Brunswik's Copy of Shannon's 1949 Book

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ABSTRACT

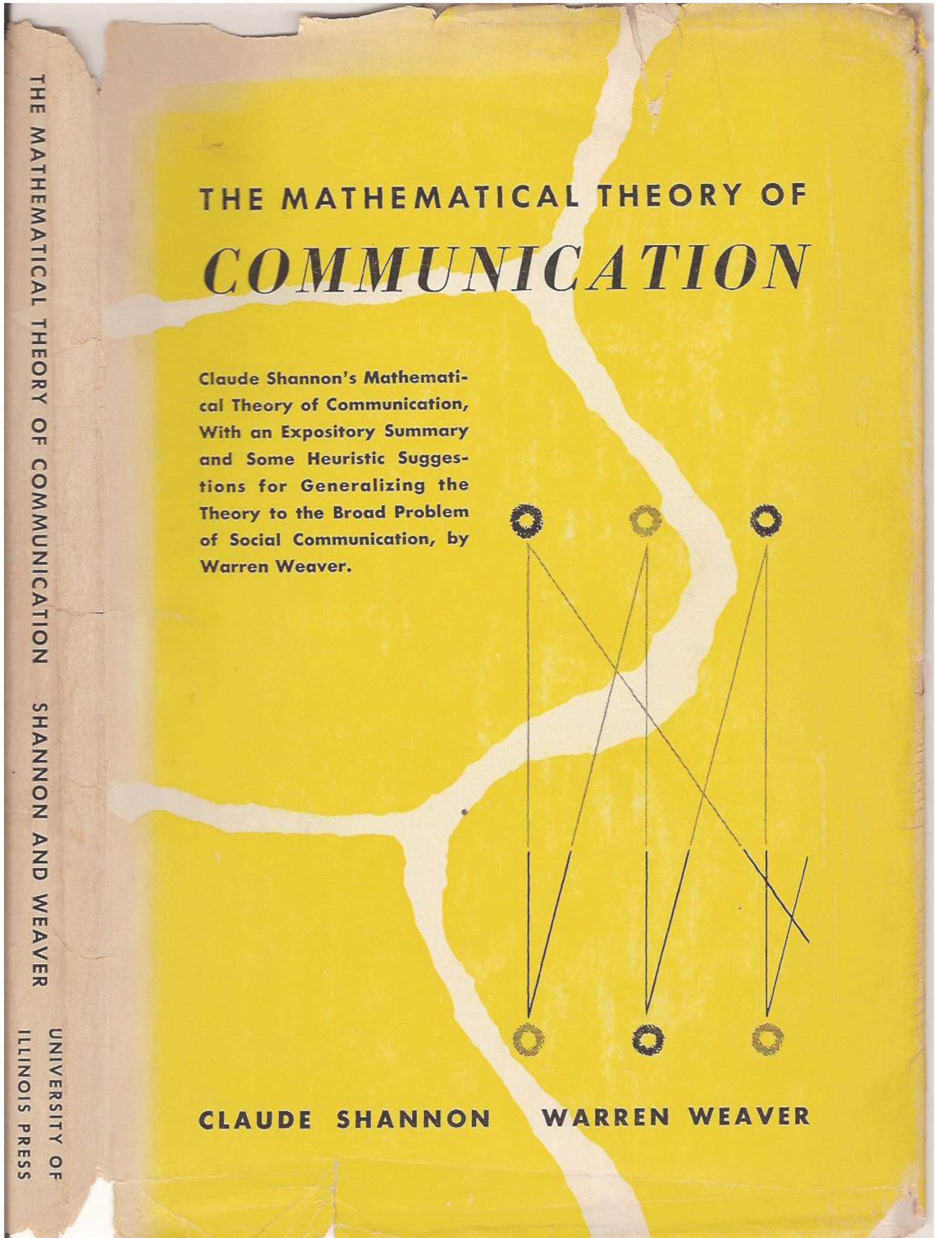
Brunswik read Shannon's Mathematical Theory of Communication (1949) intensively, and his copy of the book has recently been obtained. His notes and underlinings reveal much about his attitudes toward information theory and to cognitive issues. In addition, notes on other books included as loose slips reveal his concerns with unified science, with the place of measurement and statistics within science, and with extensions of his theory.

