TOPOLOGICAL SPACE AND WORK SITUATIONS

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ABSTRACT

The structure and dynamics of goal oriented activity were considered with respect to particular task situations. An algebraic method was developed for the detection of the phenomenal parts or the sub-goals units within the activity structure. Further, the same method was used for the quantification of the extent to which the path to the goal was organized. These considerations led to the development of two hypotheses: one on the correspondence of the algebraic method to subjective experience, and another on preference for paths that were structurally similar to the task and were 'good' gestalts.

A cognitive model of locomotion was developed to account for the dynamics of a person's movement within the activity structure. The model was based on a numerical representation of the person's experience of locational changes in the course of the activity. The correspondence of the model to subjective experience was expressed in several hypotheses under a central theme of a preference

for the paths in which the differences between locomotional variations were maximized.

All hypotheses were tested in the context of four experiments. The first experiment was designed to test the structural hypotheses, and the other three experiments were conducted to examine the various aspects of the locomotional model. The results of these experiments supported the relevance of both the algebraic method as well as the model of the relation of locomotion to activity.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

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CHAPTER I

Introduction

In general, goal oriented activities may be characterized as being organized with respect to the goal and the environment surrounding the person. The purpose of this thesis is to study, in the context of particular task situations, the phenomenal nature of this organization, and the dynamic process of the person's movement through his environment.

Consider, for example, the task of painting a room. Given the repetitiveness of the task, two general questions are of interest. (1) Does the person perceive this task as a homogeneous activity, or are there certain substructures like, "I'll paint that wall first?"
(2) Assuming that the person is painting at a steady rate, does he experience a steady rate of progress, or are there certain systematic variabilities?

The psychologist who made the most contribution to a cognitive theory of goal oriented activity was Kurt Lewin. A major source of influence on Lewin was Franz Brentano with his phenomenalogical approach, who is considered as the father of act psychology. According to Boring (1950), Brentano considered acts as opposed to contents to be the proper subject matter of psychology. He proposed that the contents existed in the acts by the virtue of intention. For Brentano, perceiving was an activity, and it is of interest to note that Neisser (1976) views perception in much the same way. In fact, Neisser's criticism of the computer based models of information processing is rather similar to Brentano's opposition to structuralism, in the sense that both authors appeal to phenomenology.

Since the Lewinian approach is the fundamental thinking instrument of this thesis it will be worthwhile to consider briefly certain aspects of his theory that are directly relevant to this work. Lewin (1938) considered life space as a hodological space in which the immediate psychological environment is represented in terms of regions of activity. Hodological space is often conceptualized as being analogous to a rubber sheet which regardless of distortions maintains the connectivity among various parts of a structure. In this kind of space direction is either toward or away from a region, and psychological distance from one region to another is measured in terms of the number of intervening regions which constitutes a path between two regions. The differentiations within a region are called sub-regions;

the relationship between a region and the sub-region is relative and the particular structure of the life space at a given time determines what is perceived as a region and what as a sub-region.

Regions in the life space may have a positive or a negative valence, i.e. a scalor value which indicates the relative attractiveness of a region at a given time. A region with positive valence sets up a central force field of attraction in the life space, and a region with negative valence creates a force field which is repellent. Vectors are used to represent forces in the life space, and the vectorial analysis of the forces or the resultant force locomotes or moves the person from one region to another.

Based on Lewin's theory, the cognitive structure of goal oriented activities may be stated as follows: a person wants to move from one region of activity to another, say from the beginning of a task situation to its end; he constructs a path which is composed of a number of sub-regions. For example, coming to university in the morning means moving through a number of sub-regions such as: getting dressed, having breakfast, and driving to university. Among several paths, Lewin suggests, the path with maximum valence would most likely be selected.

One way a path may have a greater or less valence is the extent to which it is organized, or, in Lewinian terminology, the overall unity of the path.

Chapter 2 discusses the problem of structure of activity in more detail. Unity of the path is considered in terms of its degree of "redundancy", and an algebraic method is developed which describes the phenomenal organization of the path as well as quantifying the amount of redundancy for a given path.

The dynamics of locomotion, in Lewin's theory, are based on the notion of force fields. A person who wants to move to a goal region has a force acting on him in the direction of the goal. Assuming the absence of negative valences, the path itself may be thought of as a resisting force, and the degree of this resistance and the valence of the goal determine the tension in the system. The strength of goal force, assuming a constant goal valence, is a function of the distance to the goal, the greater the distance from the goal the smaller is the magnitude of the force. In other words, a different dynamic is operating depending on where the person is with respect to the goal. So the person who is painting a room, for example, would feel differently in the beginning, middle, and towards the completion of the task. It is this functional relationship between the goal force and distance that Lewin uses to explain Hull's goal-gradient hypothesis. The rat, for example, runs faster near the goal region as the result of a greater force.

The idea of forces has been a useful concept in providing insightful explanations of many situations such as conflict. However, in connection with the interest of this thesis there are two main shortcomings. First, the precise form of the function which describes the relationship between the goal force and distance is unspecified. Second, it is not at all clear how the goal force is distributed among the sub-regions, considering that sub-regions may well be viewed as sub-goals.

An analogy to physics helps to demonstrate the manner in which the dynamics of locomotion is treated in this thesis. This is particularly appropriate since Gestalt Psychology has always been fond of analogies between Physics and Psychology. In Physics, motion of a particle can be mathematically described in accordance with two different theories; Newtonian mechanics and variational mechanics (Lanczos, 1962). Newtonian mechanics relies upon the forces that are acting on the particle at a given time, and the vectorial analysis of these forces indicates the course of motion. Variational mechanics depends upon the "work function" or potential energy, and determines the actual path based on the "principle of least action". The work function is a set of partial differential equations, and the principle of least action is a time-integration of these functions that are maximum or minimum for the actual path of motion.

The important point is that it is possible to look at the dynamics of a moving particle without considering any forces whatsoever. Similarly it is possible, as shown in Chapter 3, to develop a numerical model of the locomotional variations that a person experiences while doing a task. The model considers and evaluates each change of location in the course of an activity with respect to the overall cognitive structure of the path. A tendency to prefer those paths that maximize the differences between locomotional variations is considered as a unifying hypothesis.

Miller, Galanter, and Pribram (1960) proposed a theory of purposeful behaviour. From the point view of structure of activity there is a great deal of fundamental agreement between their approach and Lewin's theory. However, they use a different language to describe the same natural phenomena. For example, they talk about plans, hierarchical structure of these plans, strategies, and tactics. When describing the same phenomena Lewin uses terms such as: the cognitive structure of the path, regions, and the extent to which a given region is differentiated. Miller et al regard the basic unit from which activities are constructed as a cybernetic unit of Test-Operate-Test-Exit (TOTE). In Lewin's theory the smallest phenomenal unit is called a cell and is defined as an undivided sub-region. The major difference between the two theories is in the attempt to replace the dynamic notions of force and tension with the idea of "working memory". The resumption of interrupted tasks, for example, is explained with this concept.

To recapitulate, the central focus here is on work situations that are basically repetitive. Based on Lewin's topological psychology a mathematical description of the cognitive structure of the path is developed with allows for the quantification of the degree of organization for a given path. The dynamics of locomotion through the task is represented by a numerical model, without appealing to forces, based on the person's experience of change in location. Finally, specific hypotheses are experimentally tested.

CHAPTER 2

Structure of Activity

The problem of structure, in general, is the problem of specifying phenomenal organization of 'parts' in the context of the 'whole'. In terms of the cognitive structure of the path to the goal, these part-whole relationships are expressed as regions and sub-regions. One fundamental property of regions and sub-regions is that they are, phenomenally, units of activity.

The process of path construction may be thought of as transforming a goal unit into a number of sub-goal units. In relation to a goal unit and to sub-goal units three problems require further consideration: (1) structure of a sub-goal unit, (2) levels of organization; and (3) structure of the path.

Structure of a Sub-Goal Unit

A sub-goal unit of activity is composed of one or more cells (i.e. the smallest phenomenal unit) which are temporally organized. One aspect of this temporal organization is the existence of a psychological 'beginning', 'middle', and 'end'. Consider, for example, the activity of walking to the library. Where does this walk 'begin'? Suppose the first step of the walk is defined as its beginning. But, where does the person experience himself to be in the second step of the walk? The point is that he will still be in the 'beginning' of his walk. In fact, there may be several steps which are perceived as the beginning of the walk. Similarly, several steps constitute the 'end' region, and the steps between these regions formulate the 'middle' of the walk.

These regions which internally structure a sub-goal unit are not completely segregated from one another, but rather they blend into each other. That is, there is no exact step, for example, in the course of the walk where the 'beginning' is finished and the 'middle' starts. Moreover, the smaller the size of the sub-goal unit (i.e. the fewer the cells) the greater is the blending between these internal regions. Later, it will be shown that it is possible to utilize the concept of locomotion in order to compute the approximate size of these regions.

Levels of Organization

Getting a book from the library may be perceived as a goal composed of sub-goals of walking to the library, finding the index card, and getting the book. However, the same activity of getting a particular book from the library may be seen as a sub-goal with respect to the goal of writing a paper, which in turn may be a sub-goal relative to the goal of achieving a good mark in a particular class and so on. In other words, there are many levels of organization in which phenomenal units are embedded in one another. It is this characteristic of hierarchical organization which allows for planning activities.

The particular level in the hierarchy determines the appropriate goals and sub-goals for that level. For example, the walk to the library is not perceived as a sub-goal for getting a good mark in the class. That is to say, there is a cognitive figure-ground relationship which selects the sub-goal units that belong to a given goal unit, and vice versa. Similarly, in perception, a line drawn on a piece of paper is seen as a figure with respect to the paper as the ground, and not as a figure relative to the desk as the ground.

Structure of the Path

Given a goal in the context of a task situation, a person constructs a particular path or a way of doing the task from a set of possible paths. To specify the cognitive structure of a particular path, it is necessary to identify the sub-goal units, and examine their relationship to one another. Furthermore, a general hypothesis is required to explain why some paths have a higher probability of occurrence than others.

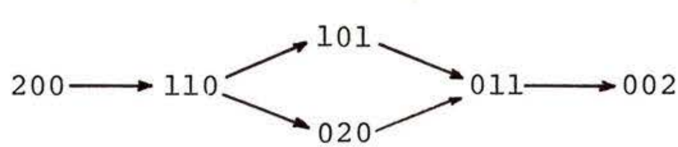
There are two ideas which are useful in determining the cognitive structure of activity. First, the gestalt principles of organization or the law of Pragnanz (Koffka, 1935), on the basis of which groupings within as well as between the sub-goals may be considered. Also a tendency to form those paths which are characterized as 'good' gestalts. Second, there is the notion of similarity between the physical lay-out of the environment and the structure of activity (Barker, 1968).

