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REDUNDANCY AND INFERENCE BEHAVIOR

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Within MCPL research redundancy has been treated as synonymous with intercorrelation among cues. As shown in the present paper this definition of redundancy is inadequate, and a definition of redundancy based on Brunswik's conceptual frame-work and made in analogy with the definition of redundancy in information theory was proposed. Redundancy was defined as the difference between the sum of all squared correlations and the squared multiple correlation. That is, when the intercorrelation between cues does not contribute to the predictable variance in the criterion the task is redundant. When the cue intercorrelation does contribute to the predictable variance in the criterion the task was defined as a suppressor task. Some implications of this view of probabilistic inference tasks for research were discussed in the paper.

1 BRUNSWIK'S CONCEPTION OF INFERENCE BEHAVIOR

According to Brunswik (1952) psychology should study the relation between the organism and the ecology. Psychology must be as concerned with the ecology as with the organism in order to understand how these two systems are related to each other.

1.1 The ecology

The ecology has two characteristic features (Tolman & Brunswik, 1935). The first is the causal texture of the environment. Different events in the ecology are dependent on each other. These dependencies constitute the texture of the ecology. As the organism learns about the relations in the ecology he will come to accept one event as a "local representative" or cue for another event. This means that the organism will react to proximal events as cues for more distal events or criteria. The proximal - distal relations define the depth aspect of the ecology. The ecology thus has both texture and depth.

The second feature of the environment is the equivocality of the "causal couplings". According to Brunswik each single cue is only equivocal evidence about the distal event and the relations between distal events and cues are not one-to-one but one-to-many. A given distal event will result in many proximal cues and the distal events are vicariously mediated by a number of "mutually interchangeable cues". That is, a certain event may "cause" a number of cues on one occasion and a number of different cues on another occasion (Tolman & Brunswik, 1935).

1.2 The organism and the ecology

The organism must be able to achieve a stable relationship with the environment, despite the fact that "nature scatters its effects irregularly". Brunswik characterized the organism as "stabilizer" of relationships (Brunswik, 1952, page 20). In order to maintain a stable relation with the distal layer in the environment the organism has the capacity of vicarious functioning. Vicarious functioning means that the organism may reach a given goal in a number of different ways and corresponds to vicarious mediation in the ecological system. Although Brunswik seems to have noticed the importance of redundancy for vicarious functioning (see Brunswik, 1952, page 92) he never incorporated the concept of redundancy within his conceptual system.

1.3 Representative design

According to Brunswik research must be done so that the behavior is represented in all its essential features, the most important one being vicarious functioning. In order to achieve that goal the environment must be adequately represented in the research designs.

According to Brunswik sampling from the ecology is as important as sampling of subjects. Systematic designs that vary one or more variables in a systematic way and control other variables will in most cases destroy the naturally mediated patterns of the ecology (Brunswik, 1955).

1.4 The lens model paradigm

Brunswik's ideas about the depth aspect of the ecology have been systematized in the lens model of behavior (Brunswik, 1952). The fundamental ideas of this model have been put into mathematical form by Hirsch,

Hammond and Hirsch (1964). The lens model of behavior together with the mathematical formulations is called the lens model paradigm.

In the lens model paradigm Brunswik's claim for ecologically representative designs of experiments has been met by formal representative design rather than by substantial representative design (Hammond, 1966). Formal representative design means that the formal aspects of the ecology are abstracted and studied in experimental designs. Within the lens model paradigm the ecology has been described as varying in seven dimensions (see e.g., Brehmer, 1975). Since the lens model is primarily concerned with the depth aspect of the ecology the formalization within the lens model paradigm is restricted to only this aspect of the ecology, and texture and vicarious mediation have been neglected.

The argument of the present paper is that the lens model paradigm has led to a neglect in research on both vicarious mediation and vicarious functioning. Within the lens model paradigm redundancy has been treated as synonymous with cue intercorrelation. As will be shown in the present paper the assumption that redundancy is equal to the cue intercorrelation is inadequate and only leads to confusion, and whereas cue intercorrelations may under certain circumstances, be described as a special dimension in a depth structure, redundancy cannot be so described. Redundancy must be considered a more fundamental aspect of the ecological structure than the cue intercorrelation.

The purpose of the present paper is to examine what meaning the concept of redundancy might have within Brunswik's conceptual frame-work. The present definition of redundancy will be made in analogy with the definition of redundancy in information theory as presented by Garner (1962), where the concept of redundancy has been thoroughly analyzed.

