Trans. Inst. Indian Geographers
Vol. 2, No. 1, January 1980

SPATIAL ANALYSIS IN GROUP DYNAMICS
A REVIEW AND AN IMPERATIVE FOR GEOGRAPHICAL RESEARCH

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ABSTRACT : This paper is concerned with the analysis of *group processes* in a spatial context. The objective is to identify the sources of variations in group processes and the sources, it is found, are confined to limited, bounded spaces. As such, *spatial analysis* in *group dynamics* is microscale. A conceptual basis for the analysis of group processes is examined within the framework suggested by recent work on spatial structure and spatial behaviour.

In particular, the *territoriality* of individuals is examined for the extent to which directions of individual mobility are random or biased in a fashion which would suggest the influence of the underlying aspects of the *physical environment.* Drawing upon empirical evidence the extensions of two models of individual mobility are suggested, a random or unbiased model and a sector or biased model. For each individual, the directions and distances of the moves are considered in the context of 10 degree sectors. The possibility of applying *random-mixing* models to reflect a society in which interaction is random within certain restraints is hinted.

Of particular importance, it seems, is the identification of the inter-relationships between individuals and several different types of travel patterns, and the effects of individual behaviour on these relationships and travel patterns; in the context of *personal space.* Also attempted in these pages is a plausible explanation of spatial preferences in terms of the reinforcement possibilities associated with various *spatial positions* of the members of a group. Finally, this discussion outlines certain approaches, including mathematical, to certain spatial aspects of social communication. The mathematical solution for problems relating to it is examined through exploring possibilities of using *heuristic programming.*

Introduction

A potentially fruitful area of research in which *spatial analysis* is brought to bear on the problems of behaviour is *group dynamics.* If we accept the terminology of this paper, then, group dynamics has been one of the objects of investigations by psychologists interested in spatial analysis. One argument of this paper is that spatial considerations are a concern of group dynamicists interested in the examination of complex environmental setting that exerts a strong influence on almost every aspect of *group process.* It may be legitimately argued that it is difficult, if not impossible, for a group dynamicist to be competent in the mode of spatial analysis, but this surely does not suggest he is incapable of comprehending spatial dimensions of group process. There is, however, a relative sparsity of reported studies in which group dynamicists have attempted to treat spatial considerations. Yet this does not exhaust the possibilities of an approach that is spatial well within the class of research– that is, group dynamics– considered here.

The view that group dynamics has a *spatial component* is by no means new. Indeed, some have argued that group process is or should

be spatial. The argument put forth here is definitely not that group process is or should be all spatial. The justification for emphasising the spatial approach is based on two counts :

1. *Previous writings on group dynamics have either discussed the influence of environmental setting on the group process or defined a partial spatial approach.*
2. *Writings on group dynamics have time and again suggested that the personal characteristics that group members individually bring to the group may be considered as one aspect of the environmental setting.*

Although many aspects of the complex environment (physical, personal, social, and so on are potential determinants of *group behaviour,* only a few of them have been examined systematically. Among those studied, physical aspects are important as the group must exist in a physical environment. Consideration, therefore, is restricted to those aspects of physical environment which have been studied extensively enough to permit strong conclusions about their effects on group process. Particular attention, however, is devoted to *territoriality, personal space, spatial arrangements,* and *patterns of communication channels.* While the examination of territoriality and personal space reveals the psychological significance of the physical environment, the same of spatial arrangements and patterns of communication channels reveals how the elements of the physical environment can influence the *group interaction* along a variety of dimensions.

Territoriality

One of the commenest behavioural adaptations of individuals, human or animal, is that they approriate *space* and assume *proprietary rights* to it in almost all situations in which several people come together over a period of time–the establishment of a geographical area for carrying out life activities. This area is known as the *' home range '.* If all or part of this range is carefully defended against any other members of the species (the behaviour of dogs is commonly cited as an illustration), the area is known as a *territory.* Defence of such an area is known as *territoriality* (Franke and Franke, 1975. p. 200). The proprietary orientation towards geographical area is distinguished from ownership in that the individual or group has no legal right to the geographical area in question. The territory is simply occupied and used for life activities.

The orientations that individuals adopt towards geographical areas and objects in these areas have highly significant implications for *small group behaviour.* While the territories themselves serve many functions, the smooth functioning of the individual or group depends upon the degree to which other group members respect that person's or group's assumed territorial right. In the absence of respect for such an assumed right, intra-group or inter-group conflict is inevitable; inter-personal relation, more often than not, is at jeopardy (Shaw, 1976, P. 116). Whyte's (1949) investigation on the social structure of restaurants, Altman and Haythorn's (1967) study on the interactions of *isolated dyads* and Lyman and Scott's (1977) exploration on the tendency to assume proprietary orientation towards public geographic areas have amply proved this. The popular fad of establishing *' people's parks '* in the United States and elsewhere is an example of this behaviour. It is clear, then, that individuals assume territorial rights over physical space and objects in that space and that groups also establish this orientation is discussed below.

Unlike *individual territoriality, group territoriality* has wider significance for spatial behaviour. The areas are usually larger and sometimes less clearly delimited than in the individual territoriality : the group frequently occupies a much larger geographic area, such as a city subdivision

or sometimes a whole town.