Later, a hypothesis is formulated based on the combination of these ideas. However, at this point the basic task situation will be considered in order to proceed with the analysis of a concrete situation.

Basic Task Situation

Consider m objects and n spaces. The spaces may be connected to one another or unconnected. The goal is to move the objects from one specified arrangmenet to another by a sequence of steps. A step is defined as the movement of one object to an adjacent space in the direction of the goal.

The number of possible paths can be determined by either a tree diagram or a computational formula based on combinatoric principles. Tree diagrams are a systematic way of keeping track of the possibilities at the choice points. For the present task, the situation may be represented by a numbering system in which the n spaces are shown with n+1 zeros (the extra zero is for the initial state), and the m objects with numbers from 0 to m, corresponding to possible distributions along the way. For example, for m=n=2, with the initial state of 200 and the final state of 002, the following tree diagrams may be drawn for the two possible paths.



The problem with a tree diagram is that it is limited to situations in which the number of possible paths are relatively small. It is practically impossible to draw a tree diagram for thousands of possible paths, as it is the case for larger values of m and n. For example, for m=n=4, there are 24,024 possible ways of doing the task. Bowden and Smith (1978) have developed the following formula which can directly compute the number of possible paths for m indistinguishable objects.

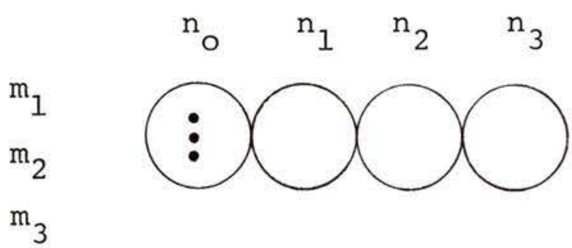
$$n\,(m,n) = (nm)!\ .\ \prod_{i=o}^{n-1} \frac{i!}{(m+i)!}$$

The next two sections are devoted to the development of an algebraic method in the context of which sub-goals are detected, structure of the path is quantified, and relevant hypotheses are formulated.

A Method For Detecting Sub-Goal Units

The objects are enumerated from m_1 to m_m, and the spaces from n_o to n_n. The lower values of m and n denote the number of objects and the number of spaces respectively. Each step is shown as $m_i n_j$ referring to a particular object which has been moved to a particular space. The path is represented as an algebraic statement in terms of the summation of the time-ordered sequence of steps leading to the goal. Note that the order of the steps, unlike algebra, cannot be changed.

Consider, for example, the situation in which m=n=3. All objects are located in n_o and are to be moved to n_3. In this kind of situation, which is the basic arrangement considered in this thesis, there are m.n steps. The number of possible paths is 42. For illustrative purposes consider the following two paths: path one (P_1) involves moving the first object to the end, and repeating the process for the remaining objects; path two (P_2) consists of moving all of the objects one space, and then moving each one to the end. The algebraic statements for these paths are written in the following form.



$$P_1 = m_1n_1+m_1n_2+m_1n_3+m_2n_1+m_2n_2+m_2n_3+m_3n_1+m_3n_2+m_3n_3$$

$$P_2 = m_1n_1+m_2n_1+m_3n_1+m_1n_2+m_1n_3+m_2n_2+m_2n_3+m_3n_2+m_3n_3$$

One of the ways in which phenomenal sub-goals are formed, like other groupings, is based on similarity. In the context of the present task, there are two ways in which two or more steps may be similar to one another; either on the basis of a common object, or in the sharing of a common space. It is possible to factor out the common elements in the algebraic statement. Thus, P_1 and P_2 may be rewritten as:

$$P_1 = m_1(n_1+n_2+n_3) + m_2(n_1+n_2+n_3) + m_3(n_1+n_2+n_3)$$

$$P_2 = (m_1+m_2+m_3)n_1 + m_1(n_2+n_3) + m_2(n_2+n_3) + m_3(n_2+n_3)$$

Two or more steps that are, algebraically, in a multiplicative relationship to one another are called an expression. For example, $m_1(n_1+n_2+n_3)$ is an expression composed of three steps.

It is worth noting that there is a direct correspondence between a person's verbal description of the path and the expressions. For example, in the case of P_1, a person may say; "I moved the first object all the way down." In the expression $m_1(n_1+n_2+n_3)$, the "first object" is represented by m_1 and "all the way down" by $(n_1+n_2+n_3)$.

For any path it is possible to detect the sub-goal units by the factoring procedure. A hypothesis concerning the formation of sub-goal units may be stated as follows:

> *Hypothesis I:* There is a tendency to perceive those groupings of steps as sub-goal units which correspond to the factoring method.

Quantification of Path Structure

The first level of factoring was based on the similarity between the steps. A second level of factoring is a way of detecting the similarity between the sub-goal units. As the result of the second level of factoring paths one and two can be written as:

$$P_1 = (m_1+m_2+m_3) \quad (n_1+n_2+n_3)$$

$$P_2 = (m_1+m_2+m_3)n_1+(m_1+m_2+m_3) \quad (n_2+n_3)$$

The algebraic statement at the second level of factoring may be thought of as a general description of the path. For example, P_1 may be read as; "moving all the objects all the way down." The number of expressions in the statement represents the extent to which the path is segmented. In other words, the less the number of expressions, the greater is the 'goodness' or unity of the path.

In gestalt theory, two sets of organizing forces have been postulated; those that tend to unify, and those which tend to restrain this process (Koffka, 1935). The interaction between these forces results in a state of minimum energy, which is the simplest possible form under the prevailing conditions. There are different levels of minimum energy depending upon the strength of the unifying forces. The greater the strength of the forces of unification, the more stable is the resulting structure, and the amount of energy or tension is further reduced.

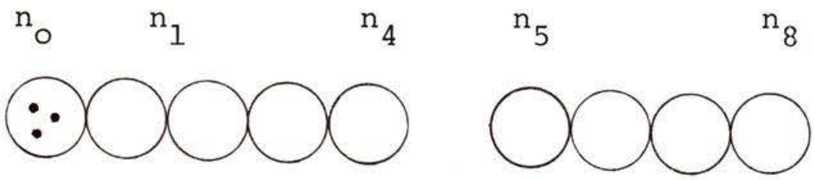
Thus, a 'good' gestalt has a smaller energy level than an alternative organization of the same elements. A statement with a single expression (P_1) may be considered to have less energy than (P_2) which has two expressions, since in P_1 all of the steps have been unified. That is, a greater force of unification because of a greater degree of similarity between the steps.

It is also possible to describe 'good' gestalts as those forms that have a high degree of redundancy (Attneave, 1954). Redundancy is the extent to which a signal repeats the same message. Thus, part of a redundant pattern may reduce the uncertainty about the entire pattern.

The proposition is that the amount of redundancy within the cognitive structure of activity can be quantified in terms of the number of expressions in the algebraic statement after the second level of factoring. More specifically, the degree of redundancy of a given path has an inverse relationship to the number of expressions. For convenience, let $r = \frac{1}{N(e)}$, where r refers to the degree of redundancy and N(e) to the number of expressions. The value of r may vary from 1 to $\frac{1}{(m.n)-2}$, since there are unavoidable groupings at each end.

This measure of redundancy may be validated independently either by correlating it with the minimum number of words required to describe a path, or the amount of time required to learn a path. In other words, the more redundant paths would be described in less words, and would be learned faster. It is also possible to let a person guess the steps of a path, the more redundant paths would result in fewer errors.

In light of the above considerations a hypothesis based on gestalt theory may be stated is terms of a tendency to construct those paths that are maximally redundant. However, this hypothesis by itself is insufficient to account for two kinds of cases. First, systematic preference of people for one of the two paths with identical r values. For example, for m=n=3, it is possible to select a path (P_3) which involves moving all the objects one space, and repeating the process. This path, which is seldom selected, has an r=1 which is identical to the r value for P_1. Second, selecting paths with lower r values for certain configurations. For instance, for m=3, n=8, with a break between n_4 and n_5, consider the following two paths written after the second level of factoring as:



$$P_4 = (m_1+m_2+m_3)(n_1+n_2+n_3+n_4+n_5+n_6+n_7+n_8)$$

$$P_5 = (m_1+m_2+m_3)\ (n_1+n_2+n_3+n_4) + (m_1+m_2+m_3)\ (n_5) + (m_1+m_2+m_3)\ (n_6+n_7+n_8)$$

One path (P_4) consists of moving the first object to n_8, and repeating the process. This results in an r value of one. In the other path (P_5), the objects are moved, one at a time, to n_4; then all objects are moved to n_5; and finally they are taken to n_8 one by one. This path, which is often preferred, has an r value of 1/3.

Barker's notion of similarity between structure of activity and task structure has already been introduced. This similarity may be thought of as a correspondence between the units of activity and the task structure. Thus, for the above cases; the sub-goal units of P_1 correspond to the beginning and the end of the task structure which are spatial locations, and P_5 is constructed to map onto the two segments of the task, each with its own beginning and end. Note that the second segment is structured to match the activity in the first segment. That is, n_5 is the initial state for the second segment or a second n_o, and n_6 a second n_1. In other words, the similarity between the activity structure and the task structure is a two way street; task structure shapes the activity structure, and in turn the activity structure shapes the task structure.

Task structures that are segmented can be easily incorporated in the algebraic framework. The different segments of the task structure may be represented as different classes of n (e.g. n', n") where grouping of steps between classes do not occur.

A general hypothesis concerning which paths are most likely to be selected may be stated as follows:

> *Hypothesis II:* There is a tendency to construct those paths that are similar to the task structure and are maximally redundant.

Psychological Domain of Possible Paths

It is worth pointing out that the psychological domain of possible paths is larger than the number of possible paths that are computed by either the tree diagram or the formula. The reason is that in computing the number of possible paths the objects are considered to be indistinguishable, whereas in the course of the activity they become distinguishable with respect to a particular sub-goal.

Consider a path, for n=m=2, which may be represented as: 200 ⟶ 110 ⟶ 020 ⟶ 011 ⟶ 002

Psychologically, this corresponds to two different paths which may be written as:

$$P_1 = m_1n_1+m_2n_1+m_1n_2+m_2n_2$$

$$P_2 = m_1n_1+m_2n_1+m_2n_2+m_1n_2$$

Factoring for sub-goal, the paths are represented as:

$$P_1 = (m_1+m_2)n_1+(m_1+m_2)n_2$$

$$P_2 = m_1n_1+m_2(n_1+n_2)+m_1n_2$$

P_1 may be described as moving both objects one space, then another. In P_2, the first object is moved one space, the second object is taken to the end, and finally the first object is moved to the end.

This suggests another way of testing the redundancy hypothesis. The steps of a given path may be presented in a sequence. The subject will be asked to learn the sequence. The prediction is that the most redundant path will be learned. Thus, in the above example the subject will learn P_1 with an r value of 1 as opposed to P_2 which has an r value of 1/3.

