to discriminate between stimuli is fundamental to perception (Posner & Mitchell, 1967; Proctor, 1981; Robinson, Brown, & Hayes, 1964). However, students may have difficulty appreciating the relevance of psychophysical issues without some concrete examples. In addition to grabbing attention, examples may help to make the underlying theories easier to understand and serve to introduce the necessary mathematics in such a way that math-phobic students are more comfortable. The subsequent demonstrations engage students' interest and encourage students to seek answers to questions concerning the absolute threshold, the difference threshold, and stimulus discriminability. Although the main point of the demonstrations is to emphasize the conceptual nature of these topics rather than their methodologies, it is certainly possible to include methodological discussions. The demonstrations require no special equipment, little preparation time, and are useful in courses at all levels.

Demonstration 1: Absolute Thresholds

Introduction. Define the absolute threshold and explain its theoretical basis. The demonstration provides a simple and concrete illustration of one type of absolute threshold. Subsequent discussion explores underlying mechanisms for the threshold and considers other types of thresholds.

Preparation. None. The demonstration should require about 5-10 minutes.

Presentation. Students pair up; one acts as experimenter and the other as observer. The experimenter locates a single isolated hair on the back of the observer's hand or finger (or forearm if the observer's arms are not too hairy). The experimenter uses a pen or pencil point to move the lone hair until the observer detects the stimulation. The observer looks away during testing so that no visual input accompanies the tactile sensation. The experimenter deflects the tip of the hair a fraction of a mm and then asks the observer to report the presence or absence of a tactile sensation. The experimenter continues to move the hair to a greater extent on each successive trial (judged visually) until a sensation occurs. After detection, the experimenter and observer switch roles and repeat the procedure. Students may repeat the demonstration several times to see whether the threshold changes from trial to trial, or while both students watch the hair movement to see whether the threshold changes with visual input.

Discussion. One explanation for the tactile sensation is that the amount of hair follicle deflection at threshold causes enough skin deformation to activate receptors, signaling the presence of a stimulus. A smaller amount of hair deflection does not activate receptors and is thus undetectable. When visual input accompanies the tactile input, thresholds may decrease (detection requires less hair movement), and instructors can discuss the role of expectations (top-down processing) on perception. This simple demonstration intrigues students, and they often ask questions that lead to several variations of the method of presentation described. For example, students may wish to examine effects of location by taking measurements on the upper arm, lower arm, hand, and finger. Students may wish to examine the effects of attention by varying the location of the test site and either informing observers where they will test or not.

The primary focus of the demonstration is to provide students with a simple concrete example of the concept of a threshold, not the methodological issues surrounding threshold measurements. However, one obvious limitation of the demonstration is a lack of precision in quantifying the force necessary to elicit a threshold sensation. The discussion may be extended by explicit mention of this limitation, pointing out the need for precision and reliability in measurement to examine how an individual's threshold may vary from trial to trial and to compare results across subjects.

Demonstration 2: Discrimination Thresholds and Weber's Law

Introduction. Discuss the difference threshold and its relationship to stimulus intensity (Weber's Law). After the demonstration, review how Weber's Law relates to the difference threshold at various stimulus intensities.

Preparation. Prepare the classroom so it is as dark as possible. Hide a small flashlight from students' view by placing it behind a textbook. The demonstration should require about 5-10 minutes.

Presentation. Turn off the classroom lights to create a "low-intensity" standard stimulus. There is light in the room even with the room lights off because light leaks in from around the edges of the doors and windows. Then turn the flashlight on and off. Students will easily detect the small amount of light reflected off the back of the book. Turn the classroom lights on to create a "high-intensity" standard stimulus and again turn the flashlight on and off. With the classroom lights on, students will not detect the small amount of light reflected off the back of the book.

Discussion. With a low-intensity standard stimulus (classroom lights off), students can discriminate between the small amount of light in the room and the amount of light in the room when adding the flashlight. In terms of Weber's Law, the light intensity in the room when the lights are off is analogous to a low intensity standard stimulus (I). The light intensity added by the flashlight exceeds the increase necessary to detect a change, the difference threshold (ΔI), but for purposes of discussion it can be equated with the difference threshold. Thus, the total light in the room with the flashlight on is analogous to the intensity of the comparison stimulus at threshold ($I + \Delta I$). Pick simple "round" numbers to represent these values and calculate the Weber fraction ($\Delta I/I = k$). For example, if $I = 10$ units and $\Delta I = 1$ unit, then $\Delta I/I = .1$.