The geographers, searching for order in spatial behaviour and the spatial structure resulting from such behaviour, from both empirical and theoretical perspectives, have examined the basic *generative* processes underlying spatial behaviour. *Action-space* (geographical area for earrying out life activities) *formation* is one such process. Horton and Reynolds (197) have researched into the action-space process, presupposing individual decision-making, seeking only to identify the action-spaces of urban residents through behavioural analysis of individuals at a specific location within an objective urban spatial structure. The individual is seen as responding to his knowledge and perception of an objective spatial structure. The individual's response to this structure is manifested in his activity space, *' the subset of all . . . locations with which individual has direct* contact as a result of day-to-day activities'. In this space, the individual acting as a member of a household is therefore the basic behavioural entity. His action-space is the manifestation of his activity demands predicated upon his perception and cognition of geographical areas which can potentially satisfy his and his family's demands.

Neither an individual's perception of the environment nor his action-space can be viewed as an abstract component of a *general environmental learning process.* Based upon the work of Carr (1967) and their own research into action–space formation, Horton and Reynolds (1971) worked out a tentative stage model of the learning process. In the learning process, they hypothesised that the individual's action–space is expanding areally and his activity space at any moment in time is the result of his overt searching and is accordingly changing with the satisfactory fulfilment of his successive demands. The dominant *foci* of these spaces are either the residence or the work place, although, at the same time, other locations are being sought and sampled and subjected to what may be termed *spatial discounting procedure.* However, the individual's spatial behaviour is suboptimal in that he may, through spatial discounting procedure, delete from his current *activity space* some locations but however retain as component points the same in his action–space, even though he no longer responds to them. And it is through such behaviour he normally builds up his cognitive image of the environment and increases the size of his action–space.

The direct and vicarious environmental experience that contributes to the development of action–space is affected by *distance* and *directoinal biases.* But in course of time the individual establishes a temporary equilibrium between his activities and the opportunities that he perceives within his action-space. He becomes integrated, at least partially, into social groups based upon either the residents of his immediate neighbourhoods or his associates at work. From these informal social contacts, he learns of other potentially satifactory locations and subjects his previously satisfactory locations to spatial discounting. At this stage, the relative importance of sources of environmental information shifts from *direct contact* to *word-of-mouth* communication with members of the social groups to which he belongs. Since a number of studies have demonstrated that there is a close relationship between social and spatial *propinquity* (for example : Festinger et al, 1950; Merton, 1950), it would appear that informal social contacts are the most important in providing environmental information. And those who are integrated most easily into a social group and hence have increased sources of information are the ones who have a higher probability of developing an environmental *image* and an action–space which is at variance with those shared by comembers of informal community groups. In this regard, the work of some social scientists, social psychologists in particular, contain useful insights, albeit indirect, into the formation of an action-space and the extent to which action–spaces are shared by

similar groups of people (See, for example, Rubenstein and Haberstrol, 1964). It is in this stage that mass media begin to exert more of an impact upon spatial behaviour. In the *distance bias stage,* too little of the environment is within the individual's action-space and he rejects a major portion of the information content of the mass media because of his insufficient locational information. Now, after partial integration into the community his neighbours can help provide relevant information that mass media usually lack. The action-space of an individual who is integrated into a community not only resembles those of other community members, it is also considerably extensive and coherent.

The action-space or territory of an individual serves both *personal* and *inter-personal functions* and thus has important connotations for *inter-personal behaviour.* One of the important functions of spatial relations among persons is the establishment of communication. The role of distance in the perception and communication is demonstrated by numerous studies in geography as well as group dynamics. Golledge (1970) suggests that the *'structual changes over time are the physical manifestations of human behaviour.... the results of individual and group decision-making'.* This is a particularly imporatnt discussion for understanding movement for establishing communication. Behaviour and structure are linked in that behaviour is converted into structure and structure modifies behaviour. This point is also developed by Moore and Brown (1969) who suggest that the analysis of interpersonal contacts and the resulting *contact field* may be regarded as the first step towards the identification of *spatial regularities* in information flows. It may be imporatnt at this point to take note of Justice's (1969) findings on *inter-person distance* and intimacy of the topic being discussed. Implicit in his analysis is that movement does play a role in determining the distance and establishment of communication : contact field. In such a case, we might expect either a biased pattern of movement or a random pattern of movement. In addition, it seems likely that any potentially mobile individual will investigate several areas rather than look in one particular direction. Thus an initial hypothesis can be that a *random movement is more likely than a biased pattern.* In this context, two models suggested by Clark (1971) are plausible, but the principles have to be examined in microscale. The first model describes directions of movements within the contact field as a random vector model. The other is a sectol model. We may designate a direction di from Xi Yi the original location of a mover (member of a group), and Di represents a distance from Xi Yi (interaction distance).

(1) For any mover
  a. select d_1 ($0 < di \leq 360$) by a random procedure
  b. select Di in accordance with $D = ab^n$, the Pareto formula
(2) For any mover (with $D = 0.5$)
  a. select di ($0 \leq di \leq 60$)
  b. select Di in accordance with $D = ab^n$, the Pareto formula.

It should be mentioned that the choice of an angle of less than 60 degrees to represent a sectoral bias is arbitrary but the literature has never specified the exact nature of a sector.

