Report No. 67/1985, Zentrum für
interdisziplinaire Forschung,
Universitat Bielefeld

August 1985

BRUNSWIK AND GIBSON: SIMILARITIES AND CONTRASTS WITH IMPLICATIONS FOR CONTEMPORARY PSYCHOLOGY

Dominic W. Massaro

Program in Experimental Psychology
University of California, Santa Cruz
Santa Cruz, CA 95064 U.S.A.

and

Zentrum fur Interdisziplinare Forshung der
Universitat Bielefeld
Wellenberg 1
D-4800 Bielefeld 1
West Germany

No. 67

send correspondence to:
Dominic W. Massaro
Program in Experimental Psychology
University of California, Santa Cruz
Santa Cruz, CA 95064 U.S.A.

Abstract

We have inherited two ecological perspectives on perceptual science from Egon Brunswik and James J. Gibson. The general metatheoretical approaches of these two theorists are contrasted along three dimensions of scientific inquiry. These dimensions are 1) the nature of environmental influences on behavior, 2) the nature of the processing involved in perception, and 3) the appropriate scientific method for the study of behavior. Although the two scientists had considerably different perspectives on the first two dimensions, they arrived at similar opinions concerning the third dimension. Limitations of ecologically-valid designs and traditional psychophysical experiments are discussed and an alternative is offered to complement traditional inquiry. The alternative approach utilizes factorial designs, functional measurement, and the testing of mathematical models of information integration. Historical inquiry appears valuable in that assessing the tenets of the Brunswikian and Gibsonian frameworks offers an informative perspective of psychological science.

This essay should be read as a discussion of history in the service of contemporary psychological inquiry. My reluctance to be taken seriously as a historian is fueled by what seems to me as the historian's perogative to maintain a confirmation bias and present for discussion only those aspects consistent with the theme of the message. Given prolific theorists like Brunswik and Gibson, we confront the possibility that the two important men might be presented as similar or as different as necessary to support some interpretation. We also have the development and changes over the span of their careers. One might make the case that early Brunswik was more Gibsonian than early Gibson, but that late Brunswik diverged significantly from a biological perspective. Given these reservations, I want to focus on only the most obvious differences and similarities of the two frameworks articulated by Gibson and Brunswik, and to address their implications for contemporary research and theory. I will consider what I believe to be three important dimensions of comparison and evaluation of the two frameworks. These dimensions are 1) the nature of environmental influences on behavior, 2) the nature of the processing involved in perception, and 3) the appropriate scientific method of study of behavior.

<u>Nature of Environmental Determinants</u>

Although Gibson and Brunswik have many similarities, their views of the visual information in the environment are considerably different. This difference also provided for very different views of the organism's interaction with the environment. The most productive contrasts evolve around the conceptualization of the environmental influences on the perceiving and acting organism. Table 1 gives a list of the various properties that appear to be important in contrasting the two views. With respect to environmental causation, Brunswik described the environmental properties as cues and Gibson as invariants. This difference in terms captures the important differences of the two views of the environment. Brunswik (1952) did not break with the tradition since Berkeley that the visual world is impoverished whereas Gibson (1950) did. Gibson (1950) coined the term invariants to replace the term cues and the necessary processing that the latter entail. Gibson's framework of ecological optics stresses the available optical information for perception. The different terms are meaningful since one trusts invariant information but not necessarily cues.

The meaning of cues/invariants was conceptualized in terms of goal achievement for Brunswik and affordance for Gibson. Brunswik was a student of Buhler (1934), who believed that meaning achievement in communication was indirect. Language contained only signs (things standing for something else). (Hormann, 1979). Extending this logic to the process of perception, Brunswik (1944, 1952) believed that meaning achievement was indirect. The perceptual world could contain only signs or things standing for something else. A cue is a sign for some property of the environment; as an example, vertical position of points in the optic array might inform the perceptual system about the distance of the object containing these points.

Affordance was the concept used by Gibson (1979) to solve the problem of meaning. The fundamental ways in which surfaces are laid out have intrinsic meaning for behavior. We only detect invariants, but we perceive affordances or the actions that the objects and events permit or constrain us to do. It is clear that the two different sets of descriptors used by Brunswik and Gibson represent their different views concerning the directness

of perception. We will address this difference in a later section, but it might be worthwhile to consider a recent distinction that parallels the one concerning the between cues as signs and affordances as actions.