2 THE CONCEPT OF REDUNDANCY IN INFORMATION THEORY

Redundancy in information theory means "an amount of uncertainty which could be used as information but is not so used because of some constraint between the variables" (Garner, 1962, page 64). Constraint refers to amount of interrelatedness or structure of a system of variables. In information theory a distinction is made between distri-

butional and correlational redundancy. Distributional redundancy refers to the marginal distributions and will not be treated here. Correlational redundancy is a measure of the extent to which two variables are correlated. Correlational redundancy is the type of structure of interest in the present study.

2.1 Total structure, external structure and redundancy

Total structure is the total amount of relations that exists in a given set of variables. When the purpose is to relate one subset of variables to another subset the total structure is divided into external and internal structure. External structure is the relation between one set of variables and another set of variables. Internal structure is the relation that exists within a set of variables. Total structure is the sum of external and internal structure, i.e., $\text{total structure} = \text{external} + \text{internal structure}$.

In order to maximize the amount of external structure or predictability from a set of variables there should be no internal structure or redundancy. An increase in amount of internal structure or redundancy decreases the external structure or predictability if total structure is constant. Thus in information theory it is always true that there should be no redundancy if it is important to maximize external structure, as is the case in prediction-tasks. Any change in redundancy is always accompanied by changes in external or total structure.

In summary, redundancy is defined as the difference between total and external structure and with a given amount of total structure the introduction of redundancy decreases the predictability from a given set of variables to an external criterion.

2.2 Form of structure

The form of both external and internal structure may vary. The structure may be in the form of (a) "single contingent uncertainties", which means variance or uncertainty in the criterion that is predictable from single predictor variables or (b) "interaction uncertainty", which means variance or uncertainty in the criterion that is predictable from combinations of predictor variables.

3 THE CONCEPT OF REDUNDANCY IN MULTIPLE-CUE PROBABILITY LEARNING

3.1 Total structure

In correlation statistics there is no measure of total structure. Let us, however, define total structure for a set of variables as the sum of all squared correlations in the system, i.e., total structure = Σr^2 . Let one of the variables be the criterion that is to be predicted from the other variables, the predictor variables. Total structure may then be written as

$$\begin{aligned} \text{Total structure} &= \Sigma r_{ei}^2 + \Sigma r_{ij}^2 \\ \text{where } r_{ei} &= \text{cue-criterion correlations} \\ r_{ij} &= \text{cue intercorrelations} \end{aligned} \quad (1)$$

3.2 External structure

External structure is given by the multiple correlation between cues and criterion, R_e^2 . This expresses the proportion of variance in the criterion that can be predicted from a linear combination of the predictor variables.

$$\text{External structure} = R_e^2 \quad (2)$$

3.2.1 Forms of external structure: orthogonal tasks and suppressor tasks

When external structure is equal to total structure, i.e.,

$$\Sigma r_{ei}^2 + \Sigma r_{ij}^2 = R_e^2 \quad (3)$$

the task is nonredundant. There are two forms of nonredundant MCPL-tasks

a) orthogonal tasks, where $r_{ij} = 0$ and the external structure is entirely due to the cue-criterion correlations, i.e.,

$$R_e^2 = \Sigma r_{ei}^2 \quad (4)$$

and b) tasks where $r_{ij} \neq 0$ and where the cue intercorrelation contributes to the predictability of the task. This occurs when external structure, R_e^2 , is due both to the cue intercorrelation, r_{ij} , and the cue-criterion correlations, r_{ei} , i.e.,

$$R_e^2 > \Sigma r_{ei}^2 \quad (5)$$

This kind of task will be called a suppressor task. In summary, the two forms of nonredundant MCPL-tasks are a) orthogonal tasks and b) non-redundant suppressor tasks. It should be stressed that, according to the definition above, certain MCPL-tasks with intercorrelated cues are nonredundant.

3.3 Internal structure or redundancy

In analogy with information theory redundancy will be defined as structure or correlations that do not contribute to the predictability of the criterion. As in information theory redundancy is equal to total structure - external structure or

$$\text{Redundancy} = (\Sigma r_{ei}^2 + \Sigma r_{ij}^2) - R_e^2 \quad (6)$$

3.3.1 True redundancy in MCPL: redundant suppressor tasks and redundant non-suppressor tasks

In the spirit of information theory, a truly redundant MCPL-task, is defined as a task where the external structure is less than the total structure, i.e.,

$$(\Sigma r_{ei}^2 + \Sigma r_{ij}^2) - R_e^2 > 0 \quad (7)$$

Thus, there is redundancy in a MCPL-task only when the sum of all squared correlations is greater than the squared multiple correlation. In a redundant task, then, a part of the total structure is redundancy or internal structure, and cannot be used for prediction of the criterion. Since the external structure, R_e^2 , is defined as a value between 0 and 1 in MCPL, redundant tasks should be rather common, particularly if the number of cues is large.