In order to test the model, the distance and direction for each mover can be calculated. Simple *Euclidean distance* can be computed.

$$(3)\ d = \sqrt{(X_2 - X_1)^2 + (Y_2 - Y_1)^2}$$

and direction can be computed as

$$(4)\ O \text{ degrees} = \arcsin Y_2 - Y_1 / d.$$

To facilitate the use of these methods in group interaction analysis of a residential quarters (say, acity neighbourhood, or even a part of the neighbourhood or even a village or hamlet), a grid of cells as shown in Figure 1-A may be randomly located over it (the residential quarters in question). Within each of the regions (cells) the direct-

tions taken by movers may be assumed to originate from the centre of the region and the number of movers falling in any particular sector (10 degree, 20 degree, 30 degree and so on (may be calulated) Figure 1–B). As a final step, the proportions of moves (angles of moves) can be compared with the proportions falling in each sector according to the models. The directions of movement are illustrated for the 30 degree sectors in Figure 1–C. Once a tabulation of moves for each of the thirty-six 10 degree sectors is carried out and plotted, tht delineation of territories can be attempted (Figure 1–D). And, possibly, the plotted directions of movement by sector for the thirty–six regions can be analysed descriptively. In order to test the models of direct. ion of individual movement, the angles of movement grouped by the 10 degree sectors can be compared with angles of movement generated by the model of random movements. The results of the tests generally follow the descriptive outline of differences between the actual number of moves per sector and the number of random moves per sector.

There are several other, plausible models to describe interaction in groups with a social or spatial structure in which it is equally likely that any pair of individuals interact, one such is *random-mixing* model of different formulations (Hudson, 1971). The important assumption is that the mixing of the population is almost always random. But this random-mixing becomes less plausible as N (number of individuals) increases in size due to the restructuring effects of distance and social groups. The formulation postulating random-mixing are the most easily treated into a *stochastic* framework, as well as *deterministically*. These models ignore specific channels of *influence-flow* in the population but may incorporate various interaction rates between and within population subgroups.

Personal Space

This space sometimes referred to as ' *Proxemics ' is the area immediately surrounding the individual in which the majority of his interactions with others takes place* (Little 1965, P. 237). This, unlike a territory, is carried about with the individual and not tied to a geographical area. Thus, it has flexible boundaries which vary with the personal and social reiationships between the person and others, as well as with the nature and purpose of the interpersonal contact (Sommer, 1959). However, a somewhat different conceptualization from that of Little-Sommer is possible and probably valid : an individual personal space is delimited by an imaginary line connecting those points around his body at which the approach of another person evokes an *affective response,* positive or negative or between these two extremes. Most (and perhaps all) social psychologists investigating personal space have adopted the Little Sommer viewpoint : *personal space* is the result of his overt searching and is accordingly changing with the satisfactory fulfilment of his successivc demands.

Also, the personal space varies in size but intrusion into it always elicits negative reactions. Like territoriality, personal space has important consequences for group process. For example, there is a characteristic individual distance that is most comfortable for interaction with others. This interpersonal distance, an individual matter, varies systematically with the intimacy of the relationship between the person and others and the circumstances under which the interaction occurs. Although interaction distance is an important aspect of inter-personal behaviour, relatively little careful research has been done to establish the limits of comfortable interaction or the variables related to it. Results of some of the investigations reported in the literature, however, are enlightening. For example, interaction distances were measured by Little (1965) in a study

designed to determine the relationship between such distances as measured by a projective method and by *live-person* interactions. Also some evidence concerning interpersonal distance in real interactions has been provided by Justice (1969) who was primarily interested in inter-person distance as a function of the person's *field dependency* and as a function of the intimacy of the topic being discussed. Cross-cultural differences in interaction distances have also been observed (Baxter, 1970). Curiously enough, most of this research was not stimulated by personal space theory, but by the growing concern about our social problems, specifically, concerns about crowding and racial tension.

Implicit in several studies of inter-person distance is that we should not assume the zone of personal space has regular boundaries such as a circle around the person's body, which merely expand or contract with circumstances. Insead, the zone seems to form an irregular pattern about the person.

Spatial privacy, protected by offensive display and avoidance of invading individuals, has been less extensively treated by some (for example : Sommer, 1969). The conclusion to be drawn from these studies is that individuals device various techniques to guard against invasion of personal space and thus of spatial privacy. If these devices fail, the studies suggest, intrusion of another into the personal space evokes discomfort, unease, and other negative, affective responses, ultimately ending in flight.

The role of inter-person distance in the perception and communication of status and thus in spatial relations has been amply demonstrated by many. The distance that a person 'maintains between himself and another communicates something about his status relative to that other. But, the direction of the difference often depends upon factors other than distance. This is to say that inter-person distance alone does not indicate which person has the higher status and which person the lower. However, these investigations may have been influenced by the general idea that the personal space of higher status persons is larger than the personal space of lower status individuals. The conclusion is merely due to culturally established patterns ef interaction. It is even possible that long familiarity with such situations has produced a cultural expectation of greater interperson distance for higher status individuals.

The matter of interpersonal space in the interaction process requires some clarification. It is understood that individuals arrange themselves in space according to their distance from each other. The object may be

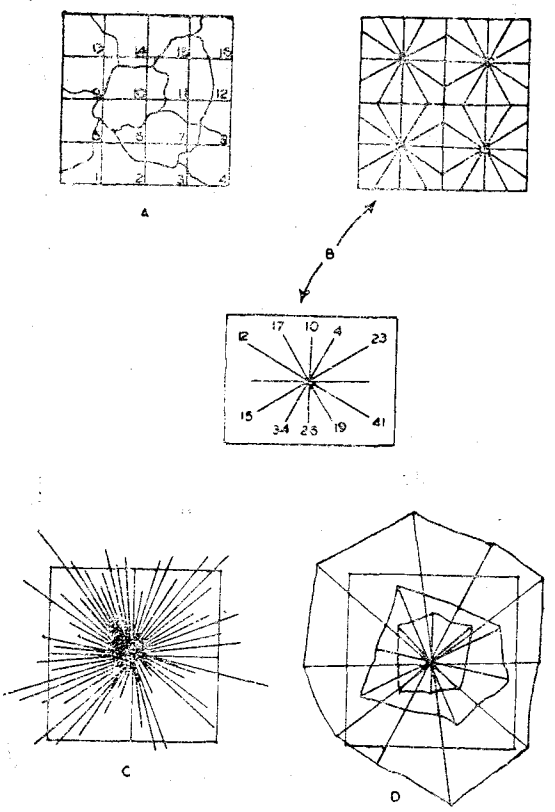

Fig. 1 : Territorial Delimitation. (A) A Grid Arbitrarily located on residential quarters. (B) Directions (30 degree sectors) of movement, numbers indicating individual moves. (C) Originating Cell and Directions and Distances of a single individual. (D) Delineation of territories or action spaces.