CHAPTER 3

A Mode of Locomotion

The concept of locomotion refers to a person's movement within the activity structure. Locomotion in the life space does not necessarily correspond to physical movement. For example, when the solution to a particular puzzle is discovered, the person locomotes to the goal region. However, it is possible to set up situations in which there is a relationship between physical movement and locomotion. The nature of this relationship is the primary concern of this chapter.

The task of moving m objects through n spaces is composed of a number of physically identical steps. Under the assumption of a direct linear relationship between the steps and locomotion, a person should experience a steady rate of movement toward the goal by a series of steps that are alike. Phenomenally, however, steps are not alike; there are those steps, for example, which complete the sub-goal units, or steps which are the beginning of sub-goal units, and so on. In other words, locomotion corresponding to a particular step must be considered relative to the environment in which it occurs, namely, the cognitive structure of the path to the goal.

Consider, for example, the situation in which two individuals are in a similar job situation. The only difference is in the quantity of the work; person A is supposed to stamp two letters, whereas person B is to stamp twenty letters. Suppose each person has stamped one letter. Physically, it can be assumed that they have done the same amount of work. But, psychologically, person A may feel that he is half way through his job, whereas person B may experience a small difference in the total job situation. In other words, as the result of the same amount of physical work person A has locomoted more than person B.

A Numerical Model

The attempt of the model is to numerically evaluate the amount of locomotion or change resulting from the steps in the context of the activity structure. In order to do this the following assumption is made.

> *Assumption:* The amount of locomotion associated with a single step is equal to the proportion of change in distance to the goal.

Consider, for example, the case of m=1, and n=4, which is, structurally, a single goal unit. The first step changes the distance by 1/4, the second step by 1/3, the third step by 1/2, and the last step by 1. In other words, how much a given step accomplishes depends on the number of remaining steps, the greater the number of remaining steps, the smaller is the accomplishment of a step.

The fraction assigned to a particular step, based on the above assumption, is called the *Locomotional Value (LV)* of that step. It is worth pointing out that the basic procedure is applicable not only at the level of steps within a sub-goal, but also at the level of sub-goals within a goal.

Structurally, a sub-goal unit consists of a number of steps that are linked together. In terms of locomotion, this linkage corresponds to an experience of change in the locomotional values as opposed to the experience of a number of locomotional values independent of one another. That is, there is a relativity of locomotion based on the differences between the locomotional values of consecutive steps. In the above example the differences are as follows: (1/4-0), (1/3-1/4), (1/2-1/3), and (1-1/2). These differences are referred to as *Relative Locomotion (RL)*. The distribution of the RL values is considered to be an analogue to the person's experience of locomotion within the activity structure. This basic idea of the model may be expressed as a hypothesis.

> *Hypothesis III:* There is a direct correspondence between the properties of the RL distribution and the experience of locomotion within a path.

The functional relationship between the RL values and the steps for m=1, and n=4 is presented in Figure 1. The peaking of RL values toward the goal may be considered as understandable because of its resemblence to Lewin's goal force or Hull's goal gradient. That is, something is building up as a person approaches the goal. But, why should the RL for the first step be greater than the RL for the middle two steps? The RL for the first step was obtained by comparing the LV of the first step with zero or a state in which no step has yet been taken. Phenomenally, the larger value of RL for the first step corresponds to the significance of "getting started", i.e. an orientation with respect to the beginning of the task. Dennis (1935) re-interprets Hull's findings on speed of running in an alley and writes, " . . . the hypothetical excitation gradient also fits the data much better if it is measured from the entrance of the apparatus than if measured backward from the goal."

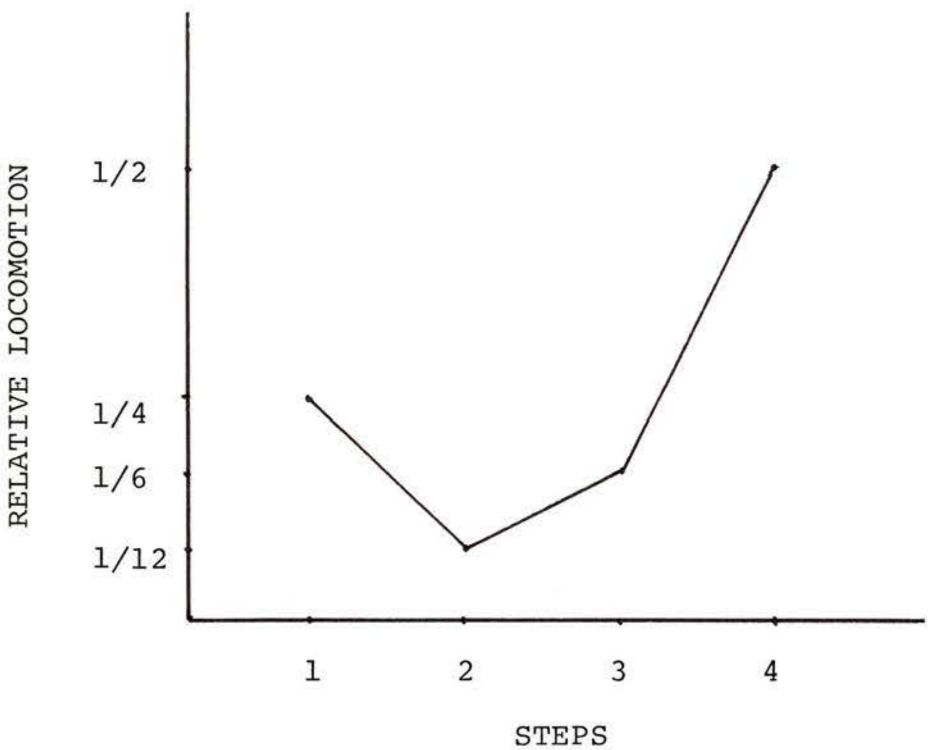


Figure 1. Relative Locomotion as a Function of Number of Steps for m=1, and n=4

Consider the following example of computing the values of RL for the case of m=3, and n=4. Suppose the activity structure is one of moving the objects, one at a time, to the end space or the goal. There are two levels; the number of objects represents the number of sub-goals, and the number of spaces represents the steps within each sub-goal. Thus, in the object dimension the LV's are 1/3, 1/2, and 1, and in the space dimension they are 1/4, 1/3, 1/2, and 1. These values can be used in a two dimensional matrix for computation of the LV of each step with respect to the activity structure (see Table 1). The values within the matrix are the result of multiplying the corresponding values for the objects by the values for the spaces. For convenience, the numbers in the matrix may be written as percentages (e.g. 50 instead of 1/2). The values of RL are calculated by performing subtractions between the numbers in each row, and are summarized into an average which allows for comparison among different situations. In the above example the Avg. RL=15.28.

A similar procedure may be used for computing the RL values for tasks that are segmented. For example, for the case of m=1 in a task composed of a 4-space segment followed by a 2-space segment, since each segment represents a sub-goal unit the locomotional value of the 4-space

Table 1

Computation of the Locomotional Value For Each Step in m=3, and n=4

SPACES

OBJECTS	0	1/4	1/3	1/2	1
1/3	0	1/12	1/9	1/6	1/3
1/2	0	1/8	1/6	1/4	1/2
1	0	1/4	1/3	1/2	1

segment is 4/6 and the locomotional value of the 2-space segment is one. The LV's of the steps within the activity structure may be computed by multiplying the LV's of the steps with each segment by the LV of that segment. The RL distribution is calculated by performing substractions between the LV's of each segment.

In comparing segmented tasks, involving identical number of steps with different average RL values, one rule must be observed. The LV of the last step of the preceding segment should be larger than the LV of the first step of the following segment. If this condition is not met the break between the segments is described by subjects as being "stupid". This condition ordinarily occurs when one of the segments is relatively small (e.g. a 5-space segment followed by a 1-space segment).

In general, larger values of RL correspond to the experience described by subjects as; "easy", or "fast". And, smaller values of RL are referred to with words such as: "slow", or "hard". A general hypothesis may be stated as follows:

> *Hypothesis IV:* Among two or more task situations that are identical in total number of steps as well as the degree of path redundancy, there is a tendency to prefer those task situations in

which the amount of relative locomotion toward the goal is maximized.

Unspecified Goal

Consider a situation in which there are a finite number of objects and an infinite number of spaces. A person's job may be such that he is to move the first object for as many spaces as he likes, repeat the process for the remaining objects so that they are all together, and then repeat the entire cycle. The question is what determines how far the first object would be taken.

Since there is no goal and the process is continuous, the person's behaviour cannot be understood in terms of maximizing the RL values. However, the person may set the goal such that it would minimize the difficulty of locomotion - in other words, a minimum tolerable level of RL. Based on the idea of minimum RL the following hypothesis is formulated:

Hypothesis V: When the goal is unspecified, there is a tendency to set the goal such that a minimum tolerable RL is not exceeded.

It is possible to compute the minimum RL after the goal has been set for a given number of objects, and predict, for the same person, the number of spaces or an approximate location of the goal for a *different* number of objects. For example, suppose for m=2 the person sets the goal at n=8. The minimum RL is given by the difference between the first and the second step of the first sub-goal unit.

$$\text{Minimum RL}=1/2(1/7-1/8)=1/112$$

For m=5, n=? an equation can be set up in which the minimum RL is expressed in terms of the unknown n, and then the equation is solved for the minimum RL from the previous condition.

$$1/5(1/n-1-1/n)=1/112$$

or

$$5n^2-5n-112=0$$

$$n=5.25$$

This means that if the person sets the goal 8 spaces away for 2 objects, he should set the goal about 5 spaces away for 5 objects.

The Size of 'Beginning', 'Middle', and 'End'

From the present discussion it is clear that the first step of a unit has a greater RL value than the steps in the middle. But the beginning, especially for longer units, is not limited to the first step. That is, the beginning may consist of several steps. Thus, the higher value of the RL may not be located just in the first step, but rather distributed in the beginning region. It may be assumed that this distribution has the same form as the distribution with respect to the goal, except the values are in a decreasing order. Therefore, for longer sub-goal units there are two RL distributions; one for the beginning, and another for the goal.

Phenomenally, to be in the beginning region means that the person still has some orientation relative to the point of departure, the beginning region ends when this orientation no longer exists. In terms of the two RL distributions; at the beginning, the RL of the steps is the contribution of the beginning distribution, and then a switch to the goal distribution. The switch occurs when the two distributions cross each other. That is, a step which has a greater RL value with respect to the end than relative to the beginning.

Consider, for example, the situation in which m=1, and n=8. The values LV and RL are as follows:

Steps	1	2	3	4	5	6	7	8
LV	1/8	1/7	1/6	1/5	1/4	1/3	1/2	1
RL	1/8	1/56	1/42	1/30	1/20	1/12	1/6	1/2

The values of LV and RL with respect to the beginning are as follows:

Steps	1	2	3	4	5	6	7	8
LV	1/8	1/16	1/24	1/32				
RL	1/8	1/16	1/48					

In this example the third step has a RL=1/42 in the goal distribution which is greater than RL=1/48 in the beginning distribution. Thus, the beginning region ends at the third step.