There are two forms of redundant MCPL-tasks a) redundant suppressor tasks, where a part of the cue intercorrelation contributes to the external structure and a part of the cue intercorrelation is redundancy or

$$\Sigma r_{ei}^2 < R_e^2 < (\Sigma r_{ei}^2 + \Sigma r_{ij}^2) \quad (8)$$

and b) redundant non-suppressor tasks, where the cue intercorrelation does not contribute to the external structure or

$$\Sigma r_{ei}^2 \geq R_e^2 < (\Sigma r_{ei}^2 + \Sigma r_{ij}^2) \quad (9)$$

This, there are two forms of redundant MCPL-tasks a) redundant suppressor tasks and b) redundant non-suppressor tasks.

3.4 Negative redundancy in MCPL

Negative redundancy seems to have no correspondance in information theory. Negative redundancy occurs only in suppressor tasks and may be considered a special case of a suppressor effect. When the external structure is greater than the total structure or

$$R_e^2 > (\Sigma r_{ei}^2 + \Sigma r_{ij}^2) \quad (10)$$

there is negative redundancy. In order to understand more about the different forms of structure in MCPL it is necessary to define suppressor effects in MCPL.

3.5 Definition of suppressor effects in MCPL

According to the classical definition, (Horst, 1941) a suppressor variable, is uncorrelated with the criterion but increases the predictability of the criterion variable due to its correlation with another predictor variable. The increase in predictability is due to the fact that the suppressor variable subtracts error variance in the valid predictor variable with which it is correlated. There are other definitions of suppressor variables. Darlington (1968), for example, defines a suppressor variable as a variable which when included in the regression equation recieves a negative weight.

The present definition emphasises that in a suppressor task a part of the task predictability is due to the cue intercorrelation, i.e., that R_e^2 is increased beyond the level given by Σr_{ei}^2 due to r_{ij} .

The advantage of the present definition of suppressor effects is that it contributes to the understanding of redundancy in MCPL. The formal definition of a suppressor effect will be given for the two-cue case.

The multiple correlation between cues and criterion may be written as

$$R_e^2 = \frac{r_{el}^2 + r_{e2}^2 - 2r_{el}r_{e2}r_{12}}{1 - r_{12}^2} \quad (11)$$

(See Dudycha, Dudycha & Schmidt, 1974, for a description of the relation between R_e^2 and r_{ei} and r_{ij} .)

If cues are orthogonal, $r_{12} = 0$ and (11) is reduced to

$$R_e^2 = r_{el}^2 + r_{e2}^2$$

A suppressor effect is present when the cue intercorrelation, r_{12} , contributes to the task predictability, R_e^2 . Thus, if

$$\frac{r_{el}^2 + r_{e2}^2 - 2r_{el}r_{e2}r_{12}}{1 - r_{12}^2} > r_{el}^2 + r_{e2}^2 \quad (12)$$

there is a suppressor effect.

This will happen a) when one of the correlations has a negative sign or when all three correlations are negative and b) when $0 < r_{12} < 1$ if r_{12} is larger than the expression obtained if (12) is solved for r_{12} . The solution of (12) for r_{12} is given below:

$$r_{el}^2 + r_{e2}^2 - 2r_{el}r_{e2}r_{12} > (1 - r_{12}^2)(r_{el}^2 + r_{e2}^2) \quad (13)$$

$$- 2r_{el}r_{e2} > - r_{12}(r_{el}^2 + r_{e2}^2) \quad (14)$$

$$r_{12} > \frac{2r_{el}r_{e2}}{r_{el}^2 + r_{e2}^2} \quad (15)$$

which is the solution of (12) for a positive value of r_{12} .

According to this definition it is not possible to tell whether a single cue will act as suppressor because it has a zero correlation with the criterion and a high correlation with another predictor, or because it has a negative sign in the regression equation. The crucial point is that when r_{12} is positive the value of r_{12} exceeds the value in (15). Thus, it is necessary to consider the total structure of a task in order to establish whether there is a suppressor effect or not.

3.6 Summary and examples

We have found that MCPL-tasks may vary in two dimensions: the tasks may be redundant or non-redundant and there may or may not be suppressor effects. In addition, there is a special case of suppressor effects when there is negative redundancy. The different forms of MCPL-tasks may be illustrated by a fourfold table (see Table 1).