to be as near as possible to those they love as far as possible to those they hate, or at a convenient distance from those who lie between the two extremes. This is what is earlier referred to as affective response. When examining inter-personal space, which is *the linear distance separating an individual from his neighbours,* we ask : How many meters is a given individual from his nearest neighbour, his second, his third, and so on ? This of approach type is termed as an *autocorrelation* method because it involves the relation of other individuals to oneself. Geographers frequently use this approach but never once did they use it in the context of a microscale, including inter-personal space. But extension of this wihthin geographical research perspectives is possible and the following discussion thus purports to discuss precisely this as it concerns spatial analysis.

Interpersonal space, in the context of interaction process, entails an *itinerant* (mobile, or travelling, or ambulant) individual who makes visits to several places from a home base. The mobile individual's *itinerary* is selected with the intimacy of a given set of individuals in mind. Thus, if there are, say, five individuals within a practical radius of operation from the individual's home base, and if his visits are frequent such that on any day of the week there are meetings with any or all of them, the mobile individual has a wide choice of a precise itinerary. It is also possible that the mobile individual selects a particular itinerary at least partly because he perceives it as corresponding to some relationship which already exists between himself and that other. This seems to be one indication of '*interaction rings* ' for cycles or circuits' which are defined as being composed of a complex and integrated sequence of meetings taking place over a period of seven days.

The itineraries of mobile individuals vary only very little over long periods. The travelling individual's itinerary thus represents only by substituting one or more alternative modes in his original itinerary. The itinerant would however prefer *circumferential* routes (the shortest) because longer distances weigh heavily in the travelling individual's *locational calculus* and shorter distances minimize effort. However, the itinerary is not selected only with the principle of *least effort* in mind; presumably, the individual assesses the likelihood of there being a comfortable interaction. If there is sufficient number of such nodes with different meeting schedules within the individual's *working distance* (his practical radius of operation), he could conceivably obtain a nearly circumferential pattern. However, if this is not the case, for whatever reason, the individual will have to settle for a less than optimal route. (See Figure 2.)

A test of these hypotheses can be conducted on maps showing the locations and days of one individual meeting others in an area. The scheduling by spatially adjacent locations of meetings close together in time is consistent with mobile individual circumferential routes. The reverse situation *(proximity in space implies separation in time)* suggests diagonal patterns of *locational shift* which work to the advantage of the interacting individual. Average *location spacing* values can however be calculated for locations with different temporal spacing characteristics, the latter chosen to represent the two sets of conditions. Social psychologists have not made any previous attempt to test these hypotheses. As such calculations can be carried out on individual networks of contacts and thus brought to bear on any relationship to interaction cycles as perceived by itinerant individual. More important, such computations must take account of hierarchical, functoinal, and size stratification of small groups. Further, deliberate invasion by any individual of spatially *proximate* individuals can be taken up for investigation. Nevertheless, it is probably unwise to push the examination of *spatio-temporal synchronisation* beyond some day

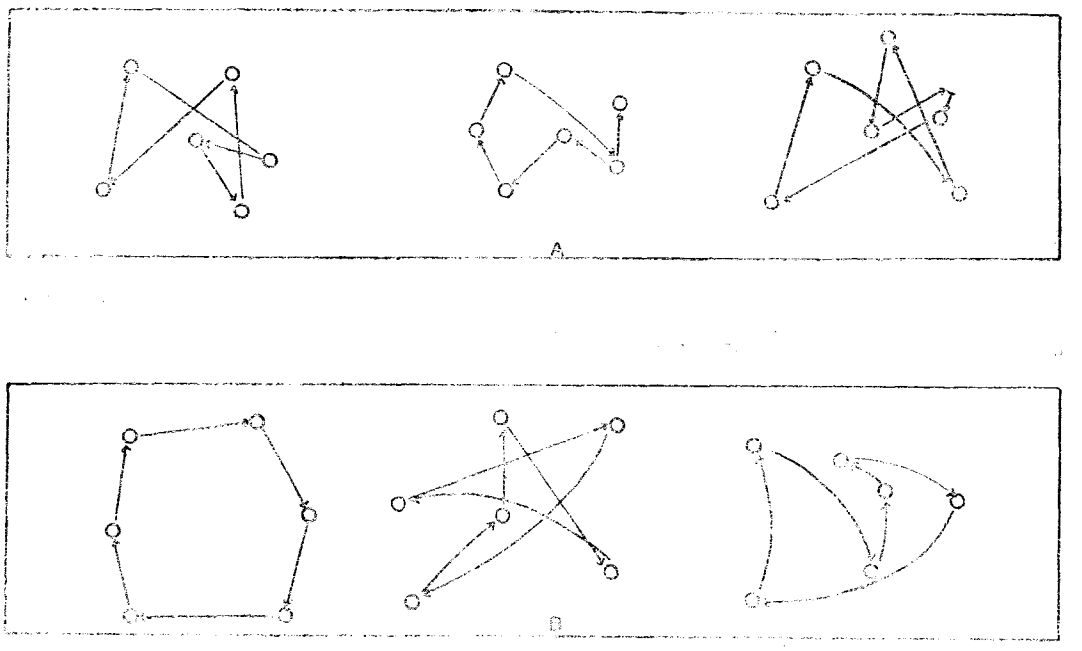

Fig. 2 : Group communication paths. (A) An Itinerant individual's routes through networks of group communication, (B) Cycle paths through networks of group communication.