Pattee (1974) has developed the distinction between specificational and indicational concepts of information, and this distinction has been important for the neo-Gibsonians (Carello, Turvey, Kugler, & Shaw, 1984). The specificational perspective on information implies that appropriate activity is specified (constrained) by the environmental context. In contrast, the indicational perspective on information implies a more arbitrary link between perception and action. The former entails a qualitatively different process than the latter. I have difficulty with accepting a binary distinction between these two types of information, since it is easy to generate examples spanning a continuum between the extremes. A looming target towards one's head seems to specify the appropriate action of avoidance whereas a stop sign might only function in an indicational or symbolic mode. Between these extremes, however, I wonder whether my keyboard and terminal are indicating or specifying action? The written word seems indicational, but it clearly specifies, at some level, pronunciation as can be seen in the Stroop (1935) effect.

One important property of characterizing the environment is in terms of complexity. As in other cue theories, Brunswik viewed cues as simple whereas Gibson glossed invariants as complex. As pointed out by Cutting (1982), however, complexity appears to be a value-laden concept. If cues could be complex and invariants simple, a critical distinction between the two types of descriptors can not be justified on the basis of complexity. To say cues are simple and static and invariants are complex and dynamic does not justify the theoretical distinction being made.

The question of validity of the environment appears to be more central to differentiating Brunswik and Gibson. The validity of the information is used to represent the extent to which the information reflects the environmental property of interest. The validity of cues could be relatively low, but the validity of invariants could only be high. Height in the vertical plane is a cue with somewhat low validity for distance because it is influenced not only by distance but also by absolute height of the object. The horizon ratio is , for Gibson, a highly valid specification of the height of the object.

Brunswik emphasized the difference between ecological and functional validity. Being so functional in viewpoint, Gibson did seem to appreciate the value of this distinction. It seems important to define the extent to which a cue/invariant is a valid indicator of some property of the environment versus the extent to which the cue/invariant is utilized to inform the system about some property of the environment. The distinction is meaningful because there is no isomorphism between ecological and functional cues/invariants. Ecologically-valid attributes might be nonfunctional and functionally-valid attributes might be ecologically invalid. Given an organism's long biological history, Gibson would have difficulty accepting that an ecologically property would be nonfunctional or that a functionally-valid property would be ecologically invalid. This distinction is discussed more comprehensively in a later section.

A related property to validity has to do with the reliability or consistency of the environmental determinants. For Brunswik, the "environment to which the organism must adjust

presents itself as semierratic"(Brunswik, 1955, pg. 193). In Brunswik's view, behavioral responses are based on insufficient evidence. For Gibson, there are complex environmental invariants responsible for much of behavior and the discovery of these properties will explicate behavioral observations. "The suggestion is that, philosophers and estheticians to the contrary, order exists in stimulation as well as in experience."(Gibson, 1950, pg. 187).

The finding of only moderate ecological validity and reliability for various cues probably contributed to Brunswik's development of probabilistic functionalism. Like Gibson, the functionalism half of Brunswik's theory referred to the adjustment of organisms to the environment. Unlike Gibson, however, the probabilistic half was based on the premise that the cues in the environment were equivocal and only probabilistically predictive of objects and events. Objects and goals in the environment are only probabilistically related to the available cues. A cue such as height in the vertical plane is an equivocal, and thus a probabilistic cue, to depth in that it only predicts depth with some probability. Having been informed by the development of fuzzy sets (Zadeh, 1965) and continuous information (Massaro & Cohen, 1983), however, we see that an equivocal cue might be better thought of as providing fuzzy rather than probabilistic information. That is, a depth cue provides continuous information about the degree to which a given depth is present, not simply the probability that a given depth is present.

On the heels of validity and reliability, we can inquire about sensitivity or the ability to resolve the cues/invariants. Gibson was committed to high sensitivity: If variants are simply extracted, there should be no loss of information in the transfer between environment and organism. Brunswik would appear to be on the side of low sensitivity given his early observations (Brunswik, 1934) of subjects' inability to process selectively the relevant cue for the judgment. Subjects seem to be influenced by irrelevant dimensions, which would dilute the judgment and decrease its sensitivity.

The number of cues/invariants provides another distinction between the two perspectives. Greater numbers appear to be necessary for Brunswik. Given low reliability and sensitivity of any one cue, the perceptual achievement of the organism must result from the availability of many cues. For Brunswik, more than a single cue could inform the system about some property, whereas Gibson seemed to believe that a single invariant was sufficient to provide information about a single property. Invariants are relatively unique whereas cues are not. Brunswik was impressed with the intersubstitutability of cues or that different cues can be used to achieve the same goals. Gibson did not seem to address the possibility of the coexistence of multiple invariants specifying the same property and might have operated with the premise of no more than one invariant specifying a single property. This would not be contradicted by observations that a single invariant could specify two or more properties of the environment.