Table 1. Different forms of MCPL-tasks varying in both the presence of redundancy and suppressor effects.

	Non-suppressor tasks	Suppressor tasks
Nonredundancy	Orthogonal task	Nonredundant suppressor task
Redundancy	Redundant nonsuppressor task	Redundant suppressor task <u>Negatively redundant task</u>

Examples of these different forms of MCPL-tasks will be given for the two-cue case (see Table 2).

Table 2. Examples of different forms of MCPL-tasks for the two-cue case.

r_{e1}	r_{e2}	r_{12}	R_e^2	Form of task
.80	.40	.00	.80	Orthogonal task
.80	.40	.60	1.00	Nonredundant suppressor task
.80	.40	.50	.64	Redundant nonsuppressor task
.80	.40	.87	1.00	Redundant suppressor task
.80	.40	-.23	1.00	<u>Negatively redundant task</u>

In a nonredundant non-suppressor task, i.e., an orthogonal task, total structure is equal to external structure and is due to r_{ei} only. In a nonredundant suppressor task all structure is external structure and due to both r_{ei} and r_{ij} . In a redundant non-suppressor task r_{ij} does not contribute to the external structure and a part of the total structure is redundancy or internal structure. In a redundant suppressor task a part of the external structure is due to r_{ij} and a part of the total structure is redundancy. In a negatively redundant suppressor task the external structure is greater than the total structure due to the cue intercorrelation, and the external structure is due to both r_{ei} and r_{ij} .

4 EMPIRICAL RESULTS ON SUPPRESSOR EFFECTS AND THE EFFECT OF REDUNDANCY ON PERFORMANCE IN MCPL

Most studies within the lens model paradigm have used orthogonal tasks (see Slovic & Lichtenstein, 1971). Recently, the number of studies on the effect of cue intercorrelation on performance has increased (Armeli-
lius & Armelius, 1974, 1975d, 1976b; Brehmer, 1971; Knowles, Hammond, Stewart & Summers, 1971; Miller & Sarafino, 1970; Muchinsky & Dudycha, 1975; Naylor & Schenk, 1968; Schmitt & Dudycha, 1975a, b). In most studies cue intercorrelation has been treated as synonymous with redundancy (e.g., Naylor & Schenk, 1968). As shown in the present study, however, the cue intercorrelation may have quite different effects on the structure of a task, a fact which has been overlooked by most previous authors.

In inference tasks subjects are usually required to learn the relation between a set of predictor variables and a criterion variable, an external structure. Thus, in terms of the general partitioning of structure proposed in the present study, the research in MCPL has been restricted to the effects of the form and amount of external structure on performance. No attention has been given to total structure and internal structure and their relation to external structure.

Internal and external structure may be important for different psychological functions. Thus, while performance is the relevant psychological function with external structure, confidence or choice may be more important with internal structure.

There is no study specifically designed to investigate the different classes of MCPL-tasks. Therefore, we will pick out certain tasks from different studies in order to see if they contribute to our understanding of the effects of various forms of structure on performance.

4.1 Studies of non-redundant MCPL-tasks: orthogonal tasks and suppressor tasks.

It is well established that subjects' performance is directly related to the amount of external structure or task predictability in orthogonal tasks (e.g., Brehmer, 1976). In general, the same positive relation between amount of external structure and performance seems to hold also in suppressor tasks (Armeliu & Armeliu, 1975d).

There is, however, evidence suggesting that subjects reach a higher level of performance when the external structure is in the form of cue-criterion correlations rather than in the form of cue intercorrelations. This is clearly illustrated in an experiment by Armeliu and Armeliu (1974) where the cue criterion correlations contributed more to the external structure in one task than the cue intercorrelation. In another task the reverse was true. Performance was much higher in the task where a larger part of the external structure was due to cue criterion correlations. R_e^2 was equal in the two tasks. This means that the relation between external structure and performance is weaker in suppressor tasks than in orthogonal tasks. This indicates that it is easier to learn an external structure in the form of cue-criterion correlations than in the form of cue intercorrelations.