Based on the above considerations, a hypothesis regarding the size of the beginning region may be stated as follows:

> *Hypothesis VI:* There is a tendency to perceive those steps as the 'beginning' that have a greater RL value with respect to the beginning than with the goal.

Computation of the size of the end region is based on the idea that the RL values reach a peak in this region. Thus, the beginning of the end region is when the first value of RL occurs which is greater than the RL for the first step. In the above example the end region begins at the 7th step with the RL=1/6 which is greater than the RL=1/8 of the first step.

Hypothesis VII: There is a tendency to perceive those steps as the 'end' that have a greater RL value than the first step.

Theoretically, the beginning distribution should be taken into account for the computation of the average and minimum RL values. However, for shorter paths the difference is negligible and the computational procedures are much simpler if they are based on the first step as the representative of the beginning distribution.

CHAPTER 4

Experimental Predictions

The purpose of this chapter is to discuss the behavioural concomitants of the hypotheses. For the convenience of the reader a list of all hypotheses is provided in Table 2. Some of the predictions have been either already mentioned, or they directly follow the statement of the hypothesis. Thus, certain parts of the following material are redundant.

Hypothesis I

This hypothesis was concerned with the correspondence between the phenomenal units and the factoring method. Several predictions can be based on this hypothesis.

1. Subject's verbal description of the activity should match the algebraic description. That is, a similarity in a way the two descriptions are punctuated. For example, a plus which punctuates the algebraic description should correspond to words such as: 'then' or 'and finally'.

2. In order to preserve the identity of the phenomenal units they should be segregated from one

Table 2

A List of All Hypotheses

Hypothesis	Statement
I	There is a tendency to perceive those groupings of steps as sub-goal units which correspond to the factoring method.
II	There is a tendency to construct those paths that are similar to the task structure and are maximally redundant.
III	There is a direct correspondence between the properties of the RL distribution and the experience of locomotion within a path.
IV	Among two or more task situations that are identical in total number of steps as well as the degree of path redundancy, there is a tendency to prefer those task situations in which the amount of relative locomotion toward the goal is maximized.
V	When the goal is unspecified, there is a tendency to set the goal such that a minimum tolerable RL is not exceeded.
VI	There is a tendency to perceive those steps as the 'beginning' that have a greater RL value with respect to the beginning than with the goal.
VIII	There is a tendency to perceive those steps as the 'end' that have a greater RL value than the first step.

another in time by a pause. Thus, the time interval between the last step of one unit and the first step of the next unit should be longer than the time interval between any two steps within the units.

3. Since there is a natural pause between sub-goal units, subjects should prefer interruptions that are located between the sub-goal units as opposed to within a unit.

Hypothesis II

The following predictions are based on the idea of constructing maximally redundant paths that are similar to the task structure.

1. Subjects should prefer to move a number of objects from one location to another by choosing a maximally redundant path.

2. A path with low degree of redundancy should be constructed if the subjects are asked to move the objects in an unusual way.

3. For segmented task structures, the subject should unitize the activity structure not only to match the task structure but also to match itself.

4. The paths with greater degree of redundancy should be learned faster and require fewer words for their descriptions.

5. Subjects may be presented with a sequence of pictures each corresponding to a step and asked to learn the sequence. The steps may be grouped together in different ways thus resulting in paths with different degrees of redundancy. The subject should learn the path with the greatest degree of redundancy among the possible ways of organizing the steps.

Hypothesis III

There are a number of predictions that can be based on the correspondence between the RL distribution and the experience of locomotion.

1. Subject's verbal description should match the RL distribution. Those regions of the path that have a larger RL value should be described as being faster than the regions with smaller RL values which should be perceived as being slow.

2. For relatively longer paths the 'middle' or the region with a lower RL value should correspond to a behaviour that may be characterized as being disorganized and impatient. This behaviour should be more apparent when the task is demanding. Consider, for example, the task of making equal time intervals by reading a paragraph to yourself with a constant pace. Under these conditions

the subject should subjectively locate his errors in the middle region and report the type of the errors as making shorter time intervals as opposed to longer time intervals. The subject should not report any errors for the beginning and the end regions which have larger RL values.

3. The objective measurement of the time intervals should indicate a greater amount variability for the middle region than the beginning or end regions.

Hypothesis IV

This hypothesis was concerned with a tendency for selecting a path with maximum RL values over other possible configurations with equal number of steps. The following predictions are based on this hypothesis.

1. A given task situation consisting of certain steps may be set up for various values of m and n such that the total number of steps remain constant. The average RL can be computed for each condition, the subject should prefer the task with maximum RL value.

2. A given number of spaces may be segmented in various ways resulting in a set of configurations with different average RL values. The subject should indicate a preference for the arrangement with maximum average RL value.

3. Subjects should choose a step with maximum RL value among a number of steps each with a different RL value. For example, the subject may be presented with a configuration in which two objects are distributed such that movement of one would result in greater RL than the movement of the other object.

Hypothesis V

The basic idea of locating the goal on the basis of a minimum RL value predicts where the subject should locate the goal for a certain number of objects. This prediction is based on where the same subject sets the goal for a different number of objects.

Hypotheses VI and VII

These hypotheses made predictions about the size of the beginning and end region based on the properties of the RL distribution. Another prediction is that the subject should be oriented toward the end region when the beginning ends. This change of orientation may be observed in a momentary movement of the eye-head system toward the goal.

CHAPTER 5

Experiments

The four experiments that are described in this chapter were carried out in a single session. Twelve subjects participated in these experiments. All subjects were university students. Upon their arrival the subjects were informed that they would be taking part in four small experiments. Each subject was tested individually. The entire session lasted about an hour.

The only experiment that could have been affected by the order of the four experiments was carried out as the first experiment. The order of the other three experiments was the same as their order of appearance in this chapter.

Experiment I

This experiment was designed to test the first two hypotheses. The experiment consisted of three parts:
(a) a task of moving 4 objects through 5 spaces;
(b) indicating an unusual path with respect to the same task structure; and (c) describing paths for three different segmented task structures that were drawn on a card.

The purpose of the experiment was to provide information concerning the kind of path that would be constructed by the subject, as well as the formation of the sub-goal units, their verbal descriptions, and the time intervals between the steps.

Method

Apparatus

The apparatus consisted of a sheet of paper (37.5 cm x 86 cm) that was taped to a desk. Six connected circles each 6 cm in diameter were drawn on this paper such that they formed the lower arc of a larger imaginary circle 50 cm in diameter. A metal box (5 cm x 4 cm x 7 cm) was located in the center of the large circle (see Figure 2). On top of the box there was a black cylindrical button (height = 1 cm). The button was connected to a tone generator which in turn was connected to a tape recorder. Each time the button was pushed a silent tone was recorded on the tape. The four objects to be moved (0.5 cm x 1 cm x 1 cm) were made of hard colourless plastic with the top side (0.5 cm x 1 cm) painted black.

There were also three cards (10 cm x 15 cm) which were used for the third part of the experiment. On each card a number of circles with a diameter of 1 cm was

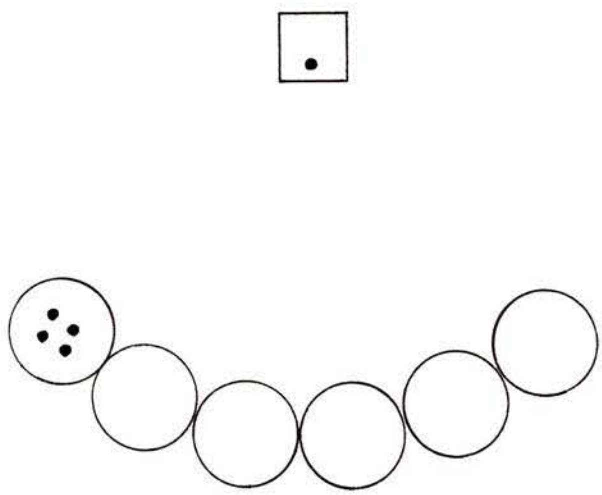


Figure 2. Schematic Representation of the Task Situation in Experiment I

drawn in a straight line. The arrangements of the circles were: (1-3-1-3), (5-5), and (1-4-4); the numbers refer to the number of connected circles. The distance between the unconnected circles was 1 cm. There were three filled in dots, representing objects, located in the far left circle of each card (for pictures of these stimuli see Table 3, Part III, Page 46A).

Procedure

The subjects were seated behind the desk. For the first part of the experiment, the task of moving 4 objects through 5 spaces was explained to them. The subjects were told that they were supposed to move the objects, which were located on the far left circle, to the circle on the far right, one step at a time, and should push the button after each step with the same hand. The complete instructions to the subject are presented in Appendix A. When the subjects reported that they were ready to start the task, the tape recorder was turned on.

Upon completion of this part of the experiment, the subjects were asked to verbally describe the way they performed the task such that another person could perform it. For the second part of the experiment the objects were moved back to their initial state and the subjects were asked to construct an unusual path.

In the last part of this experiment, the three cards were presented in a random order and the subjects were asked to describe a path that most people would select for moving the objects from where they were to the circle on the far right.

Results

All 12 subjects selected the same path. They moved the first object to the end space and repeated the process for the remaining objects. That is, a path with maximum degree of redundancy ($r = 1$). This result was significant ($p < .001$), using binomial expansion based on the probability of the selected path occurring by chance.

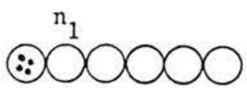
The verbal descriptions of the path were highly consistent among the subjects. This description corresponded to the algebraic description of the sub-goal units (see Table 3, Part I).

The time intervals between the steps were analyzed in two different ways. First, for each subject the time interval between two sub-goal units (T_b) was compared to the time intervals within (T_w) either units. A one-tailed binomial test on the frequency of times that T_b was greater than T_w was significant ($p < .003$) for

Table 3

Experiment 1 - Description of the Selected Paths

Part 1



Verbal description - I moved one of the objects to the end space, then moved another one to the end, then moved the third object to the end, and finally moved the last object to the end.