' a sequential path through a series of nodes ' (locations of individuals). The length of any particular path will fall somewhere on a continuum between the shortest and the largest routes through these nodes. The travelling individual can vary his itinerary and adjacent day meetings.

A satisfactory approach to this problem is to place an interacting individual's route on the continuum from the shortest to the longest path through the nodes identified in his itinerary. The procedure varies the day and time of meeting between individuals analytically, it has no relevance, however, for the itinerant individual, but it does provide a normative frame of reference in which to evaluate his itinerary. If the size, in terms of number of meeting nodes, of an individual's itinerary is determined by the length of the period of interaction (n), there are, for example $\frac{(n-1)}{2}$ different routes through that network.

Spatial Arrangements

The preceding pages have been concerned with the orientations that individuals adopt with regard to the space about them and to other persons and objects in that space. It is necessary now to consider some of the consequences of certain *spatial arrangements* in group situations. Relatively little research has been devoted to this important aspect of group interaction but there is however good evidence that spatial arrangements in groups exert significant influences upon the perception of status, the patterns of participation, the affective responses, and so on group members.

It is not surprising that there are consistent position preferences in group situations. The choices that people make with regard to where they position themselves in the group are thus consistent with what is known about the effects of spatial arrangements on group process. The choices, when persons

are free to choose their position, in a group usually reflect the cultural import of various locations.

As such, persons who perceive themselves to have relatively high status in the group select positions that are in accord with this perception. For example, data obtained on managerial classes show that managers from professional institutions selected the chair at the head of the table more often than did persons from other classes. Similarly, professors, belonging to an academic group, in which positions of members are predetermined, chose to sit at the table in a commanding position.

But group situations other than professional ones have shown a number of alternatives in spatial arrangements in the context of different activities : *face-to-face* arrangement for conversations, *side-by-side* arrangement for co-operating individuals, a *minimized intimacy* such as across and opposite ends for coacting pairs and so on (See Figure 3 A). The results of questionnaire studies on seating preferences in real groups of children were in substantial agreement with findings reported by the earlier study on professional managers (Sommer, 1969). The findings reported by Myers (1969) in a counselling setting showed that the counselees overwhelmingly preferred an informal *knee-to-knee* arrangement to a formal face-to-face arrangement.

However these investigations are not able to show whether the preferences are due to cultural expectations concerning the appropriate spatial relationship in a given setting or to the feelings that various arrangements produce in the individual under certain conditions. Hence, explanations of this sort may be considered at best as rationalisations rather than true causes of the observed phenomenon. Also, it is not difficult to see that the *position-status* relationship should make positions positively rewarding and others negatively rewarding (unpleasant, punishing). Therefore, one plausible explanation of spatial preferences is in terms of the reinforcement probabilities associated with various spatial positions.

The rewarding values of spatial positions derive in part from their consequences for group interaction. It is obviously difficult to interact with another person at a great distance and interaction with a person one cannot see is less satisfactory than face-to face. For example, most people find a telephone conversation less satisfactory because there is absence of the *non-verbal* parts of communication (physical proximity, eye contact). Their importance lies in their functioning as a cue to guide the course of interaction. That is, the pair of individuals in interaction can signal to each other their intentions and expectations.

There are consequences of spatial arrangements which are not so obvious: for example, *the flow of communication in a group is a function of the spatial relationships among group members*. When members of a group are seated at a round table, there is a strong tendency for members to communicate with persons across the table and facing them rather than with persons adjacent to them (Figure 3B). Steinzer's (1950) findings in this regard are valuable in that he found no consistent relationship between inter-person distance and following, but members across the table followed each other significantly more often than chance. This so-called *' Steinzer effect '* was also verified in a study of group members seated at a square table. Though this study found that more comments were directed to neighbours than to those sitting opposite, this latter finding does not negate the hypothesis that *seating arrangements influence the pattern of communication in the group*. On the contrary, it specifies some of the limiting conditions of the Steinzer effect.

The fact that the seating arrangement has an effect on the quality of interaction is shown by Russe (1967) through his study on subject's perceptions of the social relationship exisiting between two persons occupying different spatial relationships at