Shannon’s 1949 book:

Seminal text of information theory

Used by Brunswik in *Conceptual Framework of Psychology* (1952):

“Shannon’s diagram showing the fanning out of ‘reasonable causes’ (messages, inputs) for a given ‘high probability received signal” or effect, and of ‘reasonable effects’ (signals, outputs) from a given ‘high probability message’ (or cause) ‘in a channel,’ bears formal resemblance to the present writer’s diagram showing the univocal and equivocal types of ‘coupling between intra- and extraorganismic regions’ which can also be read into our diagram of the lens model.” (p. 91)



E. Brunswik

(97) openl. ←
(103) freedom of choice, shuffledness entropy
mech

U.Sc (39) (38) (95 to End: ll) (84) (90)
(47) (17 "length" ←)
(117) canonically conjugated variables in quantum theory ←

Pers.

(38) (101) log & natural measures
(98) sound pressure
(102) stochastic – ergodic
related not fnally but statist. ←

Conditional probty (25)
Dependent " (101) [Miller & Frick, Ps Rev Jan 1949]

U.Sc Print:
Quots. from 41, 111 f, 116 f

Ulc Print:
Quots. from 41, 111 f, 116 f

the input is known and conversely. Among these quantities we have the relations

$$H(x,y) = H(x) + H_x(y) = H(y) + H_y(x).$$

All of these entropies can be measured on a per-second or a per-symbol basis.

12. Equivocation and Channel Capacity

If the channel is noisy it is not in general possible to reconstruct the original message or the transmitted signal with *certainty* by any operation on the received signal E. There are, however, ways of transmitting the information which are optimal in combating noise. This is the problem which we now consider.

Suppose there are two possible symbols 0 and 1, and we are transmitting at a rate of 1000 symbols per second with probabilities $p_0 = p_1 = \frac{1}{2}$. Thus our source is producing information at the rate of 1000 bits per second. During transmission the noise introduces errors so that, on the average, 1 in 100 is received incorrectly (a 0 as 1, or 1 as 0). What is the rate of transmission of information? Certainly less than 1000 bits per

Shannon, p. 35

The situation is summarized in Fig. 10 where the input sequences are points on the left and output sequences points on the right. The upper fan of cross lines represents the range of possible causes for a typical output. The lower fan represents the range of possible results from a typical input. In both cases the "small probability" sets are ignored.

Now suppose we have another source S, producing information at rate R with $R < C$. In the period T this source will have 2^{TR} high probability messages. We wish to associate these with a selection of the

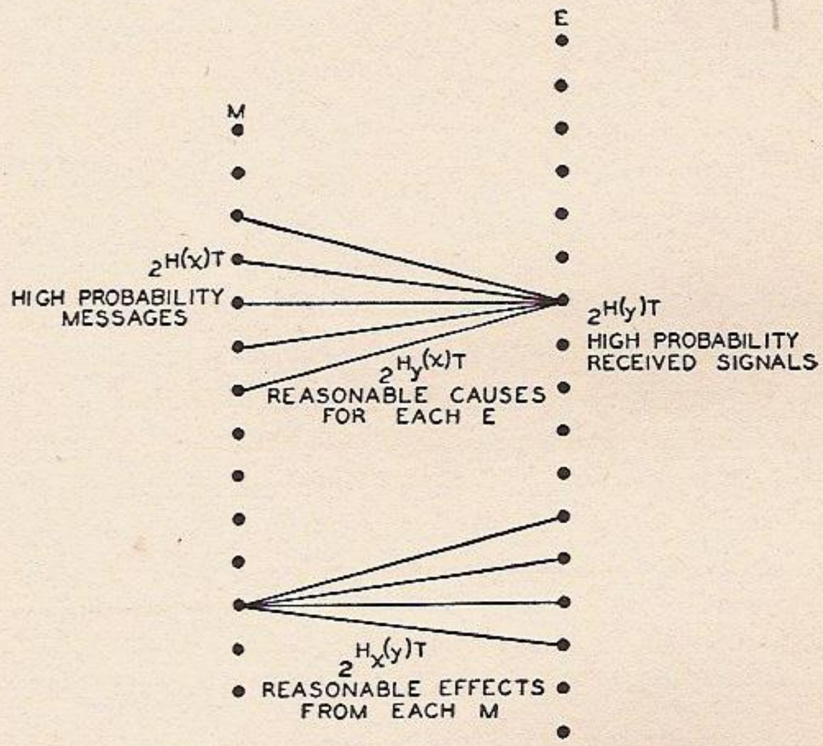


Fig. 10—Schematic representation of the relations between inputs and outputs in a channel.

possible channel inputs in such a way as to get a small frequency of errors. We will set up this association in all possible ways (using, how-

We may add that vicariousness of psychological cues and means may be viewed as a special case of receiving or sending messages through redundant, repetitive channels, thus reducing the probability of errors, that is, the set of possible causes, or effects, that could result in, or be produced by, the type of event in question. Vicarious functioning is thus indeed of the essence of behavior.