4.2 Studies of redundancy in MCPL: suppressor tasks and non-suppressor tasks.

In a redundant non-suppressor task or a truly redundant task the cue intercorrelation does not contribute to the external structure. Instead, the cue intercorrelation increases the internal structure. As stressed earlier the important aspect to be learned in prediction tasks is the external structure. The redundancy may not be expected to have any

direct effects on performance. In MCPL there are a number of studies that have used redundant tasks (Armeliu & Armeliu, 1976b; Brehmer, 1971; Knowles et al., 1971; Miller & Sarafino, 1970; Schmitt & Dudycha, 1975a; Naylor & Schenk, 1968). The results in some of the studies support the hypothesis that there are no effects of redundancy on performance in inference tasks (Armeliu & Armeliu, 1976b; Brehmer, 1971; Knowles et al., 1971). In none of the studies, however, amount of redundancy was systematically varied while external structure was controlled. The results in the study by Knowles et al., indicate that redundancy may increase rate of learning. The interpretation in terms of redundancy is, however, jeopardized because the cue-criterion correlations and amount of redundancy were not separated. Finally, some results indicate that a large amount of redundancy may have a deteriorating effect on performance (Schmitt & Dudycha, 1975a; Miller & Sarafino, 1970).

Redundant suppressor tasks, where one part of the cue intercorrelation contributes to the external structure and another part is redundancy, have been used in the studies by Armeliu and Armeliu (1975d, 1976b) Schmitt and Dudycha (1975b), and by Brehmer (1971). It is very difficult to draw any conclusions about the effect of redundancy in suppressor tasks mainly because the appropriate controls for external structure are lacking. The results, however, indicate that it may be more difficult to utilize a suppressor effect in a redundant task (Armeliu & Armeliu, 1975d, 1976b).

4.3 Studies of negative redundancy in MCPL

In a task with negative redundancy the external structure is greater than the total structure due to the cue intercorrelation. Only three studies have used a task with negative redundancy (Armeliu & Armeliu, 1976b; Knowles et al., 1971; Schmitt & Dudycha, 1975b). The results suggest that the external structure in a task with negative redundancy is learned as well (Knowles et al., 1971; Schmitt & Dudycha, 1975b) or better (Armeliu & Armeliu, 1976b) than other redundant tasks. More studies of this special case of suppressor effect are, however, needed before it is possible to say whether this form of structure affects subjects' inference behavior.

The empirical results may be summarized in five hypotheses about how performance is influenced by suppressor effects and redundancy in MCPL. (1) subjects performance in nonredundant MCPL-tasks, both suppressor tasks and orthogonal tasks, is positively related to amount of external structure. (2) it is easier to learn an external structure in the form of cue-criterion correlations. (3) if redundancy has any effect at all on performance in two- cue MCPL-tasks it a) increases rate of learning, b) makes it more difficult to utilize the suppressor effect and c) reduces performance when the amount of redundancy is large.

5 A THEORETICAL FORMULATION OF REDUNDANCY IN BRUNSWIK'S CONCEPTUAL FRAMEWORK

5.1 Vicarious mediation and redundancy

In this part of the paper Brunswik's theoretical concepts will be translated into the present conceptualization of the ecology.

In the present context, Brunswik's concept texture, i.e., the dependencies among different events, corresponds to total structure. The concept of depth, which is the relation between cues and a distal event, is related to external structure or the part of the total structure that contributes to the predictable variance in the criterion. The part of the total structure that does not contribute to the predictable variance in the criterion is internal structure or redundancy. Thus, it is only in relation to a criterion that it is possible to talk about redundancy. Without a criterion there is only total structure.

Vicarious mediation means that it is possible to maintain the same external structure with different sets of cues. This is obviously possible only in a redundant structure. In a nonredundant structure each cue is necessary for the end result. This is a consequence of the fact that in a nonredundant structure total structure is equal to amount of predictable variance in the criterion or external structure (see section 3.2.1).

This means that if one cue is removed in a nonredundant structure, the external structure is reduced at the same time as total structure. In a redundant structure, on the other hand, it may be possible to remove

one cue without affecting the external structure. Only total structure and redundancy is reduced. The redundant task in Table 2 in the present study may be taken as an example. There $r_{e1} = .80$, $r_{e2} = .40$, $r_{12} = .50$ and $R_e^2 = .64$. If cue 2 is removed the external structure is not changed. Thus, it is possible to maintain the same external structure with different sets of cues only in a redundant task. An example of how total structure may express itself in vicarious mediation may be taken from medicine. Ulcers e.g., may give rise to a number of different symptoms, which constitute the total structure. The symptoms present for different patients may, however, vary. One patient may show symptom A and B, another B and C and so on, and yet all have ulcers. In order to maintain a stable relation with the vicariously mediated distal layer in the environment, the organism must have a capacity to utilize the vicarious mediation in the ecology. This aspect of behavior was called vicarious functioning by Brunswik.