<u>Ecological and functional validity</u>

Gibson often addressed the issue of the many ways of describing the optical array and the appropriate description of the stimulus information for the perceptual system. This concern parallels Brunswik's formal distinction between ecological and functional validity, even though Gibson might have argued with what should be considered functional for perception. With

respect to the world of information, Brunswik distinguished between two kinds of validity. Ecological validity defines what cues are informative about the structure of the world. As an example, height in the vertical plane can be shown to be correlated with distance of the object from the observer. Functional validity defines what information people actually use in perceptual processing.

Given this distinction, it can be seen that a study of ecological validity is not sufficient, since some ecologically valid property of the physical world may not be used and hence not be functionally valid. As an example, the onset frequency and the contour of the fundamental frequency are ecologically valid cues to the voicing distinction of consonants in word-initial position. Only the onset frequency and not the contour is functionally valid, however, at least in the /zi/-/si/ distinction (Massaro & Cohen, 1976). One might expect that functionally valid cues might always be ecologically valid, but many counterexamples exist. The gambler's fallacy of using the outcome of a preceding roll of the dice to guide prediction of the current roll is one of many ecologically invalid decision heuristics. A complete description of the environmental-behavior relationship requires an analysis of both ecological and functional validity.

Both Gibson and Brunswik seem to have been more concerned with ecological than functional validity. Their writings and observations appear to focus on aspects of optical stimulation such as texture gradients for the early Gibson and certain Gestalt organizational factors for Brunswik. As an example, Brunswik and Kamiya (1953) found some ecological validity for the proximity of two lines as a cue to those lines defining the boundaries of a single object. Similarly, Seidner (cited in Brunswik, 1956) found that vertical position of points was positively correlated with distance from the observer. These latter two observations were only demonstrations of ecological validity since they did not evaluate functional validity in terms of the extent to which these cues are utilized in perception and recognition.

The distinction between ecological and functional utility by Brunswik can be used to clarify the use of information in current scientific endeavor. Like Brunswik, we believe it is necessary to distinguish between environmental properties that are potentially informative about some object or event and the properties actually used in perception and recognition of the object or event. The former might be called data and the latter information. As is apparent from the examples of ecological and functional utility mentioned earlier, there is no reason to expect a one to one correspondence between data and information (or between ecological and functional utility).

Nature of Perceptual Processing

The issue central to much current debate is what these two views of the environment imply about processing. For Brunswik, significant processing is necessary since cues are only partially informative and can also be substituted for one another in guiding behavior. The intentionality involved in this act was called vicarious functioning that permitted the organism to achieve the same goal with different cues and by different routes. For Gibson, we simply extract invariants with no processing involving inference, decision making, and the like.

One might accuse both Brunswik and Gibson of being equally noncommittal about the nature of perceptual processing. "The extraction of invariants from the sensory flux" is about as

uninformative as the "accumulation and combination of cues." One might argue that the two men differed primarily in their view of the rationality of the perceptual process. There is no doubt that Gibson deserves credit for the most consistent and elaborate rejection of perception as a form of epistemology. Although this suggestion might be considered heresy, the early Gibson (1950) might be interpreted as a multiple-cue theorist, since the optical information was demonstrated to be potentially informative given variations in texture, size, shading, and binocular disparity. Gibson specifically rejected, however, any internal process of combining, computing, and comprehending the data (Gibson, 1950, pg. 22). In his view, the total stimulation is sufficient to account for visual perception and does not need to be supplemented by inference, reasoning, or organization.

In contrast to Gibson, Brunswik might be considered to be much more rationalistic in approach. Gibson (1979) also interprets Brunswik as proposing a quasi-rational if not a fully rational process of perception. However, the early Brunswik (1944) was less reluctant to reject Helmholtz's (1856) idea outright, and to view perception as a primitive and relatively autonomous process within the total cognitive system. Although the late Brunswik (1955, pg. 207) did admit to espousing a statistical reasoning process reminiscent of Helmholtz's unconscious inference, it did not have introspectionistic and perfectionistic overtones. Brunswik drew upon communication theory for a metaphor of the utility of redundancy when there is noise on the channels of transmission. Thus, the perceptual process might be viewed as reducing the probability of error by utilizing redundant sources of information. It is not necessarily perjorative to envision Brunswik as accepting a formal description of perception analogous to the statistical theory of communication such as that given by Shannon and Weaver (1949). Although it would seem to require more processing, combining cues does not necessarily entail more rationality than does extracting invariants.