Relevant to our above discussion of an "objective language" in science and its close relationship to statistical reliability and validity (secs. 4 and 7) is the following quotation from Weaver:[102] "Language must be designed (or developed) with a view to the totality of things that man may wish to say; but not being able to accomplish everything, it too should do as well as possible as often as possible. That is to say, it too should deal with its task statistically."

In the manner described, communication theory may well contribute to the efforts, stressed in the present paper, to determine the structural and functional properties of the unit of behavior in abstract terms. Such determination will in turn contribute toward an explicit recognition not only of the rules and restrictions but also of the licenses and liberties of the objective as well as of the molar approach. It will further contribute to the much-needed establishment of psychology as a discipline of distinctive, well-circumscribed internal coherence and formal unity of purpose within the more broadly unitary framework of science at large.

Conceptual Foundations (1952), p. 92

Perhaps more interesting: Inserted notes on

WORKS READ BY BRUNSWIK

Alfred J. Lotka (1925), *Elements of Physical Biology*

George Kingsley Zipf (1949), *Human Behavior and the Principle of Least Effort*

D'Arcy W. Thompson, (1942), *On Growth and Form* (2nd edn, 2 vols.)

W.M. Smart (1938), *Stellar Dynamics*

And others, briefly noted:

Ernst Mach (1902), *Science of Mechanics* (as quoted by Thompson),

Boltzmann

Clausius

(428) Velocity of light in vacuo
299,774 km/sec
186,271 miles/sec

Stellar Dynamics

[seems all nomothetic; no predicts from phot.]

W. M. Smart 1938
Glasgow

London: Cambridge (N.Y.) Univ. Press

(vii) from Kapteyn's discovery of star-streaming in 1904 → import in theory & astron. obs.

Eddington, Schwarzschild: two-drift theory → altern. hypoth. of stellar motions

Jeans & A. Eddington

(3f) Stellar magnitudes:
(a) Visual (photometer) < apparent / (real) absolute
bright. comp. with standard star such as Polaris, or with artific. light
(b) photographic
bright. → larger, or, if plate is placed outside the focus of the objective → greater density
(c) photovisual
(d) photoelectr.
(e) bolometric (total radiation temperatures)

deduce from obs. certain frequency functions associated with various characteristics of the stars.

(21) "perfect gas"-state

(267) the mean proper motion $\mu(m)$ of stars of given apparent magnitude $= \frac{F}{3} e^{-\lambda m}$
Kapteyn's formula for the mean parallax of stars of given apparent magn. & proper motion (orig. derived empirically)

(5) Stellar parallaxes: Bessel 1838 first posit. determ. of the distce of a star (61 Cygni), soon others for α Centauri & Vega. As earth moves around sun, direction of a near star viewed against backgd of the very faint & presumably very distant stars alters by a minute amount: f (distance & radius a of earth's orbit) angle of parallax / p, def. by $\sin p = \frac{a}{d}$ (for nearest star 0."76); trigonometrical parallax
angular displacement max.

(8) proper motions: Halley vs. Hipparchus, 1718 indiv. changes in positions
Since: every star in motion
seconds of arc per annum
"both 50 years" intervals (or longer)

---

(189) (7) Parallax det. of single star: large amt. of work (trigon.) [2 obs. wichtig]
(Recently trigonom → spectrosc. (but dependent on former representative parallaxes))

~~188~~ In trigon. method the parallax of the star under investig. is relative to the mean parallax of the comparison stars used in the reductions (10th or 11th magn., presum. at greater distces from us)
For absol. parall.: must know mean parallax of the comparis. stars "and this can only be ascert. by stat. methods based on proper motions of representative stars of these magn.)
easy to measure, photogr., as faint as 15th & 16th magn.