When the intensity of the standard stimulus is increased by turning on the room lights, the previous difference threshold is no longer sufficient for discrimination. With the room lights on, a new, higher difference threshold is necessary for detecting an increase in intensity. Show students that the Weber fraction you previously calculated for the low intensity standard stimulus (.1) can be used to estimate the difference threshold for the high intensity standard stimulus. For example, if the value of the high intensity standard stimulus is 1000 units, the new difference threshold would be .1 × 1000 units, or 100 units (100 flashlights). As in Demonstration 1, mention could be made of precise laboratory control over stimulus intensities when applying Weber's Law.

Demonstration 3: Above-Threshold Stimulus Discriminability and Amount of Information

Introduction. Discuss information theory, discriminability, and the effect of the number of potential stimuli (set size) on identification. Information theory (Shannon & Weaver, 1949; Wiener, 1961) regards information as a reduction of uncertainty about the world. Each time uncertainty is reduced by one-half, one bit of information is acquired (# bits = $\log_2 N$, where N is set size). Observers are treated as information transmission channels and the maximum number of bits of information that observers can transmit is called their channel capacity.

Preparation. Create two sets of one-dimensional stimuli and one set of two-dimensional stimuli in the following manner. For the first set of one-dimensional stimuli, cut out eight rectangles of white paper differing only in length. Start with a 5 cm by 10 cm rectangle, and increase the length of each of the next seven rectangles stepwise by 1 cm. Label the rectangles "A" through "H" in order of ascending size using *faint* letters on one side. Make a second one-dimensional set of eight rectangles, except increasing in length by steps of 2 cm. For the two-dimensional set of stimuli, make eight differently-sized rectangles that also vary in color by progressively shading them from white to dark red in seven equal steps (label the white sides of each rectangle). The demonstration should require about 10-15 minutes.

Presentation. Hide the rectangles from students' view. Using the first set of eight smaller white rectangles, present D and E simultaneously (labeled side toward you) and tell students the rectangles have the names "D" and "E" respectively. Then randomly present one of them at a time and ask students to name them as quickly and accurately as possible (students are processing 1 bit of information). Simply tell students to note how quickly they feel they can respond. Now add the C and F rectangles and repeat the above procedure using only four of the eight rectangles (2 bits of information). Ask students whether they believe their response times have increased now that there are four possible stimuli. Finally, add the A, B, G, and H rectangles, repeating the above procedure with all eight rectangles (3 bits of information). By now, response times should be noticeably slower. Obviously, it is impossible to measure accurately differences in response times in a classroom demonstration such as this one. Nonetheless, students should get an "intuitive feel" for how response times increase with increased information processing. Repeat the entire demonstration using the set of eight larger white rectangles and again using the set of eight shaded rectangles.

Discussion. Response times are faster when using more discriminable stimuli. However, for all three sets of stimuli, students respond more slowly and make more errors as the number of rectangles increases because they will be processing more information. In this example, the Hick-Hyman Law (Hick, 1952; Hyman, 1953) predicts that response times will increase as a linear function of the amount of information (the number of rectangles). Students learn about information transmission and channel capacity, the effect of discriminability on channel capacity, and the notion that channel capacity increases when using multidimensional stimuli, as demonstrated by the shaded rectangles.

Conclusions

The demonstrations are quite vivid, generally well received, and students attend closely to explanations following each demonstration. There are minimal constraints for using the first two demonstrations: They work well in small rooms or large lecture halls. The demonstrations motivate students to ask questions about psychophysical principles, often leading to discussions of further psychophysical phenomena and theories. Students appreciate the opportunity to experience threshold and discriminability effects directly instead of reading about them and to actively participate in measurement and observation. Students also enjoy contributing ideas and suggestions for other ways of investigating psychophysical issues.

The demonstrations have several practical advantages. The stimuli are easy to construct and the materials are cheap and readily available. Preparation time involves only the short time needed for stimulus construction. Presentation and discussion times for each demonstration vary depending on class size and the amount of discussion following each demonstration.

Students observed the demonstrations during a 1-hr class meeting of an upper division Sensation & Perception course. Following the demonstrations, 17 students responded to three questions about the effectiveness of the demonstrations using a 10-point rating scale (with 10 as the highest score). The mean ratings were calculated for the questions: “How interesting were these demonstrations?” (*M* = 7.6, *SD* = 1.46), “How useful were these demonstrations for learning each topic?” (*M* = 8.2, *SD* = 1.48), and “Should these demonstrations be used in future classes?” (*M* = 9.0, *SD* = 1.05). Clearly, students found the demonstrations worthwhile for learning concepts related to psychophysics. Of particular interest are the fairly high ratings on the last two questions, which strongly suggest these demonstrations are useful for providing concrete examples of abstract concepts.

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