Brunswik's (1952) lens model, illustrated with more contemporary terms in Figure 1, seems to acknowledge component operations involved between input and output. In other ways, aspects of the model's description are Gibsonian (Brunswik, 1952, pg. 20). Organisms were viewed as "stabilizers" of events or relationships. The input and output were called focal variables. The correlation between the two was considered to be high but not perfect. The process detail involves some chaos, although Brunswik was relatively mute on either the chaos or the order. The most specific aspect of the process detail was the probabilistic attribute. It was based on the premise that the cues in the environment were equivocal and only probabilistically predictive of objects and events. One can find the antithesis of Gibson in the statement, "any organism has to cope with an environment full of uncertainties."(Brunswik, 1952, pg. 22). Given contemporary emphasis on the relation between perception and action, it is interesting that Brunswik also viewed the relationship between action and its consequences as equivocal or probabilistic. Given this view, one can recognize an important contribution of feedback in accomplishing the achievement of the organism in its environment.

<u>Scientific Method of Study</u>

In contrast to their divergent views of the environment and the processing of it, Brunswik and Gibson converged on a similar forum for psychological inquiry. Brunswik's representative design instantiates Gibson's dictum that the laboratory should be

like life. Brunswik argued against single-factor experiments and Gibson criticized peep-hole experiments. For Brunswik, the achievements of the organism in its ecological niche should be recorded. For Gibson, one also is required to isolate the invariants psychophysically. Both men would have agreed that understanding of perception was not to be obtained in experiments degrading the environment to render a typically successful system with error.

It is striking that the two men with almost antithetical views of the psychology of perception believed in the same methodology. Their goal was a description of the organism functioning in its natural environment rather than a description of any mediational processes on the part of the organism. Although cues providing indirect evidence for perception is the antithesis of the concept of invariants and although Brunswik believed in complex mediational processes and Gibson did not, both men proposed what might be called ethnographic and ecological frameworks for inquiry. Both Brunswik and Gibson believed that environment-behavior relations were more important than the internal processing of the behaving agent. The gold was to be mined in the former, not the latter.

Notwithstanding their discrepant views of the world of visual information, Brunswik and Gibson would have reached considerable agreement on the appropriate methods for visual science. "The laboratory must be like life"(Gibson, 1979, pg. 3) summarizes Brunswik's prescriptions for scientific inquiry which were more elaborately described and are probably better known (Petrinovich, 1979). Brunswik called for the study of natural situations rather than artificial experimental tasks. Thus, recent calls to natural ecology in the study of perception such as those by Neisser (1976) and Haber (1983) were already existent in the psychological literature decades earlier.

Theorists within the Gibsonian framework usually ask that investigators focus on the higher-order structure of the environment and relate it to behavior (Gibson, 1979; Haber, 1983; Turvey, 1977; Turvey & Shaw, 1979). Studying behavior in a natural situation follows naturally given this assumption. If these higher-order invariants are eliminated as supposedly occurs in simple laboratory tasks, then they will elude discovery as well as the experiment having no valid generalization to typical situations.

<u>Representative Designs</u>

Brunswik's framework called for representative designs or designs that are random samples of natural ecology. Thus, only correlational rather than experimental methods could be used since behavior must be studied within the context of the multiple cues as they co-occur in the natural world of the observer. Brunswik argued that single-factor and factorial designs are artificial since they decorrelate naturally occurring cues. For this reason, Brunswik contended that experimental results cannot be generalized to the real world. He made a distinction between internal and external validity. The results derived from a factorial design may be internally valid but yet may not be externally valid since they have no generality outside the experiment itself.

Brunswik's concept of representative design is nicely illustrated in a study of size constancy (Brunswik, 1944) in which he followed up a laboratory study of size constancy with a representative design. A graduate student was interrupted in her daily routine at irregular intervals and asked to make judgments of the object currently being viewed. The subject was asked to

estimate the size of various objects in a natural setting across a wide range of sizes and distances. The subject judged the size of trees, telephone poles, bookcases, inkwells, and so on. The primary measure of performance was a correlation between the subjective estimates and objective physical size. The study included five different kinds of perceptual judgments and produced measures of objective size, projective size, and distance. The data analyses were centered around correlations between the various aspects of the judgments and the environment. The largest and most impressive (to Brunswik) correlation was between perceived size and objective size. The correlation between estimated projective size and actual projective size was low. These results are identical in principle to classical laboratory studies of size constancy. The question is whether the representative design of Brunswik offers a more informative study of the phenomenon and whether it can address the issue of the information used in perception.