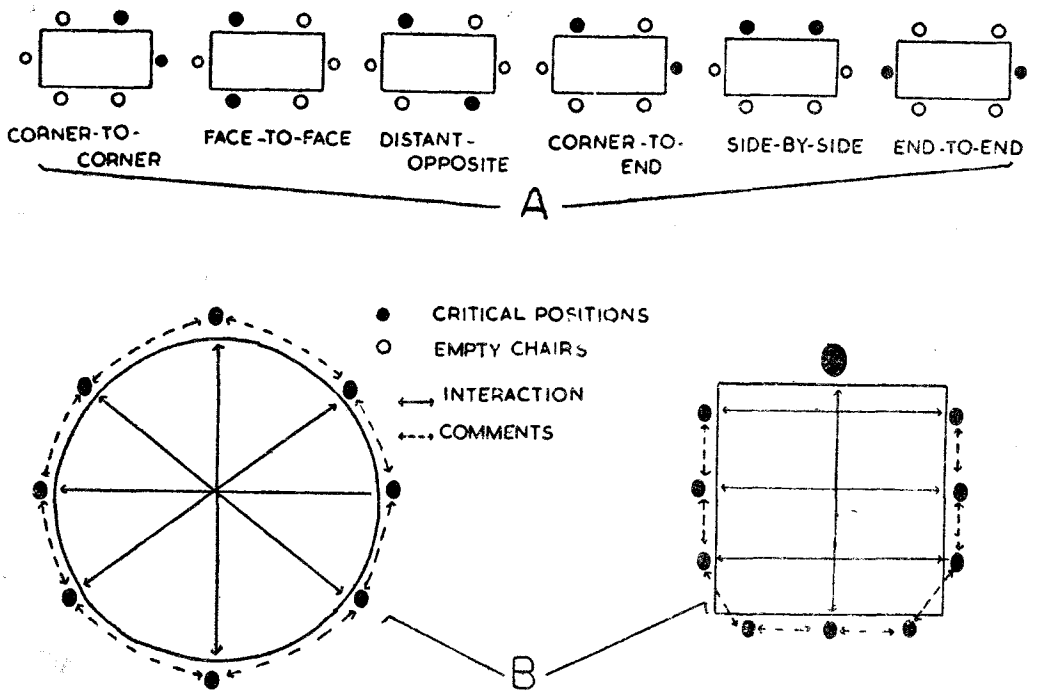

Fig. 3 : Seating Arrangements and Spatial Relations. (A) Seating arrangements in the study of perceived social relationships. (B) Comm unication across the tables : Face-to-face.

the table. The general conclusion was that *the more distance there was between the two persons, the less friendly, acquainted and talkative they were perceived to be.* This was qualified by the fact that situations permitting easy eye contact showed less of the inter-person effect.

In sum, it is abundantly clear that spatial arrangement has a profound influence not only on the pattern as communication but also on qualitative aspects of group interactions.

Communication Networks

The physical distance could influence the flow of communictaion and the perception of status is conclusively proved in the foregoing analysis of group process and behaviour. Similarly, the number and arrangement of communication channels among group members exert a powerful influence upon the group is considered here.

When considering the physical arrangement of communication channels among group members, we are supposed to deal with *topological space* rather than *Euclidean Space.* As such, it does not matter where the individual group members are located with respect to others. What is important is the distribution of communication channels among them, that is, who communicate with whom, whether the communication is direct or via another group member, and so on.

It was Bavelas (1948,1950) who gave the lead to numerous social psychologists to conduct studies on communication channels. Most of these studies concerned the effects of *imposed communication* networks upon *leadership emergence, organizational devolopment, problem-solving effectiveness,* and *member reactions.* The investigated commu-