(215) Distrib. adjusted: by omitting several of larger proper motions ... correct great majority of total proper motions for accid. errors and leave uncorrected a few of the larger ones; together with residual numbers between theor. & obs. distrib of the adjusted stars; prob. error

(221) the space "density" of the stars derived from their proper motions
empir. density laws, one of several sugg. laws of stellar distrib

(199) Factor of exaggeration
Frequ. function (415) (329) (277)

Mean ... (32) haphazard (29) (34f) (204) (220) (267)

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exact sc.: numerical
Ego as coord refce frame:)
(373) Simplest expr. in terms of a refce frame fixedly attached to the more solid features of the external world, and a second to the camera
(appce upon the ground glass screen)
L Holt, Freudian wish
relative permanence leads interest;
aim of sc. sci search for invariants of nature:
[F.W. Brown, Sc. Monthly 1921, p. 408
(374) Boundaries self & ext. world cannot be clearly drawn: partic. receptors & effectors largely "shared" by a number of persons

Part IV: Dynamics
Ch. XXIV Energy transformers of nature
(325) fund. characteristics: cyclic working; outputs & efficiency
'finite cycle, returning periodically to initial state
(329) living organism & energy accumulator
(337 ff) transformers & energy source: functional rel (in math. sense) betw. (actual mechanical union trf.-source) motion of transformer & topography of source (eg. trolley car)
purely random collisions of trf.-source more probable: ≠ fund rel, only correl.
aimed
all transformers vulnerable: being coord with injurious features
Accuracy & versatility of aim characteristic of each species; dynam. of evol. est.-tist. dynam of a set of energy transformers. Here: meth. of thermodyn. inadequ., da

The correlating apparatus
"it austere virtue of impartiality tow diff. mechanisms becomes a vice when inform. is sought reg. systems in which mechanism plays a leading role"
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[Petzoldt, Maxima u. Minima u. Ökonomie
(358) Stat. Mechanics of Systems of Organisms
[Index: prob.

[other children] Utility
Ch. The correlating apparatus
Ch. XXIX Consciousness — 390 as bound up with life processes & structures
XXX Function of a — Instincts (McDougall, Freud)
(404) purposive adjustment within the biologics
Unstable equilibria

Elements of Physical Biology — Alfred J. Lotka 1925
Preface: 1902 student in Lpz; Johns Hopkins at invit. of Dep. of Biometry & Vital Statistics
Thompson
Baltimore: Williams & Wilkins (XXX & 460).
QH308-L75
Biol. Lib
returned

[Zipf (551): This transformation of energy, carbon Chaps 24-28 Lotka (✓)
also: [Thompson D.W., On Growth & Form, Macmillan 1943 QP84-T5 Chaps 1-6
Ego as refce frame Lotka 372-374 (✓)
(552) Consciousness Chaps 29-32 Lotka (refces to earlier lit) (✓)
danger of dichot. self-envir., 374 f Lotka
Food chains & cycles 136 f, 176-184 Lotka

Abb: Perc:
(394) ... (91) (102 ff)
(121)
(319) [2 centres] field of force with 2 poles
(371) (397) ... (444 ff) ... boundary state
(297) Extension of polarity customary in dynamics; "radial polarity", one or sev. centers of polarity (several) in single cell
(212) (216) ... 1892
(357) In all cases where the principle of maximum & minimum comes into play as it conspicuously does in films at rest under surface-tension, the conf. so produced are characterized by obvious & remarkable symmetry.
On phyl. epoch. to find ... & structural regularity:
[Mach Science of Mechanics, 1902, p. 395: "In every symm. system every deformation that tends to destroy the symmetry is complemented by an equal & opposite deformation that tends to restore it....
see also his Ueb. d. physiol. Bedeutung der Symmetrie, Lotos 21, 1871, 139-147
rarely absent in living things, except a few cases of Amoeba where rest & equilib. is lacking.
... max or min. of work corresp. to the form of equilibrium ...
Regularity is ...
Crystal: symm. in external form, regul. in internal lattices
Princ. of least action but setting of a still more universal law: passing from less to more probable configs.
(Clausius' sec. law of thermodynamics)
(378) Boltzmann: equilibrium and probability nearly allied: state most likely to occur is most likely to endure
(377) steady state or pseudo-equilibrium
(481) symmetry, curvature
centre of symmetry tetrahedral / hexagonal
bee's cell
polar furrows
Embryo-stages, wings
(748 ff) Spirals
Arist.-Hero
(769) continued similarity
(924?) future line
Leaf-arrangement or phyllotaxis
(995) bending moments
stress-diagram
continuous girder
"Comp. Anatomy of bridges"
(1035) isotropy
Comp. of related forms: leaf (1040 ff)
enfeeblement of jaws