In the publication of a symposium on Brunswik's representative approach, Hilgard (1955) provided important criticisms of representative designs and correlational analyses that are still relevant today. High correlations can be obtained even with a relatively high error in the estimation of size. Some of the errors in Brunswik's observations were as great as 3 to 1. Hilgard conjectures that repeating the experiments with a blind subject also would give high correlations. If the blind subject were given a name of the objects the estimations would correlate with the actual size of the object and not with the object's projective size. The blind subject also would not have a basis for estimating the projective size since the distance of the object would not be known. The investigator would obtain size constancy even with a subject who could not see. In the representative design used by Brunswik, there is an artificial link between the known size of the object and the perceived size of the object. This kind of error in a representative design would not be obtained in a laboratory study of size constancy in which the known object size would not be available because artificial stimuli would be used.

Hilgard's observations made two important points. First, correlation, or the more contemporary use of multiple regression, can be a highly misleading index of environmental influences. Birnbaum (1973) and Anderson and Shanteau (1977) have provided convincing demonstrations of the inadequacies of correlation. Consider a situation in which two variables X_1 and X_2 are processed first independently and then combined in a multiplicative fashion as illustrated in Figure 2B. Figure 2B shows that the "obtained" behavior is a relatively complex function of the product of the values of these two cues. Now imagine a representative design of a situation in which X_1 and X_2 are independently varying and the researcher measures the "obtained" behavior across the various combinations of X_1 and X_2. Assume further that the investigator proposes some higher-order invariant responsible for the behavior and the "invariant" is some additive combination of the two variables X_1 and X_2. A correlation computed between this "invariant" and the same results given in Figure 2B gives the impressive fit in Figure 2A with a correlation of 0.93. Needless to say, it would be catastrophic if the investigator concluded a functional role for the "invariant". Not only would we be misled about the invariant, we would be misled about whether there was an invariant. The design and analysis precluded discovery of the component contributions of X_1 and X_2 and their particular form of

combination in contributing to the obtained result. This caveat should convince even the most dedicated believer that the recent correlational findings of time-to-contact and visual flow-fields (Lee & Reddish, 1981; Wagner, 1982) are not demonstrations of a causal role for these "invariants."

The second point made by Hilgard (1955) is that representative design is not capable of discovering causal factors for behavior. As Hilgard observes it is difficult to see how a naturalistic study of recovery from pneumonia would have ever found that Penicillin speeds up recovery or, analogously, whether the relationship between diabetes and insulin would have resulted from just a correlational study. Three decades later, Shepard (1985) gives the example of eliminating the diurnal cycle of light and darkness to assess whether this external cycle is necessary for the animal's diurnal cycle. In these three cases some sort of experimental intrusion was necessary to discover the causal factors.

Representative designs impose a major constraint on the type of psychological investigation that can be done. If two cues do not occur independently in the natural world, then they cannot be manipulated independently in the psychological investigations using representative designs. In research on bimodal speech perception, for example, it would not be possible to determine the relative influences of visible and audible speech without independent manipulation of these two sources of information. We conclude that representative designs are inadequate for psychological inquiry.

Psychophysics

Neither Gibson nor his followers accept the strong constraint of Representative designs. Gibson (1979, pg. 305) seems to accept the common strategy in psychophysics of isolating and manipulating some aspect of the environment. In these experiments, the isolated variable is an invariant such as early studies of texture gradients and recent studies of stair-climbing and a glass breaking or bouncing (Warren, 1984; Warren & Verbrugge, 1984).

The Brunswikian and Gibsonian frameworks are instantiations in many important respects of the classical psychophysical approach inaugurated by Fechner (1860), in which variation in the stimulus world is related to variation in performance. The Fechnerian paradigm dictates the discovery of relationships between objective and subjective worlds without fundamental concern for the intervening mental processes and representations. In contrast to the Brunswikian assumption of multiple cues, however, Gibson believed that higher-order invariants are directly perceived and will stand on the left side of the S-R chain. Both the component-cues and higher-order invariants proposals bring the investigator into the domain of psychophysics.

