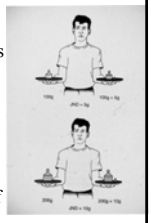
Roots of Experimental Psychology: Psychophysics and Memory

Psychophysics: First Empirical Investigations of the Mind

- Challenge for psychology as an empirical science:
  - How to study mental phenomena empirically
  - How to bring them into the laboratory
- Psychophysics: Focus on the relationship between sensory stimuli and perceptual experience
  - Quantify the relationship between the intensity of the stimulus and its perceived intensity

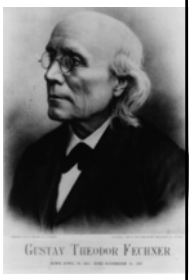
Ernst Heinrich Weber (1795-1878) anatomist, then physiologist at Leipzig

- How sensitive are we to differences in weights
  - Whether we are lifting them or have them placed on our skin?
  - How to quantify the relationship?
- Introduced *just noticeable differences* (jnd-- ΔI) as the unit of measure
  - Discovered that jnd's were a constant ratio of the weight
    - $\Delta I/I = K$
  - K differed with the activity: could distinguish differences of 1/40 in lifting, but only 1/30 when passive
  - Could differentiate closer distances on front of fingers (approx. 1 mm) than on back (40-60 mm.)



Gustav Fechner (1801-1887) physicist, then philosopher at Leipzig

- Rediscovered, then formalized and developed Weber's law
  - Rephrased as $d\gamma = \kappa d\beta/\beta$
- Showed that it implied a relationship between stimulus intensity and the intensity of a sensation captured by logarithms: $\gamma = \kappa \log(\beta/b)$
- Also discovered a very intriguing visual illusion in which we see colors where there are none: http://dogfeathers.com/java/fechner2.html



Limits to Application of Weber's Law

- "There are . . . limits to its validity . . . Yet even where this law ceases to be valid or absolute, the principle of psychic measurement continues to hold, inasmuch as any other relation between constant increments of sensation and variable increments of stimulus, even though it is arrived at empirically and expressed by an empirical formula, may serve equally well as the fundamental basis for psychic measurement, and indeed must serve as such in those parts of the stimulus scale where Weber's law loses its validity. In fact such a law, as well as Weber's law, will furnish a differential formula from which may be derived an integral formula containing an expression for the measurement of sensation."

Implications for Psychophysical Measurement

- Even if Weber's law turns out to be wrong, the idea of precise measurement and discovering regularities is solid
- What is the status of the resulting principles?
- Comparison with Kepler and laws of optics
  - Initially ignore the deviations so as to find the basic generalities
  - Then take into account the deviations
- Distinguish outer and inner psychophysics
  - Outer: relation of stimulus to sensation
  - Inner: mediation by physiological processes
    - The generality will (in all likelihood) apply precisely to the relation of stimulus to physiological process

Turning to Mental Phenomena: Hermann Ebbinghaus (1850-1909)

- Inspired by Fechner to discover quantitative order in higher mental processes
  - Learning and memory
- "In the realm of mental phenomena, experiment and measurement have hitherto been chiefly limited in application to sense perception and to the time relations of mental processes. By means of the following investigations we have tried to go a step farther into the workings of the mind and to submit to an experimental and quantitative treatment the manifestations of memory. The term, memory, is to be taken here in its broadest sense, including Learning, Retention, Association and Reproduction."

Relearning

- "A poem is learned by heart and then not again repeated. We will suppose that after a half year it has been forgotten: no effort of recollection is able to call it back again into consciousness. At best only isolated fragments return. Suppose that the poem is again learned by heart. It then becomes evident that, although to all appearances totally forgotten, it still in a certain sense exists and in a way to be effective. The second learning requires noticeably less time or a noticeably smaller number of repetitions than the first. It also requires less time or repetitions than would now be necessary to learn a similar poem of the same length. In this difference in time and number of repetitions we have evidently obtained a certain measure for that inner energy which a half year after the first learning still dwells in that orderly complex of ideas which make up the poem. After a shorter time we should expect to find the difference greater; after a longer time we should expect to find it less. If the first committing to memory is a very careful and long continued one, the difference will be greater than if it is desultory and soon abandoned."

Learning Nonsense Syllables

- Out of the simple consonants of the alphabet and our eleven vowels and diphthongs all possible syllables of a certain sort were constructed, a vowel sound being placed between two consonants.
- These syllables, about 2,300 in number, were mixed together and then drawn out by chance and used to construct series of different lengths, several of which each time formed the material for a test.
- The aim of the tests carried on with these syllable series was, by means of repeated audible perusal of the separate series, to so impress them that immediately afterward they could voluntarily be reproduced. This aim was considered attained when, the initial syllable being given, a series could be recited at the first attempt, without hesitation, at a certain rate, and with the consciousness of being correct.