5.2 Vicarious functioning

According to Brunswik vicarious functioning is one of the most important aspects of behavior. Indeed, it is "the essence of behavior", (Brunswik, 1952, page 92). Vicarious functioning means that the organism may use different means to reach a certain goal, or it may use different cues in order to make an inference about a certain event. For example, the physician diagnosing ulcers may on one occasion use some of the cues in order to make a diagnosis. On another occasion he may use some other cues that are present. By means of the capacity of vicarious functioning the organism has a number of different ways to maintain a stable relationship with the environment.

It deserves to be pointed out that according to this view the most important function of redundancy is to make vicarious functioning possible. It is also possible to say that it is through vicarious functioning that the organism utilizes the redundancy that exists in the ecology. In summary, vicarious mediation presupposes redundancy in the ecology. Through vicarious functioning the organism is able to maintain a stable relation with the vicariously mediated distal layer in the environment.

One of the most important psychological functions related to redundancy is vicarious functioning. However, since redundancy has been almost neglected within the lens model paradigm, there are no studies of the most central concept in Brunswik's theory, vicarious functioning.

Although vicarious functioning has been neglected within the MCPL-paradigm, there are examples from other areas of psychology. In psychoanalytic theory e.g., the principle of vicarious functioning is recognized in the idea that the same infantile conflict may be expressed in different ways by different symptoms (Brunswik, 1952). An example from learning theory is Tolman's proposal that rats learn a maze not as a single chain of responses but as "place-learning" or how to reach a certain goal (Tolman, Ritchie & Kulish, 1946). Thus, the place-learning hypothesis means that rats have a capacity for vicarious functioning. Another example from learning theory is Hull's concept of habit-family hierarchies. In Hull's theory this concept is used to explain the fact that subjects' may use different responses in order to reach a certain goal. Another area where the principle of vicarious functioning is very prominent is the language. The same meaning may be expressed in a variety of verbal ways, which is an example of vicarious functioning.

6 SUGGESTIONS ABOUT FUTURE STUDIES OF INFERENCE BEHAVIOR

6.1 Studies of ecological structure and vicarious functioning

So far, only external structure has received any attention in inference tasks. This seems to be a consequence of the fact that the lens model paradigm only describes external structure and subjects' adjustment to such a structure. The present analysis, however, provides the means to describe other aspects of the ecology such as total structure and internal structure. Consequently, the present analysis of ecological systems is closer to Brunswik's conception of the ecology. It is possible to create an artificial total structure and study the effects of variations in external and internal structure on subjects' inference behavior.

In addition, it is possible to study how vicarious functioning depends on vicarious mediation. Vicarious functioning may also be studied by developmental studies that compare the capacity for vicarious functioning in different ages.

6.2 Consequences of redundancy

Studies of redundancy in MCPL have focused on the effects of redundancy on performance. As pointed out, however, the important aspect that may influence performance in inference tasks is the external structure and not the redundancy. As shown in the present study redundancy is, however, a very important aspect of the ecology that may influence other aspects of inference behavior than performance. It is not possible to, detail all the consequences for research of redundancy and inference behavior following from the present study, but some ideas about future research will be suggested. We will start with assumption that redundancy in the ecology is not worthless information for the subjects. The reason and consequences of this assumption will be given below.

Redundancy is defined only in relation to a certain criterion. Exactly what variables that are redundant or not will differ from context to context. Therefore, for the subjects all dependencies are important and constitute potential information about a criterion and is thus not necessarily redundant information. This is consistent with the results in studies of detection of cue intercorrelations (Armeliuss & Armeliuss, 1973, 1975b, c; Knowles, Hammond, Stewart & Summers, 1972). The results in those studies show that subjects detect the cue intercorrelation of a task as they learn the external structure, even though they do not utilize it when they make their predictions.

The same ideas have been expressed by Kahneman and Tversky (1973). According to Kahneman and Tversky subjects conceive of dependencies among cues as expressions of representativeness of cues. This means that dependencies among cues indicate that cues represent the same distal event. Expressed in factor-analytic terms subjects conceive of the criterion and cues as loaded in one and the same factor. That is, for the subjects cues are dependent because they are loaded in the same factor. Since most dependencies do not contribute to the external structure in a given situation, these dependencies will constitute redundancy. Thus, subjects behave as though cues were independent evidence about the criterion. If cues actually are independent subjects will conceive of cues as unrepresentative for the criterion. The assumption about how subjects look upon redundancy in ecological systems has a number of interesting consequences that may be tested.