The study of multiple cues and that of invariants have produced somewhat disappointing results. Gibsonians and the neo-Gibsonians have not yet delivered with respect to discovering higher-order invariants of phenomenal perception and complicated action (see Shebilske, 1985; von Hofsten, 1985). Looking out my window at grass, weeds and trees, there is no apparent single higher-order invariant that can capture my experience of depth and object constancy. Analogously, optical information alone might not be sufficient for skills such as catching (von Hofsten, 1985). The knowledge acquired in the psychophysical study of component cues has also been relatively limited (Rock, 1975). Although many cues have been proposed, very little insight has

been gained into how the perceiver evaluates and utilizes the cues in perception. We have not learned the relative importance of the cues nor how the multiple cues work together. (A recent study by Cutting and Millard (1984) has, at least, begun to address the relative importance issue.)

One limitation in the traditional psychophysical approach has been the experimental design of asking how one cue works when other cues are neutralized or held constant. This strategy is particularly apparent in studies of visual localization of points of light they are carried out in the dark without visual context. The single-cue paradigm not only fails to define how the particular cue would operate in a more natural situation, it also does not address the issue of how the perceiver evaluates and integrates multiple cues in perceptual processing. More recently, Shebilske (1985) manipulated independently both the state of efference adaptation and the presence versus absence of visual context. By utilizing a larger number of levels of each of these two variables in a factorial design, the experiment would address the issues of the relative contribution of each variable and how the variables interact with each other.

Factorial designs and Functional Measurement

The creation of artificial situations by utilizing factorial designs, on the other hand, can be very illuminating. With respect to Brunswik's and Gibson's concern with the external validity, one needs only a good theory to allow generalization from a particular experiment to the real world even if the experiment is not representative of the real world.

In terms of contemporary theoreticians, Anderson (1981, 1982) offers an alternative to representative designs and traditional psychophysics. Within the framework of information integration, it is accepted that there are multiple sources of information; the goal to date has not been to define the sources of information but to assess how various sources are integrated in perception and decision. In contrast to Brunswik's representative design and psychophysics, information integration is studied by utilizing factorial designs that manipulate independently multiple aspects of the environment.

In our study of bimodal speech perception, we have combined the information-integration paradigm with the research strategy of strong inference (Massaro, 1985). The approach to perception can be described in terms of the three dimensions used here comparing Brunswik and Gibson. We operate on the assumption of multiple but somewhat ambiguous sources of information available to the perceiver. The perceptual processing needed to achieve perceptual recognition involves the evaluation and integration of the multiple sources of information. The goal is to articulate and test formal models of the nature of this processing. The scientific method of study makes use of factorial experiments in which multiple variables are independently manipulated in identification tasks. The research endeavor is also guided by the tenets of falsification and strong inference (Platt, 1964; Popper, 1959, 1976). I think it is safe to say that the use of factorial experiments, the formalization and testing of mathematical models of perceptual processing, and the falsification of specific models were not considered by either Brunswik or Gibson as necessary or even beneficial elements of the scientific enterprise.

Integrating multiple sources of information appears to be a natural function of human endeavor. Integration appears to be functional regardless of the goals and motivations of the perceiver. Brunswik, more than anyone else, seems to deserve

recognition for the early acknowledgement of the multiple but ambiguous sources of influence on behavior. He stressed "the limited ecological validity or trustworthiness of cues . . . To improve its (the organism's) bet, it must accumulate and combine cues" (1955, pg. 207). Consider an early experiment of Bruhswik (1934). Subjects were asked to equate groups of coins that varied in number, area, and monetary value. When subjects were instructed to use just one of these three dimensions, their judgments were nonetheless significantly influenced by the irrelevant dimensions.

Given the earlier distinction between data and information, it is also possible to study one of these somewhat independently of the other. We have seen examples of evaluating ecological validity without a concern for functional validity. Research within our framework might be characterized by a primary concern for how information is evaluated and integrated without a direct assessment of what is actually informative. Thus we manipulate auditory and visual properties of the speech event, but do not isolate the actual aspects of these properties that are functional. The important assumption of this approach is that insights can be gained about the nature of perceptual processing of various environmental properties even though the exact properties that are functional are not known. As an example, manipulating the formant transitions of a stop consonant can influence the identification of place of articulation. We can then ask how this information is integrated with information provided by the speaker's lip movements even though we can not answer the question of what aspects of the formant transitions and lip movements actually are functionally valid.