First level of factoring $P = m_1 (n_1+n_2+n_3+n_4+n_5) + m_2(n_1+n_2+n_3+n_4+n_5) + m_3(n_1+n_2+n_3+n_4+n_5) + m_4(n_1+n_2+n_3+n_4+n_5)$

Second level of factoring $P = (m_1+m_2+m_3+m_4)(n_1+n_2+n_3+n_4+n_5)$

Degree of redundancy $r = 1$

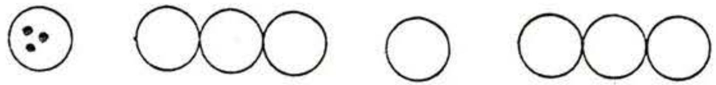
Part II

Verbal description - I move one of the objects two spaces, then move another one one space, then move the first one one more space, then move another object one space, then move this (m_2) two spaces, then move the last object two spaces, then move this (m_3) one space, then move the last one one more space, then move this (m_2 or m_3) to the end, then move this one (m_1) to the end, then move the last one two more spaces, then move this one (m_3) to the end, and finally move this (m_4) to the end.

Algebraic description $= m_1(n_1+n_2)+m_2n_2+m_1n_3+m_2n_1+m_2(n_3+n_4)+m_4(n_1+n_2)+m_3n_3+m_4n_2+m_2(n_4+n_5)+m_1n_5+m_4(n_3+n_4)+m_3(n_4+n_5)+m_4n_5$.

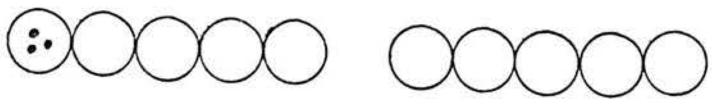
Degree of redundancy $r = 1/13 = .07$

Part III

(a) 

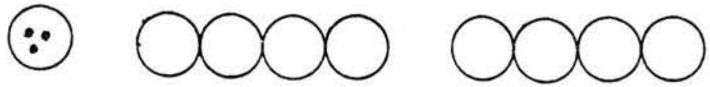
$$P = (m_1+m_2+m_3)(n_1+n_2+n_3)+(m_1+m_2+m_3)n_4+(m_1+m_2+m_3)(n_5+n_6+n_7)$$

$r = 1/3$

(b) 

$$P = (m_1+m_2+m_3)(n_1+n_2+n_3+n_4)+(m_1+m_2+m_3)n_5+(m_1+m_2+m_3)(n_6+n_7+n_8+n_9)$$

$r = 1/3$

(c) 

$$P = (m_1+m_2+m_3)(n_1+n_2+n_3+n_4)+(m_1+m_2+m_3)(n_5+n_6+n_7+n_8)$$

$r = 1/2$

every subject in the predicted direction (see Table 4). And second, two distributions were formed by grouping the results across the subjects, one for T_b and another for T_w. The time intervals between the sub-goal units were longer than the time interval within the units ($t=5.44$, $p < .0005$).

In the second part of the experiment the subjects constructed different "unusual" paths. However, there were several common features to all unusual paths: (1) All unusual paths had a low degree of redundancy; (2) the verbal descriptions corresponded to the factoring method; and (3) all subjects when asked to repeat their "unusual" path reported that they could not do the same exact path again. A typical example of an unusual path is presented in Part II of Table 3.

In the third part of the experiment with "segmented task structures", 10 of the 12 subjects selected paths which corresponded to the task structures as well as to the activity strucutre itself ($p < .001$). Part III of Table 3 gives the algebraic descriptions and the degree of redundancy for these paths.

Table 4

Experiment I. Distribution of the Time Intervals Between Steps

Subjects	Time Intervals in Seconds	Comparisons		
		$T_b > T_w$	$T_w > T_b$	P
1	2.7 2.1 2.4 2.2 2.5 2.2 2.1 2.1 2.1 2.3 2.2 2.1 2.5 2.5 2.5 2.3 2.1 2.3 2.2	19	5	.003
2	1.5 1.5 1.4 1.5 2.0 1.6 1.6 1.6 1.6 1.9 1.7 1.6 1.7 1.7 2.1 1.8 1.8 1.7 1.9	24	0	.001
3	2.7 1.6 1.6 1.5 1.9 1.5 1.4 1.4 1.4 1.8 1.5 1.4 1.4 1.4 1.6 1.4 1.4 1.3 1.4	23	1	.001
4	1.7 1.8 1.9 1.8 2.0 1.5 1.6 1.6 1.7 1.8 1.7 1.6 1.7 1.8 1.9 1.5 1.6 1.6 1.7	23	1	.001
5	1.6 1.5 1.5 1.3 1.9 1.3 1.4 1.3 1.3 1.7 1.3 1.3 1.2 1.3 1.7 1.3 1.4 1.3 1.3	24	0	.001
6	1.8 1.8 1.8 2.0 2.6 1.9 1.8 1.9 2.1 2.1 1.8 1.9 1.7 1.9 2.2 1.7 1.8 1.8 2.2	22	2	.001
7	2.2 2.0 1.7 1.7 2.2 1.5 1.5 1.7 1.7 2.3 1.7 1.3 1.4 1.5 1.8 1.5 1.3 1.5 1.6	23	1	.001
8	2.9 2.1 1.9 2.2 2.8 1.8 1.9 2.2 2.2 2.4 1.8 1.8 1.9 2.1 2.4 1.9 2.0 2.1 2.5	22	2	.001
9	2.4 2.3 2.3 2.4 2.6 2.3 2.2 2.4 2.5 2.5 2.2 2.3 2.4 2.4 2.6 2.1 2.4 2.4 2.4	23	1	.001
10	1.7 1.6 1.7 1.7 2.0 1.7 1.7 1.8 1.7 1.8 1.5 1.5 1.6 1.8 1.8 1.5 1.5 1.5 1.5	21	3	.001
11	2.5 2.1 2.1 2.2 2.4 2.0 1.9 1.8 2.1 2.6 1.9 1.9 2.0 2.1 2.7 1.9 1.9 1.8 2.0	23	1	.001
12	1.6 1.6 1.7 1.7 2.0 1.8 1.7 1.7 1.7 1.9 1.5 1.4 1.5 1.5 1.7 1.3 1.4 1.4 1.5	24	0	.001

T_b = Time interval between units   mean T_b = 2.14

T_w = Time interval within units   mean T_w = 1.79

P = One tailed probabilities for the binomial test   t = 5.44

Discussion

The results support the first two hypotheses in several ways. First, the verbal descriptions were punctuated in a similar manner as the algebraic descriptions. This correspondence between the sub-goal units and algebraic statements were also shown by the longer time interval between the sub-goal units. Second, selection of the path with maximum redundancy such that the beginning and end of the activity units corresponded to the task structure, supported the second hypothesis. Third, 'unusual' paths with low degree of redundancy that were practically impossible to remember supported the validity of the redundancy measure, and provided a perspective for the natural tendency in constructing paths. Fourth, paths which were constructed in response to segmented tasks supported the notion of a two-way similarity between task structure and activity structure.

For segmented task structures, although the selected paths had a high degree of redundancy none of the paths were maximally redundant. However, under the prevailing conditions these paths are, in fact, maximally redundant. This tendency toward maximizing redundancy in segmented tasks was indicated in two ways. First, in each segment the paths were maximally redundant. And second, the same cycle of activity was repeated, i.e. a higher order of redundancy. For example, in the task (1-3-1-3) if the initial state is included in the algebraic statement, the cycle that was being repeated becomes quite apparent.

$$P=(m_1+m_2+m_3)n_0+(m_1+m_2+m_3)(n_1+n_2+n_3)+(m_1+m_2+m_3)n_4+(m_1+m_2+m_3)(n_5+n_6+n_7)$$

Experiment II

This experiment was designed to test the third, sixth and the seventh hypotheses. The experiment consisted of three parts: (a) a task of moving a single object through 24 connected spaces with a constant pace, (b) an interview following the performance of the task, and (c) questions concerning sizes of 'beginning' and 'end' for three different path lengths.

The purpose of the experiment was to examine the correspondence between the model of locomotion and a person's experience of locomotion.

Method

Apparatus

The apparatus consisted of a sheet of paper (37.5 cm x 86 cm) that was taped to a metal desk. Twenty-five connected circles each 2 cm in diameter were drawn along a straight line on the paper. The object to be moved was a cylindrical (diameter = 1.5 cm, height = 1.7 cm) hollow metal. A paragraph was typed in capital letters and was placed on the desk such that it was 20 centimeters away from the middle of the 25 circles and formed an angle of 65 degrees with the desk. A microphone was placed on the desk for recording the sound of placing the object in the next circle.

Procedure

The subjects were seated at the desk. The metal object was located in the far left circle. The subjects were told that their job was to move the object, one step at a time, to the circle on the far right with a constant pace. Further, the subjects were instructed to keep a steady pace by reading the same paragraph to themselves between each step and to do so with the same speed. The subjects were asked to familiarize themselves with the passage and establish a pace by reading the paragraph 5 times before starting the task. The complete instructions are presented in Appendix A.

In the second part of the experiment the subjects were questioned about their performance in the task. The questions were concerned with: an estimation of the number of errors (change of speed), the perceived direction of these errors, and their approximate locations.

In the last part of the experiment the subjects were asked to indicate where was the 'beginning', 'middle', and 'end'. All subjects introduced these terms in answering the questions from the second part of the experiment. Following this part, the experimenter covered the last 8 or 16 circles with a sheet of paper and the subjects were asked to indicate the size of beginning and end for the paths on the visible circles. The order of this judgement was counterbalanced for the twelve subjects. That is, half of the subjects first estimated the size of the beginning and end for the eight circle path.

Results

The time intervals were analyzed by forming three different distributions for each subject. These distributions corresponded to the beginning, the middle, and the end regions according to what each subject had reported in the third part of the experiment. The mean and the variance of each region was computed, and the distribution of these values across the subjects were compared to one another. Table 5 presents the distribution of the means and the variances for each region. The raw

Table 5

Experiment II
Distribution of Means and Variances for Time Intervals

Subjects	Beginning		Middle		End	
	Mean	Variance	Mean	Variance	Mean	Variance
1	2.9	0.04	2.7	0.01	2.7	0.02
2	14.3	0.61	16.9	1.7	18.3	1.1
3	9.1	0.61	8.9	0.89	9.0	0.54
5	16.6	0.24	17.2	2.2	17.5	0.2
6	4.9	0.14	5.2	0.38	5.2	0.08
7	11.7	0.27	11.6	0.6	12.2	0.02
8	16.5	1.9	17.3	3.0	18.6	0.83
9	5.7	0.02	5.4	0.15	6.0	0.02
10	15.9	0.9	16.7	1.8	16.7	1.0
11	8.0	0.34	7.9	0.82	8.0	0.5
12	8.6	0.27	9.9	0.63	9.5	0.12

scores for the time intervals are given in Appendix B.

A t-test for correlated pairs indicated that the variance of the 'middle' was greater than both of the 'beginning' variance (t=3.5, $p < .005$), and the variance of the 'end' (t=3.2, $p < .005$). The variance of the 'beginning' and 'end' were not significantly different from each other (t=0.7). Application of the same test on the distribution for means showed that the speed of performance in the 'middle' was slower than the 'beginning' (t=2.02, $p < .05$), and the speed of performance at the 'end' was slower than the 'middle' (5=2.12, $p < .05$).