Savings in Relearning

- Repeated lists on successive days, recording number of repetitions until the list was recalled perfectly

Number of syllables in one series	Number of repetitions which, on the average, were necessary for the bare learning of the series on successive days					
	I	II	III	IV	V	VI
12	16.5	11.	7.5	5.	3.	2.5
24	44.	22.5	12.5	7.5	4.5	3.5
36	65.	23.	11.	7.5	4.5	3.5
1 stanza D. J.	7.75	3.75	1.75	0.5	(0).	(0).

- More improvement on longer lists

Number of syllables in one series	Number of repetitions for learning	Saving in repetitions in relearning after 24 hours	Saving in % of requirement for first learning
12	16.5	5.5	33.3
24	44	21.5	48.9
36	55	32	58.2

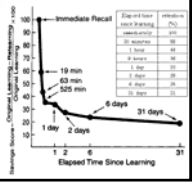
- A result "to be expected" since more effort required for first learning the longer lists

Logarithmic Relation

- Focus on the rate of decline of repetitions needed for relearning

No.	Number of syllables in one series	Number of repetitions saved on learning a series on the following day; average values				
		I-II	II-III	III-IV	IV-V	V-VI
1	12	5.5	3.5	2.5	2	0.5
2	24	21.5	10.0	5.0	3	1.0
3	36	32.0	12.0	3.5	3	1.0
4	1 stanza D. J.	4.0	2.0	1.25	0.5	...

- "If series of nonsense syllables or verses of a poem are on several successive days each time learned by heart to the point of the first possible reproduction, the successive differences in the repetitions necessary for this form approximately a decreasing geometrical progression."



The Spacing Effect

- Compare the number of repetitions on a given day to achieve a set reduction one day later with the number of repetitions spread over several days. For 12 syllables
  - 68 repetitions on one day
  - 38 repetitions if spread across three days
- "It makes the assumption probable that *with any considerable number of repetitions* a suitable distribution of them over a space of time is decidedly more advantageous than the massing of them at a single time."
- Application: "The school-boy doesn't force himself to learn his vocabularies and rules altogether at night, but knows that be must impress them again in the morning. A teacher distributes his class lesson not indifferently over the period at his disposal, but reserves in advance a part of it for one or more reviews."

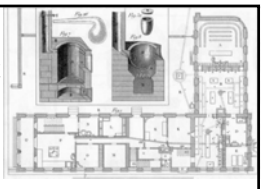
In Defense of the Artificiality of the Procedure

"The guiding point of view in the selection of material and in determining the rules for its employment was, as is evident, the attempt to simplify as far as possible, and to keep as constant as possible, the conditions under which the activity to be observed, that of memory, came into play. Naturally the better one succeeds in this attempt the more does he withdraw from the complicated and changing conditions under which this activity takes place in ordinary life and under which it is of importance to us. But that is no objection to the method. The freely falling body and the frictionless machine, etc., with which physics deals, are also only abstractions when compared with the actual happenings in nature which are of import to us. We can almost nowhere get a direct knowledge of the complicated and the real, but must get at them in roundabout ways by successive combinations of experiences, each of which is obtained in artificial, experimental cases, rarely or never furnished in this form by nature."

Frans Cornelius Donders (1818-1889), measuring the time of mental activity

- Assume that a mental activity takes a certain amount of time to perform
- Use this to gain evidence about the particular mental activities required to perform a task
- Take two activities, one of which requires an additional mental operation
  - Subtract the time to perform the simpler task from the time required to perform the longer task
    - ***Subtractive method***

Laboratory Science: A Relatively Recent Development



- Justus von Liebig—chemistry laboratory at Giessen
  - Organic, pharmacological, and agricultural chemistry
  - 20 investigators

Wilhelm Wundt (1832-1920) Professor of Philosophy, Leipzig

- Had been a research assistant for Hermann Helmholtz
  - Unconscious inference in perception

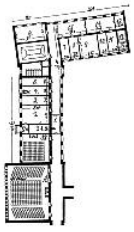
- *Beiträge zur Theorie der Sinneswahrnehmung* (1862)
  - Book on perception, but offered a plan for psychology
    - Based on experiment , observation of behavior, and self observation
    - Included Völkerpsychologie—the study of linguistic, moral ,and religious differences between ethnic groups

Wundt's Laboratory

From left to right: M. Dittrich, W. Wirth, W. Wundt, O. Klemm, and F. Sander

Psychology in the Laboratory

- Wundt established his laboratory in 1879 and expanded over 20 years to occupy whole floor
- Published its own journal, *Philosophische Studien* (mostly of students and affiliates)
- Trained 186 Ph.D.s, many of them international
  - James McKeen Cattell—word associations
  - G. Stanley Hall
  - Edward Titchner—introspection of mental elements



- On example, a project in psycholinguistics: proposed that mental representation constructed prior to speech and that the grammatical structure of an utterance served to emphasize on or another part of the representation

Reliance on introspection

- Wundt is often mischaracterized as relying principally on introspection
  - This is due largely to his American student Edward Titchner who developed a program at Cornell known as *structuralism*
  - Involves reporting on the contents of your own mental states
    - Develop a table of mental elements
    - Account for other mental states as molecules built of these elements by association
    - Requires training in introspection
  - A major target of criticism of functionalists as well as early behaviorists