Table 1

A list of various properties of environmental causation and their descriptions by Brunswik and Gibson.

Properties	Brunswik	Gibson
description	cues	invariants
meaning	indirect	direct
complexity	simple/static	complex/dynamic
validity	low	high
reliability	low	high
sensitivity	low	high
number	many	few

Acknowledgment

The author would like to thank Bruce Bridgeman, Fred Owens, Eckart Scheerer, and Wayne Shebilske for comments on the paper. The writing of this paper took place in the ideal working environment of The Center for Interdisciplinary Research in Bielefeld, West Germany and was supported, in part, by NINCDS Grant 20314 from the Public Health Service and Grant BNS-83-15192 from the National Science Foundation.

References

Anderson, N.H. (1981). *Foundations of information integration theory*. New York: Academic Press.

Anderson, N.H. (1982). *Methods of information integration theory*. New York: Academic Press.

Anderson, N.H., & Shanteau, J. (1977). Weak inference with linear models. *Psychological Bulletin*, *84*, 1155-1170.

Birnbaum, M. H. (1973). The devil rides again: Correlation as an index of fit. *Psychological Bulletin*, *79*, 239-242.

Brunswik, E. (1934). *Wahrnehmung und Gegenstandswelt*. Vienna: Deuticke.

Brunswik, E. (1944). Distal focusing of perception: Size-constancy in a representative sample of situations. *Psychological Monographs*, *56*, Whole No. 254, 1-49.

Brunswik, E. (1952) *The conceptual framework of psychology*. Chicago: University of Chicago press.

Brunswik, E. (1955) Representative design and probabilistic theory in a functional psychology. *Psychological Review*, *62*, 193-217.

Brunswik, E. (1956). *Perception and the representative design of psychological experiments*. Berkeley, California: University of California press.

Brunswik, E., & Kamiya, J. (1953) Ecological cue validity of "proximity" and of other Gestalt factors. *American Journal of Psychology*, *66*, 20-32.

Buhler, K. (1934) *Sprachtheorie*. Jena: Fischer.

Carello, C., Turvey, M. T., Kugler, P. N., & Shaw, R. E. (1984). Inadequacies of the computer metaphor. In M. S. Gazzaniga (Ed.) *Handbook of Cognitive Neuroscience*. New York: Plenum.

Cutting, J. E. (1982). Two ecological perspectives: Gibson vs. Shaw and Turvey. *American Journal of Psychology*, *95*, 199-

222.

Cutting, J.E., & Millard, R.T. (1984). Three gradients and the perception of flat and curved surfaces. *Journal of Experimental Psychology: General*, *113*, 198-216.

Fechner, G.T. (1860). *Elements of Psychophysics*. (Vol. 1). Translated and edited by H.E. Adler, D.H. Howes, & E.G. Boring. New York: Holt, Rinehart, & Winston, 1966.

Gibson, J. J. (1950). *The perception of the visual world*. Cambridge, Mass: Riverside press.

Gibson, J.J. (1979) *The ecological approach to visual perception*. Boston: Houghton Mifflin Co.

Haber, R.N. (1983). The impending demise of the icon: A critique of the concept of iconic storage in visual information processing. *The Behavioral and Brain Sciences*, *6*, 1-11.

Helmholtz, H. von (1856-1866) *Treatise on physiological optics*. Translated from the 3rd Ed. by J.P.C. Southall (Ed.) New York: Dover, 1962.

Hilgard, E. R. (1955). Discussion of probabilistic functionalism. *Psychological Review*, *62*, 226-228.

Hofsten, C. von (1985). Catching. In H. Heuer & A. F. Sanders (Eds.) *Tutorials on Perception and Action*. Hillsdale, N. J.: Erlbaum.

Hormann, H. (1979). *Psycholinguistics*. Springer-Verlag: New York.

Lee, D. N., & Reddish, P. E. (1981) Plummeting gannets: a paradigm of ecological optics. *Nature*, *293*, 293-294.

Massaro, D. W. (1985). Information-Processing theory and strong inference: A paradigm for psychological inquiry. In H. Heuer & A. F. Sanders (Eds.) *Tutorials on Perception* and Action. Hillsdale, N. J.: Erlbaum.

Massaro, D.W., & Cohen, M.M. (1976). The contribution of fundamental frequency and voice onset time to the /zi/-/si/ distinction, Journal of the Acoustical Society of America, 60, 704-717.