Table 6 summarizes the results of the second part of the experiment. The subjective number of errors did not correspond to the distribution of the variance for the middle region (r=0.1). Ten of the twelve subjects located their errors in the middle. This difference was significant using a binomial expansion based on the probability of minimum number of errors (3) occuring in the middle region ($p < .001$). Eleven of the twelve subjects indicated that they made errors by speeding up the pace of the performance ($p < .003$).

Table 7 gives the subjects' response to the third part of the experiment. The predicted values based on the model for the beginning and end regions were: for 24 spaces

Table 6

Experiment II
A Summary of the Subjective Reports on Errors

Subjects	Errors		
	Number	Location	Direction
1	5	middle	faster
2	5	middle	faster
3	7	middle	faster
4	7	beginning and end	faster
5	15	middle and end	faster
6	10	middle	faster
7	4	middle	faster
8	3	middle	faster
9	7	middle	faster
10	10	middle	faster
11	10	middle	slower
12	5	middle	faster

Table 7

Experiment II
Estimation of the Sizes of the Regions

Subjects	24 Spaces		16 Spaces		8 Spaces	
	Beginning	End	Beginning	End	Beginning	End
1	6	6-7	4	4	2	2
2	5-6	5	4	5	2	3
3	6-7	5	4	3	3	2
4	4-5	5-6	3	5	3	3
5	4-5	7	4	3	2-3	2-3
6	4	4	3	3	2	2
7	6	4	4	3	2	3
8	5	4	3	4	2	2
9	6	6	4	4	2-3	3
10	7	5-6	5	5	2-3	2-3
11	5	5	4	4	2	2
12	6-7	6	3-4	4	2	2

(5, 5) for 16 spaces (4, 4) and for 8 spaces (3, 2). These predictions were within the 99 per cent confidence interval around the means of the observed distributions.

Discussion

The results supported the hypothesis concerning the correspondence between the model of locomotion and behaviour as well as predictions for the sizes of the beginning and the end regions. The model was supported in several ways. First, the time intervals for the middle region had a greater degree variability. In other words, in the middle region behaviour was relatively disorganized. Second, the subjects located their errors in this region. Third, the direction of these errors, subjectively, were in speeding up the pace of the performance. That is, an attempt to generate locomotion since the steps in this region did not result in a significant amount of locomotion toward the goal. Fourth, the subjects referred to the 'middle' by statements such as: "It was very hard to concentrate", "It was a drag", or "It felt like its never going to finish." The 'beginning' was described by saying for example: "It wasn't bad", or "I was doing okay"; and the 'end' was referred to by sentences such as: "The last few steps were easy", or "Soon as I saw that I was close to the end there were no problems."

The fact that the subjective number of errors had an insignificant correlation with the variance of the middle region means that the two measures were sensitive to different events. The variance was sensitive to deviations with respect to the mean, whereas the subject's judgement was based on whether the paragraph was read with regularity or not. Thus, when the subject reported errors, as was often the case, he reported that the paragraph was read too fast and was followed by a compensation such as reading the last sentence again. These subjective errors may not have been registered as a significant deviation from the mean and contributed to an increase in the variance of the time intervals.

The slowing down of the performance throughout the task must have occurred in the middle region, since the beginning and the end regions had a relatively low variance. The slowing down in the middle may be attributed to the subject's attempt to either correct a previous error, or read slower so as to maintain a regular pace and decrease the probability of errors.

Experiment III

This experiment was designed to test the fifth hypothesis. The experiment consisted of two parts:

(a) the subjects were allowed to locate a goal on an indefinitely long path for a specified number of objects, and (b) the number of objects was changed to a different number and the subjects were asked to repeat the task.

The purpose of the experiment was to see whether the location of the goal in the second part of the experiment corresponded with the prediction of the model based on minimum RL value from the first part of the experiment.

Method

Apparatus

The apparatus consisted of a long strip of paper (285 cm x 16.5 cm). A total of 43 connected circles (diameter=6.5 cm) were drawn along a straight line on the paper. The paper was taped to the edge of a desk such that 21 of the circles were on the desk and 11 circles were hanging from either edge of the desk. The objects used in this experiment were the same as the objects in Experiment I. The objects were always located in the far left circle at the edge of the desk.

Procedure

The subjects were seated such that about half of the strip was on their right and another half on their left. They were told to imagine that their job was to continuously move these objects. They could move the first object for as many spaces as they liked, then they should move the remaining objects to the same location, and proceed down the path repeating the entire cycle. The subjects were told that they did not have to perform the entire task but rather move the first object, one step at a time, until they felt they had moved the object far enough. Further, the subjects were asked to indicate the size of an acceptable range around the selected location. Following this part of the experiment the number of objects was changed and the subjects were asked to repeat the same task. The complete instructions are presented in Appendix A.

The number of objects used for the two parts of the experiment were: (2,8) (3,7) and (4,6). The order of the number of objects were counterbalanced, i.e. half of the subjects started the first part of the experiment with the smaller number of objects.

Results

Table 8 summarizes the results of this experiment. The predictions of the model based on the minimum RL for the first part of the experiment are also included in the table.

The results were analyzed by rounding off the predictions of the model and comparing the subject's response to a range of ±1 around the predicted values. The responses of eight of the twelve subjects falls within the predicted ranges. A binomial expansion based on the probability of the subjects' responses falling by chance within a particular 3 spaces over the 20 possible spaces was significant ($p < .001$).

There were two subjects (number 9 and number 10) that, if their reported ranges are taken into account, their responses would fall within the predicted range for each one.

Discussion

The results of this experiment raised the following question. Why were the predictions of the model more accurate when the first part of the experiment started with a smaller number of objects? One possible answer to this question is well demonstrated in the behaviour of one

Table 8

Experiment III
Distribution of the Selected Number of Spaces For Different Number of Objects

Subjects	Part I		Part II		Prediction of the Model	Difference
	No. of Objects	No. of Spaces	No. of Objects	No. of Spaces		
1	2	6(+2,-2)	8	3(-1)	3.2	0.2
2	2	6(+1,-1)	8	4(+1,-2)	3.2	0.8
3	2	10(-2)	8	5(+1,-1)	5.2	0.2
4	3	7(+1,-1)	7	4(+1,-1)	4.8	0.8
5	3	11(+1,-2)	7	6(+1,-1)	7.3	1.3
6	4	6(+1,-1)	6	4(+1,-1)	5.	1.0
7	6	4(+1,-1)	4	4(+1,-1)	4.7	0.7
8	7	10(+1,-1)	3	3 (+1)	15.	12.0
9	7	6(-1)	3	5(+5)	8.8	3.8
10	8	8(+1,-2)	2	12(+2,+3)	15.5	3.5
11	8	7(+1,-1)	2	13(+2,-1)	13.5	0.5
12	8	9(+1,-1)	2	5(+3)	17.5	12.5

subject. This subject for 7 objects moved the first object 6 spaces, and in Part II of the experiment for 3 objects moved the first object 5 spaces, and reported a range of +5 for that location. That is, even 10 spaces would have been an acceptable location for the subject. Why did this subject locate the object on the lower bound of such a large range? Is it possible that the subject did not want to move beyond the sixth space which was where the first object from Part I was previously located? That is to say, although there were no objects in the sixth space, phenomenally, the space was structured with respect to that location.

The idea that the subject's action in the first part of the experiment structured the space such that in the second part of the experiment the subject was not operating in the same space anymore explains the order effect in this experiment. More specifically, the structured space from the first part of the experiment had a different effect on the second part of the experiment depending on whether the subjects started the first part with a smaller or larger number of objects.

A comparison among the reported ranges demonstrates this point more clearly. The algebraic sum of the ranges from the first part of the experiment was -5 (average=-0.4).

For the second part of the experiment when the subjects started the first part with a smaller number of objects the sum of the ranges was -2 (average=-0.33), and when they started the first part with the larger number of objects it was +13 (average=+2.2). Thus, when the subjects started the first part with a smaller number of objects their reported ranges for the second part did not differ from the first part of the experiment in which there were no constraints from previous action. In both of these conditions the object was located, on the average, less than one-half space off center on the upper bound of the range. However, when the subjects started the first part with a larger number of objects, on the average, they located the object for the second part more than two spaces on the lower bound of the range. In other words, while the location of the goal from the first part of the experiment did not affect those subjects who started the first part with a smaller number of objects, it constrained the action of the subjects who started the first part with a larger number of objects.

The order effect in this experiment is an interesting phenomenon in its own right, i.e. the notion that activity structures the space, particularly when the work situation is minimally structured. A special instance of this phenomenon was encountered in this thesis with respect to segmented task structures (i.e. a two way similarity between activity structure and task structure).

It may be possible to set up an experiment such that the order effect would be minimal, thus resulting in a stronger test of the hypothesis. This may be accomplished with a much longer strip of paper. In the first part of the experiment the subject would be asked to select a goal and move all of the objects to that location. Upon completion of this part the number of objects would be changed and the subject would be instructed to proceed forward down the path. Under these conditions, the goal for the second part of the experiment would fall in a region which has not yet been structured.

Another aspect of the results was that the average number of spaces for the first part of the experiment, whether subjects started with a smaller or larger number of objects, was about the same (7.6 *vs* 7.3). That is, the goal in the first part of the experiment was not selected on the basis of a minimum RL, or at least it is possible to make such a case. This case could be further supported by the fact that the subjects knew that they did not have to move all the objects. Moreover, it could be suggested that the results of this experiment could be explained much better by a hypothesis based on the idea that the subjects maintained some kind of 'proportionality' between their activity in the first and the second part of the experiment, and, because the computations based on minimum RL took into account all of the crucial variables relating to proportionality, it was a good predictor.

It is true that the test of the minimum RL hypothesis was based on the notion of 'proportionality', and there is no independent evidence, other than the successful predictions, to support the notion of minimum RL. However, it should be pointed out that whether the hypothesis is called 'minimum RL' or 'proportionality' the predictions were based on the model of locomotion, and this in itself provided further support for the model.

The experimental situation that was already mentioned should provide independent evidence for the minimum RL hypothesis. That is, if the subjects know that they have to move all the objects, they should select a shorter path in the first part of the experiment when the number of objects is larger.

It is also possible to set up a different experiment and predict the outcome on the basis of minimum RL. This experiment would consist of two conditions. In the first condition the subjects would be given a certain number of objects and would be asked to move the first object up to a point, on the indefinite path, such that after they move the remaining objects they could take a break. The subjects in the second condition would be told to move all the objects one space and repeat the process until they feel it is a good time to take a break. The RL distribution for the latter path reaches the same minimum RL sooner than the former path. Thus, the subjects performing the latter path should stop sooner.