The first consequence is that, when subjects are free to choose predictor variables, they will prefer redundant structures. They will choose predictor variables which they believe are representative for a certain event. This means that they will choose variables that form a redundant structure. This may seem paradoxical since a preference for redundancy means that subjects prefer structure that contributes no new information about the criterion. However, from the subjects' point of view there is no paradox. Another consequence is that subjects will decide on a number of cues that is larger than those actually needed for an optimal judgment. For the subjects a larger number of cues means that they have more independent information about the criterion. This may be an interpretation of the finding that as the number of cues increases subjects feel more confident even though they are unable to utilize the information to increase their accuracy (Oskamp, 1965).

A third consequence is that subjects will be more confident in a redundant structure than in a nonredundant structure. If cues are dependent subjects believe that they represent the same event. If cues are independent, on the other hand, subjects believe that they represent different events. They will, therefore, feel more confident when they predict a certain event from a set of dependent cues than if they make the same prediction from a set of independent cues. This hypothesis was already received some support (Kahneman & Tversky, 1973; Armelius & Armelius, 1975a).

A fourth consequence is that subjects will have a tendency to believe that cues are correlated and relevant even if they are not. This phenomenon has been called "illusory correlation" (Chapman & Chapman, 1969) or "positive set" (Naylor & Clark, 1968). This may be a consequence of the demand characteristics of most experimental situations in inference studies (see Nystedt & Magnusson, 1972). The phenomenon has also been illustrated in a recent study by Armelius and Armelius (1976a) where subjects said that they considered both cues when they made their judgments in a two-cue task, although they knew nothing about the relevance of the cues.

6.3 External structure and redundancy

An interesting area for research is situations where external structure and internal structure are in conflict. If the experimental situations are so arranged that subjects are able to decide how total structure is to be divided into external structure and internal structure, e.g., by choosing predictor variables, the preference for redundancy may be in conflict with the possibility to be accurate. We suggest that subjects will prefer redundancy before external structure. Usually subjects are required to choose independent predictors in order to increase the external structure. However, if subjects conceive of independent variables as not representing the same event they will not choose independent variables. From the subjects' point of view, it is most rational to choose representative information about the event, i.e., to choose variables that are dependent. This is an example of a conflict that may be present in different situations and where the preference for redundancy will make subjects behave in an irrational way.

Another negative consequence of redundancy on performance may be to draw subjects' attention to aspects of the task that interfere with learning of the external structure. This would be an analogue of the effects of redundancy found in studies of concept learning (Bourne & Haygood, 1959). A perfect correlation between the irrelevant attributes has a negative effect on performance in concept learning and a perfect correlation between relevant attributes has a positive effect. Thus, by variations in the form of redundancy both positive and negative effects on performance may be expected. The positive effects, however, are restricted to increased learning rate or to tasks where subjects do not reach an optimal level of performance e.g., suppressor tasks.

6.4 Form of redundancy

In addition to further studies of different forms of external structure (see section 3.1 and 3.3) it is also possible to study the effects of different forms of redundancy. The same amount of redundancy may vary in form. E.g., a certain amount of redundancy may be accomplished by variations in number of cues or by variations in the size and sign of the correlations in a total structure. The function relating cues may be linear or nonlinear etc. These are some examples of different

forms of redundancy that each might influence subjects' inference behavior.

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References

- Armeliuſ, B-Å., & Armeliuſ, K. Detection of cue intercorrelation and cue validities in a multiple-cue judgment task with a suppressor cue. Umeå Psychological Reports No. 74, 1973.
- Armeliuſ, B-Å., & Armeliuſ, K. The use of redundancy in multiple-cue judgments: Data from a suppressor-variable task. American Journal of Psychology, 1974, 87, 385-391.
- Armeliuſ, K., & Armeliuſ, B-Å. Confidence in multiple-cue judgments as a function of cue intercorrelation and task predictability. Umeå Psychological Reports No. 82, 1975 (a).
- Armeliuſ, K., & Armeliuſ, B-Å. Detection of cue intercorrelation in multiple-cue probability learning. Umeå Psychological Reports No. 84, 1975 (b).
- Armeliuſ, K., & Armeliuſ, B-Å. Note on detection of cue inter-correlation in multiple-cue probability learning. Scandinavian Journal of Psychology, 1975, 16, 37-41 (c).
- Armeliuſ, K., & Armeliuſ, B-Å. The effects of cue-criterion correlations, cue intercorrelations and the sign of the cue intercorrelation on performance in suppressor variable tasks. Umeå Psychological Reports No. 81, 1975 (d). (In press in *Organizational Behavior and Human Performance*).
- Armeliuſ, B-Å., & Armeliuſ, K. Combination rules in multiple-cue probability learning. II. Performance, confidence and development of rules. Umeå Psychological Reports No. 101, 1976 (a).
- Armeliuſ, B-Å., & Armeliuſ, K. Confidence and performance in probabilistic inference tasks with intercorrelated cues. Umeå Psychological Reports No. 96, 1976 (b).
- Bourne, L. E., & Haygord, R. C. The role of stimulus redundancy in concept identification. Journal of Experimental Psychology, 1959, 3, 232-238.
- Brehmer, B. Cue utilization in multiple-cue probability learning tasks with intercorrelated cues. Umeå Psychological Reports No. 45, 1971.