Massaro, D.W., & Cohen, M.M. (1983). Categorical or continuous speech perception: A new test, Speech Communication, 2, 15-35.

Neisser, U. (1976) Cognition and reality. San Francisco: W.H. Freeman.

Pattee, H. H. (1974). Discrete and continuous processes in computers and brains. In M. Conrad, W. Guttinger, & M. D. Cin (Eds.) Physics and mathematics of the nervous system. New York: Springer-Verlag.

Petrinovich, L. (1979). Probabilistic functionalism: A conception of research method. American Psychologist, 34, 373-390.

Platt, J.R. (1964). Strong inference. Science, 146, 347-353.

Popper, K. (1959) The logic of scientific discovery. New York: Basic books.

Popper, K. R. (1976) Unended quest. London: Fontana/collins.

Rock, I. (1975). An Introduction to Perception. New York: Macmillan Publishing co.

Shannon, C. E., & Weaver, W. (1949). Mathematical theory of communication. Urbana: University of Illinois press.

Shebilske, W.L. (1985). An ecological efference theory of natural event perception. In H. Heuer & A. F. Sanders (Eds.) Tutorials on Perception and Action. Hillsdale, N. J.: Erlbaum.

Shepard, R. N. (1985). Ecological constraints on internal representation: Resonant kinematics of perceiving,

imagining, thinking, and dreaming. Psychological Review, 91, 417-447.

Turvey M.T. (1977). Contrasting orientations to the theory of visual information processing. Psychological Review, 84,67-88.

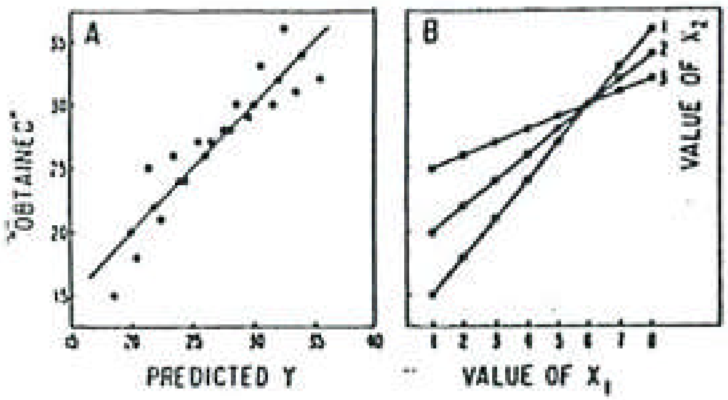
Turvey, M.T., & Shaw, R. (1979). The primacy of perceiving: An ecological formulation of perception as a point of departure for understanding memory. In L.-G. Nilsson (Ed.) Perspectives on memory research: Essays in honor of Uppsala University's 500th university. Hillsdale, N.J.: Erlbaum

Wagner, H. (1982). Flow-field variables trigger landing in flies. Nature, 297, 147-148.

Warren, W. H. Jr. (1984). Perceiving affordances: Visual guidance of stair climbing. Journal of Experimental Psychology: Human Perception and Performance, 10, 683-703.

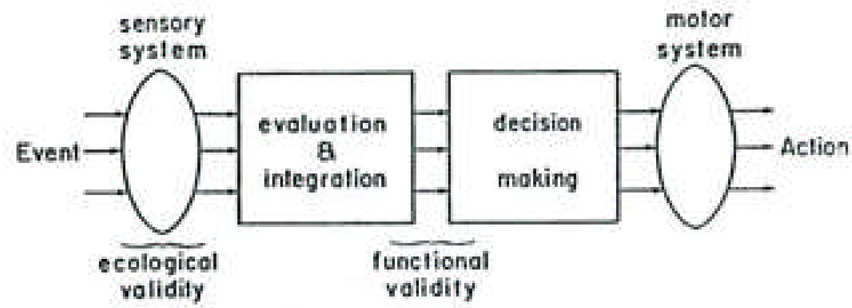
Warren, W. H. Jr., & Verbrugge, R. R. (1984). Auditory perception of breaking and bouncing events: A case study in ecological acoustics. Journal of Experimental Psychology: Human Perception and Performance, 10, 704-712.

Zadeh, L.A. (1965). Fuzzy sets, Information and Control, 8, 338-353.



2A. Correlation of hypothetical invariant that is some additive function of X_1 and X_2 with "obtained" results given in 2B.

2B. The "obtained" results are actually a multiplicative combination of the variables X_1 and X_2.



1. Schematic representation of a contemporary interpretation of Brunswik's lens model