Abb (cont'd)
(414 f) Plant vs. Rowan (Lagena) pottery
(478) (484) [complex tissue forms]
(486 ff)
(524) Color pattern of kidney beans (with diagrammatic contour lines)
(563 f) shrinkage (cube, cylinder) and shark vertebrae
(635) asym. growth
(663) salt-crystals [horiz.-vertical]
(696) snow
(885) [Kraftlinien]
(935) birds eggs
(947) sea urchins
(961) bird-digit
(967) [Brücke] (991 ff)
face (Dürer) (1076)
(1092) Zebra
(1082)
(1053)

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od chains & cycles 136 f Lotka

176-184

Perc:

ABB: [Sym circle; spheres]

frontispiece: splash of milk (Walters) angle 394

Height weight growth curves 91 102 ff

Nature variability Engl. 127

319 [2 centres] field of forces with 2 poles

379 ev.

397 Gelatin drops [endogen]

adsorption 444 ff surface phenomena, boundary state

rate of walking

sine-curve

pulsations of growth ~172

212 ~216 "dimorphism": bimodal curves of tail-forceps in earwigs

Bateson & Brindley 1892

discontinuous variation;

297 Extension of "polarity" customary in dynamics: "radial" polarity

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Also in Index

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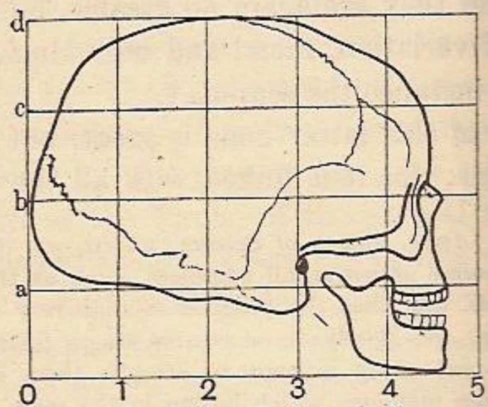


Fig. 548. Human skull.

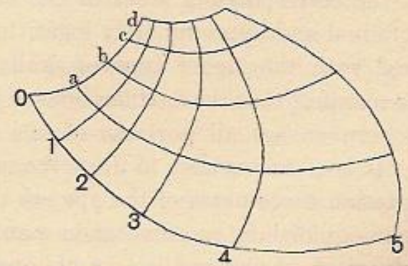
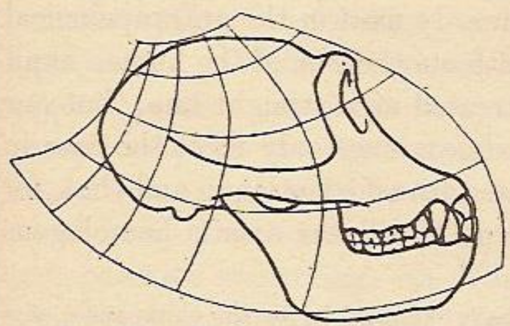


Fig. 549. Coordinates of chimpanzee's skull, as a projection of the Cartesian coordinates of Fig. 548.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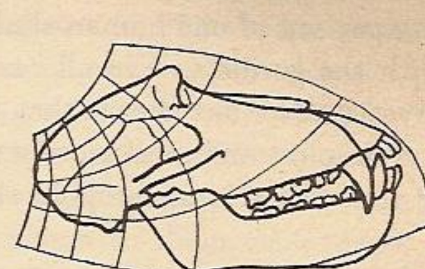
Fig. 551. Skull of baboon.

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Receptors, Elaborators, Adjustors Drive, Effectors

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Utility

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Some Common Themes:

Relation of Organism & Environment

Possible use of physical energy concepts

Use of probability in thermodynamics:

Microstatistical vs. *Macrostatistical*

Methodological:

Unity of Science

Probabilistic & Statistical Analysis

These themes converge in Shannon's book:

Information, *H*, is an entropy measure

Correlation of Environment & Organism (as Channel, as Receiver, etc.)

Macrostatistical approach

Importance of *Redundancy; "Nature takes payment by requiring just that much uncertainty ..."* (p. 39) [limiting information to channel capacity, *C*]

Conclusions:

Brunswik searching for broader synthesis

Can see why both 1952 and 1956 books end with account of Shannon

Can see relation of

Vicarious Functioning to *Redundancy*

Lens Model to *Communication Theory*

Probabilistic Functionalism to *Unified Sciences*