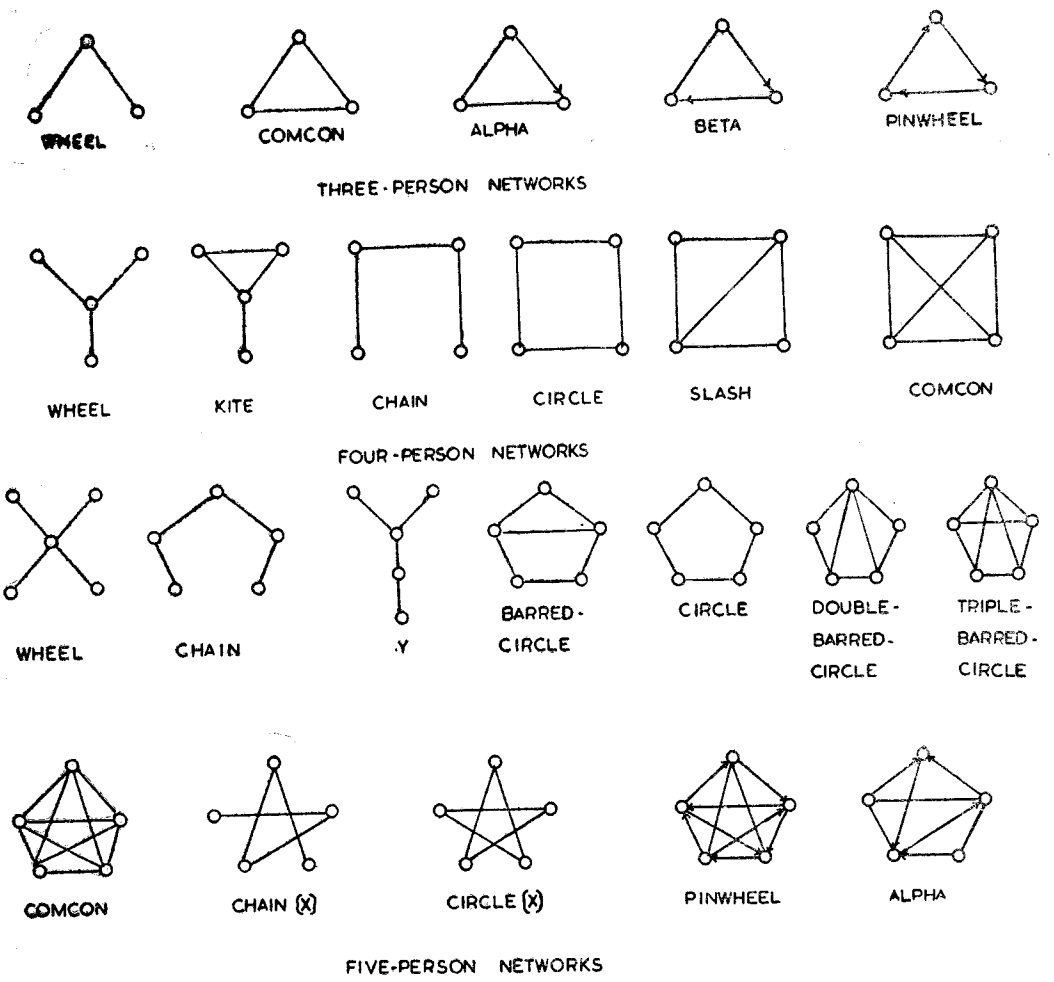

Fig. 4 : Some communication networks used in experimental investigations

nication notworks are diagrammed in Figure 4. The major findings of these investigations are summarized below :

Leadership emergence : The person who occupies a central position in a communication network has a high probability of emerging as the leader of the group. This finding has been verified in a number of studies (for example : Shaw, 1954) The *cultural generality* of this finding is indicated by the results of a study using Japanese subjects (Hirota, 1953) .

Organizational development : The imposition of a centralized communication network predisposes groups to develop a centralized organization. However, when the communication network is unrestricted, as in the *completely connected* pattern (comcon), or does not place any person in a highly centralized position, as in the *circle,* the tendency is to develop an *each-to-all* organization pattern.

Group member reactions : Since the *morale* of the group depends upon the satisfaction of its members, *group*

morale or *group satisfaction* is greater in decentralized networks. (circle, comcon) than in *centralized* networks (wheel, chain). This consequence has been reported by almost all investigations examining satisfaction in communication networks.

Problem-solving efficiency : The complexity of the task is a critical factor in determing the relative effectiveness of different communication networks. And since most of the problems that groups are faced with are more complex than the most complex task used in laboratory experiments (a simple symbol – identification task, mathematical manipulations), a decentralized communication network is most likely to be effective in natural group situations. However, it should be kept in mind, the *centralized-decentralized* dimensions of communication network does not correspond to *centralized- decentralized decision structures* (Mulder, 1960).

It was Bavelas who introduced the notion of ' *distance*, between individuals in a pattern of communication. He suggested that if we adopted some method of counting distances between individuals we could make some statements regarding differences between and within patterns. Following this suggestion he did introduce an elementary method of counting *'internal distances*; for patterns presented in Figure 5. The method of counting is illustrated below as applied to pattern B (chain) in Figure 5.

The method of counting distances as applied to pattern B

P to Q = 1	Q to P = 1	R to P = 2	S to P = 3	T to P = 4
P to R = 2	Q to R = 1	R to Q = 1	S to Q = 2	T to Q = 3
P to S = 3	Q to S = 2	R to S = 1	S to R = 1	T to S = 1
P to T = 4	Q to T = 3	R to T = 2	S to T = 1	T to R = 2
P to all= 10	Q to all= 7	R to all=6	S to all= 7	T to all=10

Thus, the summation of all internal distances for pattern B is 40' (Σ 'dx, y = 40). In a similar way, we find that the same summation for A is 30 and C is 32. Turning to the question of differences among position in the pattern B, we clearly see that position is different from position in the same pattern. But let us consider the question of distance as such. Different patterns have different Σ dx,y values and as such it may help if we express the distance in a relative manner. To do this, we have to calculate the value for the expression.

$$\frac{\Sigma dx,\ y}{\Sigma dq,\ x}$$

for each position in different communication patterns. For example, this quantity would be equal to 5.0 for all positions in the pattern A. Once this is done for all patterns of communications, comparison between patterns might be made on the basis of ' *dispersion*; (sum total of internal distances) defined as Σ dx, y and that comparisons between positions within the same pattern might be made on the basis of ' *relative centrality* ' defined as

$$\frac{\Sigma dx,y}{\Sigma dx,\ y}$$

(the sum of all internal distances of the patterns divided by the total sum of distances for any one position in the pattern).

As for how these patterns of communication might be used by a group, Bavelas suggests a sensible discussion of *'operation* ' in terms of some specified task. Given a specific task, the patterns A to D may be operated in a number of ways or ' *operationl patterns* ' . Two of the possible operational