- Brehmer, B. Social judgment theory and the analysis of interpersonal conflict. Umeå Psychological Reports No. 87, 1975.
- Brehmer, B. Note on clinical judgment and the formal characteristics of clinical tasks. Psychological Bulletin, 1976. (In press.)
- Brunswik, E. Conceptual framework of psychology. Chicago: University of Chicago Press, 1952.
- Brunswik, E. Representative design and probabilistic theory in a functional psychology. Psychological Review, 1955, 62, 193-217.
- Chapman, L. J., & Chapman, J. P. Illusory correlation as an obstacle to the use of valid psychodiagnostic signs. Journal of Abnormal Psychology, 1969, 74, 271-280.
- Darlington, R. B. Multiple regression in psychological research and practice. Psychological Bulletin, 1968, 69, 161-182.
- Dudycha, A. L., Dudycha, L. W., & Schmitt, N. W. Cue redundancy: Some overlooked analytical relationships in MCPL. Organizational Behavior and Human Performance, 1974, 11, 222-234.
- Garner, R. W. Uncertainty and Structure as Psychological Concepts. John Wiley and Sons. Inc., New York, London, 1962.
- Hammond, K. R. Probabilistic functionalism: Egon Brunswik's integration of the history, theory, and method of psychology. In K. R. Hammond (Ed.). The psychology of Egon Brunswik. New York: Holt, Rinehart and Winston, 1966.
- Horst, P. The prediction of personal adjustment. Social Science Research Council Bulletin, 1941, No. 48, 431-436.
- Hursch, C. J., Hammond, K. R., & Hursch, J. L. Some methodological considerations in multiple-cue probability studies. Psychological Review, 1964, 71, 42-60.
- Kahneman, D., & Tversky, A. On the psychology of prediction. Psychological Review, 1973, 80, 237-251.
- Knowles, B., Hammond, K. R., Stewart, T., & Summers, D. Positive and negative redundancy in multiple cue probability tasks. Journal of Experimental Psychology, 1971, 90, 157-159.

- Knowles, B., Hammond, K. R., Stewart, T., & Summers, D. Detection of redundancy in multiple cue probability tasks. Journal of Experimental Psychology, 1972, 93, 425-427.
- Miller, M. J., & Sarafino, E. The effects of intercorrelated cues on multiple probability learning. Program on Cognitive Processes Report No. 128, Institute of Behavioral Science, University of Colorado, 1970.
- Muchinsky, P. M., & Dudycha, A. L. Human inference behavior in abstract and meaningful environments. Organizational Behavior and Human Performance, 1975, 13, 377-391.
- Naylor, J. C., & Clark, R. Human inference behavior as a function of validity magnitude and sign. Organizational Behavior and Human Performance, 1968, 3, 378-399.
- Naylor, J. C., & Schenck, E. A. The influence on cue redundancy upon the human inference process of task of varying degrees of predictability. Organizational Behavior and Human Performance, 1968, 3, 47-61.
- Nystedt, L., & Magnusson, P. Predictive efficiency as a function of amount of information. Multivariate Behavioral Research, 1972, 7, 441-450.
- Oskamp, S. Overconfidence in case-study judgments. Journal of Consulting Psychology, 1965, 29, 261-265.
- Schmitt, N. W., & Dudycha, A. L. A reevaluation of the effect of cue redundancy in multiple cue probability learning. Purdue University, 1975, (Unpublished.) (a).
- Schmitt, N. W., & Dudycha, A. L. Positive and negative cue redundancy in multiple cue probability learning. Memory & Cognition, 1975, 3, 78-84 (b).
- Slovic, P., & Lichtenstein, S. Comparison of Bayesian and regression approaches to the study of information processing in judgment. Organizational Behavior and Human Performance, 1971, 6, 649-744.
- Tolman, E., & Brunswik, E. The organism and the causal texture of the environment. Psychological Review, 1935, 42, 43-77.

Tolman, E. C., Ritchie, B. F., & Kalish, O. Studies in spatial learning.
II. Place learning versus response learning. Journal of
Experimental Psychology, 1946, 36, 221-229.