Experiment IV

This experiment was designed to test the fourth hypothesis. The experiment consisted of a series of pair comparisons between two task situations in which the number of steps required to complete the task were identical.

The purpose of the experiment was to see whether there was a relative preference for those task situations whose RL distributions resulted in a larger average RL value.

Method

Stimuli

Three different sets of stimuli were used in this experiment: (1) A twelve-steps task was represented in terms of different numbers of objects and different numbers of connected spaces such that the total number of steps remained constant. For example, twelve-steps were represented by; (m=2, n=6) or (m=3, n=4) and so on. The set consisted of the following comparisons: (m=1 *vs* m=2), (m=2 *vs* m=3), (m=2 *vs* m=6), (m=3 *vs* m=4), (m=2 *vs* m=4), (m=4 *vs* m=6), (m=6 *vs* m=12), and (m=3 *vs* m=6); (2) a six-steps task (m=1, n=6) was broken up into the following two segments: (5-1), (1-5), (4-2), (2-4), and (3-3). The numbers refer to the number of connected spaces. The stimulus set consisted of all possible paired comparisons between these segmented arrangements; (3) a nine-steps task (m=1, n=9) was segmented into three parts in the four following ways: (5-2-3); (2-4-3), (2-2-5), and (3-3-3). All possible comparison between these configurations formed the stimulus set.

The comparison situations consisted of two stimuli from a given set that were drawn on a card (10 cm x 15 cm). The spaces were represented with circles and the objects with filled-in dots. The size of the circles between two comparison stimuli were identical. However, depending on the number of circles three different size circles were used (diameter=1 cm, 1.5 cm, and 2.0 cm). For segmented stimuli the distances between the segments were the same size as the diameter of the circles.

Two samples of the pair comparison situations are presented in Figure 3.

Procedure

The subjects were told to imagine performing each of the tasks on the card, which required the same number of moves to complete, and based on their intuitive feeling to decide which of the two tasks would be preferred by most people. A sample from each set was shown to the subjects before they started in order to familiarize them with the format. The cards were given to the subjects one at a time, and after they indicated their choice the next card was handed to them. The order of the sets as well as the cards within each set was randomized for each subject. The complete instructions are presented in Appendix A.

Results

Table 9 summarizes the responses of the subjects to each comparison item. The three rows labelled comparisons correspond to the three sets of stimuli. The predictions based on average RL value are indicated with an asterisk(*) on each comparison.

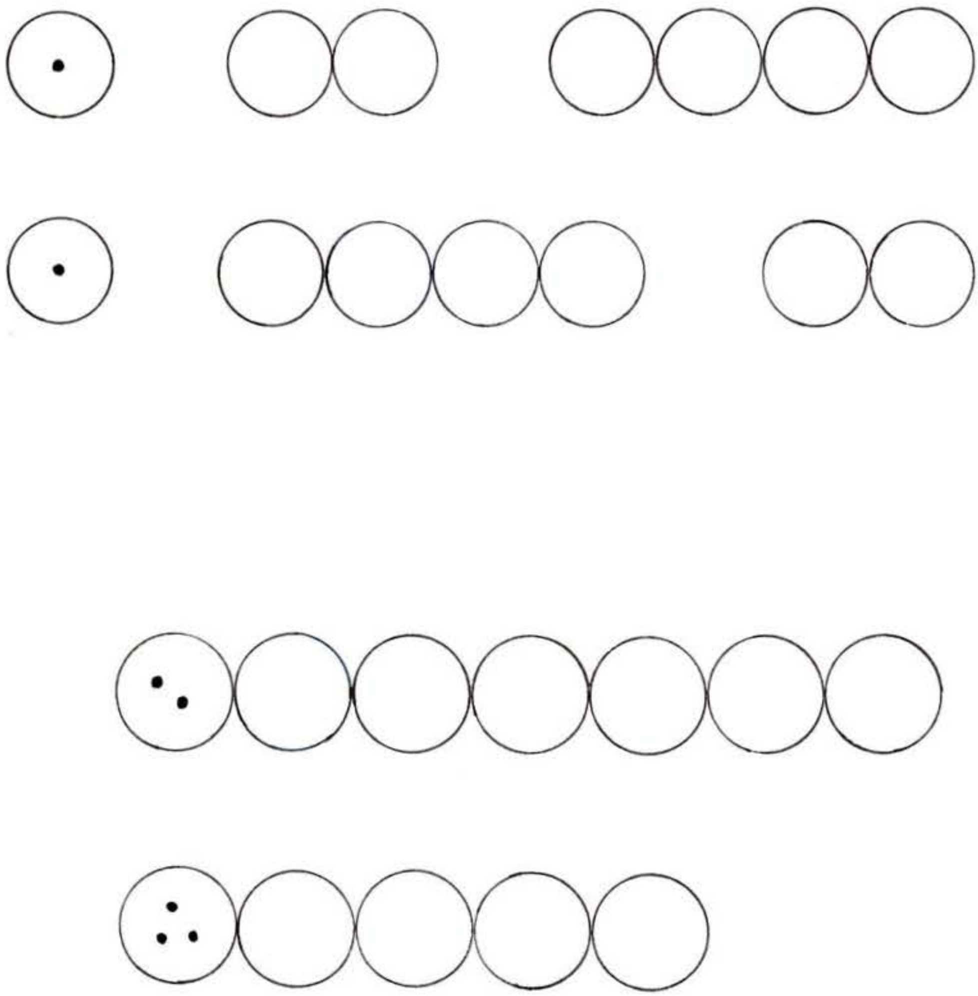


Figure 3. Two Samples of Pair Comparisons From Experiment IV.

Table 9

Experiment IV. Distribution of the Responses on Each Comparison Item

Comparisons	2	3*	4*	3	4*	2	1	4*	1	3*	1	2*	4*	5	2*	5	3*	5	1	5*
	4	3	2	3	2	4	5	2	5	3	5	4	2	1	4	1	3	1	5	1
Responses	0	12	7	5	11	1	1	11	0	12	2	10	10	2	7	5	10	2	2	10

Comparisons	2	5*	2	2*	2	3*	5*	2	5*	3	3*	2
	2	2	2	4	2	3	2	4	2	3	3	4
	2	2	5	3	5	3	2	3	2	3	3	3
Responses	0	12	2	10	2	10	11	1	7	5	11	1

Comparisons	m= 1	* m= 2	* m= 3	m= 2	* m= 4	m= 2	* m= 4	m= 3	* m= 6	m= 2	* m= 6	m= 3	* m= 6	m= 4	m= 6	* m= 12
Responses	0	12	10	2	11	1	7	5	5	7	4	8	5	7	6	6

All comparisons were statistically evaluated with a one tailed binomial test. Those comparisons which involved segmented tasks (i.e. the first two parts of the table) were all significant ($p < .019$) in the predicted direction except for the following three pair comparisons: (4-2 *vs* 3-3), (2-4 *vs* 5-1), and (5-2-2 *vs* 3-3-3).

Among the comparisons on the twelve-steps task with different number of objects only three of the eight pair comparisons were significant in the predicted direction ($p < .019$).

Discussion

In general, the results of the two sets of stimuli for segmented tasks supported the hypothesis that there is a preference for those structures which maximize the RL distribution. Two of the three comparison items which were non-significant were comparisons (4-2 *vs* 3-3), and (5-2-2 *vs* 3-3-3). That is, comparisons to structures that were segmented into equal parts. The fact that on these comparisons more than half of the subjects indicated a preference for the unequally segmented tasks may be viewed as a support for the hypothesis since the equally segmented tasks were better gestalts. On these comparisons, the subjects frequently reported that they found the comparison to be a difficult decision.

It could be argued, by the same token, that the other comparisons in which the equally segmented tasks were the predicted choice, their 'goodness' of structure worked in favour of the hypothesis. However, the subjects' responses became a chance distribution only when the average RL for unequally segmented tasks was greater than the average RL for equally segmented tasks. For example, in the comparison (3-3 *vs* 2-4) all twelve subjects chose (3-3) which was the predicted choice, but in comparison (3-3 *vs* 4-2) seven of the twelve subjects selected (4-2).

One of the consistent findings of the results was a systematic preference for unequally segmented tasks with the larger segment located in the beginning of the task (e.g. preference for 4-2 over 2-4). This, the subjects reported, made the job "easier". In the RL distribution for these situations "easier" corresponded to larger RL values toward the completion of the task.

The results from the twelve-steps tasks raised the question as to whether the subjects' responses were a disconfirmation of the hypothesis. The comparisons that were not as predicted were all chance distributions. This means that there was no clear preference for the stimulus with relatively smaller average RL, and the subjects could have been responding to two different aspects of the same stimulus situation. Since the only two things which changed in the comparison items were the number of objects and the number of spaces, it may be that some of the subjects evaluated the two situations with respect to the difference in the number of objects and others decided relative to a difference in the number of spaces. The number of objects correspond to the number of sub-goals and the number of spaces to the number of steps within each sub-goal. The smaller the number of objects the greater is the average RL for the sub-goal units, and similarly the smaller the number of spaces, the greater is the average RL for the steps within a sub-goal. Thus, it is possible that depending on whether the subjects attended to the number of spaces or the number of objects in the comparison situation, they selected the task with the larger RL value in that limited domain.

It is of interest to note that in the twelve-steps comparisons in which the number of spaces were more prominent (i.e. more spaces) the subjects selected the predicted choices, whereas when the number of objects was more prominent still about half of the subjects chose the predicted task situations. In other words, some of the subjects' were responding to the RL distribution for the entire task situation as opposed to only one dimension.

The segmented tasks were not affected by this problem since the number of sub-goal units was constant for each set. It is this experimenter's opinion that if the subjects were asked to actually perform each of the twelve-steps tasks prior to their decision the problem of responding either to the number of sub-goals or the number of steps would have been avoided.

CHAPTER 6

General Discussion

The basic approach of this thesis has been to start by describing the phenomenal properties of the structure of activity in ordinary language, in an intuitive manner, and to represent these descriptions in a different language. The new language for the structure of activity was a kind of algebra and in the case of locomotion it was a distribution of numbers representing relative position on a path to the goal. These mathematical descriptions allowed for the possibility of manipulating the descriptions into other forms, since the representational system had its own transformational rules. Among possible transformations, those were selected that preserved the phenomenal character of the original intuitive descriptions and led to new derivations with respect to behaviour. Finally, the outcomes of these transformations were related back to the original phenomena within the context of specific hypotheses and experimental situations.

The fundamental view of this thesis was based on Lewin's conceptualization of human action, and has been influenced more by considerations of the structure of activity as opposed to its dynamics. In Lewin's theory, locomotion is the result of forces based on needs and valences. In this thesis, however, the assumption was made that the person in the experimental situation was willing to cooperate and perform the required task (e.g. "need" and "valence" were induced by the experimenter), and attention was placed on subjective experience of locomotion instead of reasons for such a locomotion. This provided an alternative description of the dynamics of activity with certain advantages of simplicity and easier quantifiability. Thus, it was possible to compute distributions of locomotional changes which corresponded to particular activity structures.

Some of the predictions of the model developed in this thesis are rather difficult to make on the basis of forces, or they may require additional assumptions. The following are some examples of the way Lewinian dynamics might approach certain problems that are readily handled in the model of locomotion developed here: (1) In order to include the beginning gradient of the RL distribution, in the force function it is necessary to assume a negative valence for the beginning of the task, or to make a rather bizarre assumption that the beginning is "closer" to the goal than the middle. (2) The explanation of the preference on the part of the subjects for segmented task (4-2) over the path (2-4) runs into some difficulties. Under the assumption of four-space segment having a greater resistance than the two-space segment the opposite prediction should be made, since the force near the goal is greater for overcoming the greater resistance. However, it is also possible to assume that there is a preference for least resistance near the goal. (3) There is no way of predicting the size of the beginning and the end regions based on the dynamics of forces since the precise form of the force function is unspecified with respect to distance from the goal.

Another example is the phenomenon of mental satiation. It is explained in Lewin's theory by the concept of tension which is the result of two opposing forces: one to continue the activity, and the other to leave the activity region which has acquired a negative valence. However, it is possible to provide an alternative explanation of this phenomenon based on the proposed model of locomotion by examining the structure of such situations. In the absence of a goal, which is a common condition in satiation experiments, the person, presumably, makes some kind of structure of this apparently endless path by selecting sub-goal units and locomoting within them. Since the sub-goal units are not related to a definite goal the RL between the sub-goal units is zero, and the continuation of activity under the conditions of no locomotion toward the goal leads to disorganization and finally an end to the activity. In experiment II, it could be suggested that a mild case of satiation was encountered in the middle region of a relatively long path. In that experiment there was more variability in the response of the subjects, and the errors subjectively experienced were located in the middle region. Further, the subjects reported that the errors were made by speeding up the pace. This could be interpreted as an attempt to generate more locomotion when the amount of relative locomotion was relatively small.

It is possible to show a parallel gestalt to the model of locomotion in the field of perception. The perceived velocity of an object depends on the size of the field in which the object in motion is viewed. The smaller the size of the frame around the object the greater is the amount of perceived velocity. Since the motion of the object is directional, phenomenally, this motion starts at one side of the frame and ends in the other side. As the beginning and the end of movement are brought closer together the perceived velocity of the object is increased. Similarly, in evaluating the amount of locomotion associated with a physical step, the smaller the size of the sub-goal unit the greater is this value, and as the person gets closer to the goal the amount of locomotion increases, since in this case the size of the frame is being changed with locomotion. Further, the larger values of locomotion are, in fact, described by the subjects in terms of a "faster" pace in the activity.

The more serious challenge raised by this thesis is the development of the current model of locomotion into a more general theory of locomotion. The question is whether it is possible to explain other phenomena which have been traditionally explained by forces. Consider, for example, as an exploratory attempt the situation in which there is a goal and a barrier on the way to the goal. The goal has a positive valence and the barrier acquires a negative valence, consequently if the two opposing forces sum to zero the person's progress toward the goal is stopped by the barrier. This state in the model of locomotion corresponds to a state of zero locomotion. It may be possible to introduce the idea of expected amount of locomotion for a given location with respect to the goal. Thus, zero locomotion may be viewed as a "discrepancy" between the locomotion that is supposed to occur and the current state of the person. The attempt to reduce this discrepancy may be a restless movement - a quasi-locomotion - which is often the case in such situations.

There are several possible directions for future research. The most immediate projects are the kind of experiments that were discussed in connection with experiment III and experiment IV. That is, experimental situations in which a stronger test of the minimum RL hypothesis could be made, and clarification of the results for the twelve-steps tasks, by allowing the subjects to perform the tasks prior to their decision about which condition they prefer.

Another question of interest involves the phenomenon of activity structuring the space as a counterpart of this thesis' emphasis on space structuring the activity. This is of interest particularly with respect to activities such as pacing while in deep thought, in which there is no physical goal and minimum attention is given to the physical environment. Nevertheless, the activity follows a pattern, and deviations from this pattern are noticed. Such a deviation in direction or length might be seen as entering a new region.

Finally, it should be possible to use the algebraic descriptions described in this thesis to detect the higher-orders of symmetry within a complex activity structure, that is, when there may be several levels of sub-goals embedded in one another and larger cycles of activity are being repeated.

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APPENDIX A

Instructions

Instructions

You will be participating in four small experiments. Each experiment is different and at the beginning of each experiment I will explain to you what it is that I want you to do.

Experiment I

In this experiment your job is to move these four objects to the end space. After each move which is to move one object one space, you should push the button on the center with the same hand. In other words, after you move one object one space, leave the object and push the button. This button is connected to the tape recorder, and everytime you push it a sound will be recorded. Is it clear how you are supposed to do this task?

Before you start, I should tell you that there are many ways that these objects could be moved to the end space, but I want you to move them in the way that you think most people would move them. Do you have any questions?

Feel free to push the button or to touch the objects. When you feel you are ready to start tell me so I can turn the tape recorder on.

Questions

1. How would you describe the way you moved these objects so somebody else could move them in the same way?
2. What would be an unusual way of moving these objects?

There is one more part to this experiment. I am going to show you three cards. I want you to look at them carefully and tell me the way most people would move the objects in each of these situations.

Experiment II

In this experiment, as you can see, there are 24 circles and one object. What I want you to do is to move this object, one move by one move, through the 24 spaces. The important thing is to move the object in the same pace. In other words, try to make equal time intervals between the moves. To help you keep the same pace I want you to read this paragraph to yourself between the moves.

> Certain business organizations have as their major task the establishment of credit ratings. Individuals as well as business ordinarily need some minimum credit rating in order to borrow money or open charge accounts. This whole enterprise is based on the simple but critical assumption that there is consistency in man's behaviour.

So, you read this paragraph and move the object to the next circle, then read the paragraph again and make another move and so on. If you keep on reading the paragraph in the same pace you should be making equal time intervals. Do you have any questions?

The microphone on the desk will pick up the sound of the object each time you move it. Before you start go ahead and read the paragraph to yourself 5 or 6 times so you can establish a pace for yourself. When you feel ready to start let me know, and before your first reading of the paragraph pick up the object and put it back down without moving it so on the tape the beginning will be marked.

Questions

1. As you know I have the time measurements for the 24 time intervals that you just made. But I am also interested in how well you think you have done. So, tell me, of the 24 intervals, how many of them you feel confident about?
2. Where, in general, would you say the mistakes occurred?

3. Did you slow down the pace or did you speed it up?
4. You have been talking about 'beginning', 'middle', and 'end'. Could you show me on the sheet, approximately, where these places are? Let's start with the beginning.

Experiment III

In this experiment, as you can see, there is a long sheet of paper with many circles and no objects. There is no end and the circles continue beyond the edge of the desk. I want to imagine that your job is to keep moving these objects. You start with one of the objects and you can move it as many or as few spaces as you like, then you come back, and move the rest of the objects, one by one, to the same place.

You don't have to do the whole task. What I want you to do is to start with the first object and move it, one move at a time, until it feels that you have moved it far enough. There is no reason for stopping in one place as opposed to another, so move until intuitively you feel its a good place to stop. Do you have any questions?

Question

1. Are there any other circles that are also a good place to stop, or is this the only place?

Now, I am going to change the number of objects and put them in starting circle, and I want you to repeat what you did. So, again you start with the first object, move it until you feel you have moved it far enough.

Experiment IV

In this experiment, you will be given a number of cards. On each card there will be two situations involving objects and circles. Both situations will require the same number of moves in order to move the object (objects) from one end to another. The main difference between the two situations will be in the way each situation is arranged. There will be three sets of such cards and before you start each set I will show you an example for that set.

What I want you to do is to imagine doing the task for each of the situations on the card. And, based on your intuitive feeling tell me which of the two situations would most people prefer to do if they had to choose one of them. Do you have any questions?

APPENDIX B

Experiment II
Time Intervals Between The Steps

Experiment II

Time Intervals Between The Steps

Subjects	Time Intervals in Seconds																						
1	3.2	3.0	3.0	2.8	3.0	2.6	2.8	2.6	2.8	2.8	2.6	2.6	2.6	2.6	2.6	2.8	2.6	3.0	2.6	2.6	2.8	2.6	2.8	2.6
2	13.2	15.2	13.6	14.8	14.8	14.6	15.2	15.2	16.4	15.4	16.4	19.0	17.0	16.4	16.8	18.4	17.2	19.0	18.0	17.6	17.6	19.4	19.4	17.4
3	8.2	8.6	9.9	8.8	10.2	8.8	9.6	11.0	9.0	8.8	9.0	8.6	8.4	7.2	10.	9.4	7.8	9.0	9.0	8.4	9.4	10.	8.2	9.0
5	16.4	16.6	16.1	17.4	16.4	15.8	16.2	16.5	16.2	17.	18.	17.8	20.8	16.2	15.8	17.8	18.2	17.4	17.2	17.4	17.6	18.4	17.8	17.0
6	4.4	4.9	5.3	5.1	4.9	6.5	5.4	6.8	5.2	5.4	5.0	4.6	4.6	5.2	4.6	5.0	5.8	6.2	5.4	5.6	5.2	5.2	5.6	4.9
7	11.0	11.2	12.0	12.2	12.2	12.0	12.8	11.4	10.4	11.6	12.0	10.4	12.4	12.4	11.6	11.2	11.4	12.6	12.0	11.4	12.2	12.2	12.0	12.4
8	15.2	18.8	15.8	16.0	16.6	15.6	16.4	13.6	16.8	18.4	17.6	14.4	17.6	17.0	19.4	17.8	17.6	19.2	19.2	19.0	20.	18.2	18.	18.4
9	6.0	5.8	5.6	5.6	5.6	5.6	5.2	5.2	5.3	5.6	5.8	5.1	5.4	5.2	5.2	6.4	5.2	6.0	5.8	6.2	6.0	5.9	5.9	6.2
10	16.8	16.2	15.4	15.0	16.2	17.2	14.6	14.6	17.0	16.4	16.0	14.6	17.2	18.6	17.8	16.6	18.6	17.0	17.8	15.8	15.8	172.	16.0	18.0
11	8.8	8.4	6.8	7.6	7.4	7.6	8.4	8.0	7.6	6.0	6.0	9.2	6.6	8.0	10.2	8.4	8.2	7.0	7.2	8.6	8.0	8.8	7.8	7.0
12	8.2	9.6	9.0	8.2	8.8	8.2	8.6	10.4	10.0	9.0	11.0	10.2	8.4	9.8	9.4	10.6	9.0	9.2	9.6	9.6	9.6	10.0	9.0	9.2

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