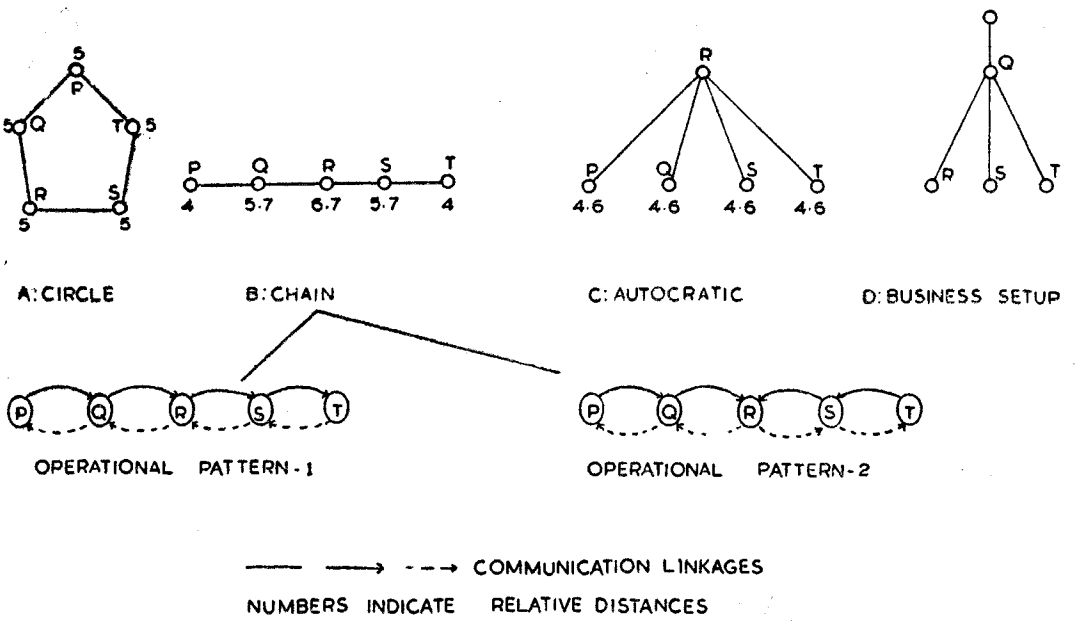

Fig 5 : Some different communication patterns

patterns for communicating necssary information are shown in Figure 5 for B. However, there are no linkage structures which would force a given method of operation into use. But, there are differences in efficiency between diffierent operational patterns. Two plausible measures of efficiency may be employed to bring out the differences: the number of messages required for task completion and the time required for task completion.

For any patterns with '*symmetrical linkage*', the number of messages required will be equal to 2 (n-1) where n stands for the total number of positions and that this is independent of the linkage pattern as such. And for any linkage pattern that is allowed, the minimum time required for completion of the task will have the following relation to the number of individual in the pattern;

$t^{min} - X + 1$ when $2X < n \leq 2X + 1$

The discussion, so briefly outlined in this section, if it does nothing more, suggests that certain approaches to certain aspects of social communication are possible and that, in all probability, it would be practically rewarding when *distances* ' involved in the process are also considered. In addition, the application of an exact solution method is not posslble especially when the complexity of problems relating to some particularity of structure in social communication may result in *intractability*.

But *heuristic programming*, a less rigidly defined mathematical procedure than a very general problem solving philosophy, may help as it represents sets of rules which produce solutions to given problems, but which do not necessarily produce the best possible solutions. Consider, for example, the problem of constructing a simple *combinatorial network* for a group of five individuals { PQRST } . A very basic kind of network for this problem is shown in Figure 6A, where every possible combination of the individuals is specified in an orderly sequence. The vertices of this network represent all possible $\Sigma i^5 = 0 (i^5) = 2^5 = 32$ different combina-

tions derivable. In this network, an arc directly links any combination containing m + 1 individuals which in addition includes all of the individuals of the preceding combination. Thus, this network corresponds to a *one-point move solution alogrithm*. A network corresponding to a *two-point move alogrithm* can be constructed by adding appropriate new arcs.

This combinatorial network has a direct *permutational analogue*. And it is an appropriate analytical instrument, though there are two basic variations : One the *combinatorial* and other the *permutational*. In the first case, the network is defined over all combinations of m individuals taken out of a total of n individuals ($m \leqslant n$), and such a network is shown in Figure 6B for all combinations of three individuals out of the total group $\{$ PQRST $\}$. In the second case, the network is defined over all simple permutations of m individuals, as exemplified in Figure 6C, for the three individuals P, Q, and R. In the network system B, the ordering of the individuals in any solution is without importance but whereas in C the ordering is what distinguishes one solution from another. Both of these network structures are constructed in such a way as to define the superstructure for simple one-point move alogrithm. And there still remains the problem of specifying strategies for searching heuristically but selectively for a solution within them. However, given the identification of these basic networks, the problem of defining a *search-procedure* is greatly simplified.

The use of heuristic programme procedures in the solutions of *iterative* structures of the types of networks depicted in Figure 6 is not new. For example, Karg and Thompson (1964) have used it in their study of the travelling salesman problem which is concerned with the establishment of a circuit around a set of n points distributed in a plane in such a way that

a. each point is intersected once and only once by the circuit, and

b. the circuit is of minimal length.

Cooper's (1964) alogrithm for partitioning a point set supposes a set of n points distributed in the plane. Any point, j, has a *Cartesian co-ordinate* set $\{ u_j, v_j \}$ which exactly identifies its location. Suppose now that it is desired to partition these n points into m discrete groups (the alogrithm developed by Cooper, in our context, is a viable solution for communication networks for social groups) in such a way that

a. each group of points has attached to it a centriod (however defined),

b. the location of each centroid is an element of the solution, and

c. the aggregate distance from each point to its associated centroid is a minimum.

In the situation under study, group process, may be we can define a centroid as a member of a group occupying a central position (in status and otherwise) and with whom others in the group interact. The location of this central member would then become an element of the solution sought. And the aggregate distance (topological or physical as the case may be) should be minimum as the group communication process in which inter-person distance plays a dominant role warrants a minimum aggregate distance for effective communication and thus group interaction.

Mathematically, this problem might then be expressed as the minimization of

$$(1) \quad Z = \sum_{i=1}^{m} \sum_{j=1}^{n} \lambda_{ij} \sqrt{(U_i^* - u_j)^2 \, (V_i^* - v_j)^2}$$

subject to

$$(2) \quad \sum_{i=1}^{m} \lambda_{ij} = 1 \quad (j = 1, 2, \ldots, n)$$

$$(3) \quad \lambda_{ij} = \begin{matrix} 1 \\ 0 \end{matrix}$$

where $\{ U_i^*, V_i^* \}$ is the co-ordinate set of the ith member occupying the central position. Usually, these centrally positioned members would be defined as centres of gravity or as

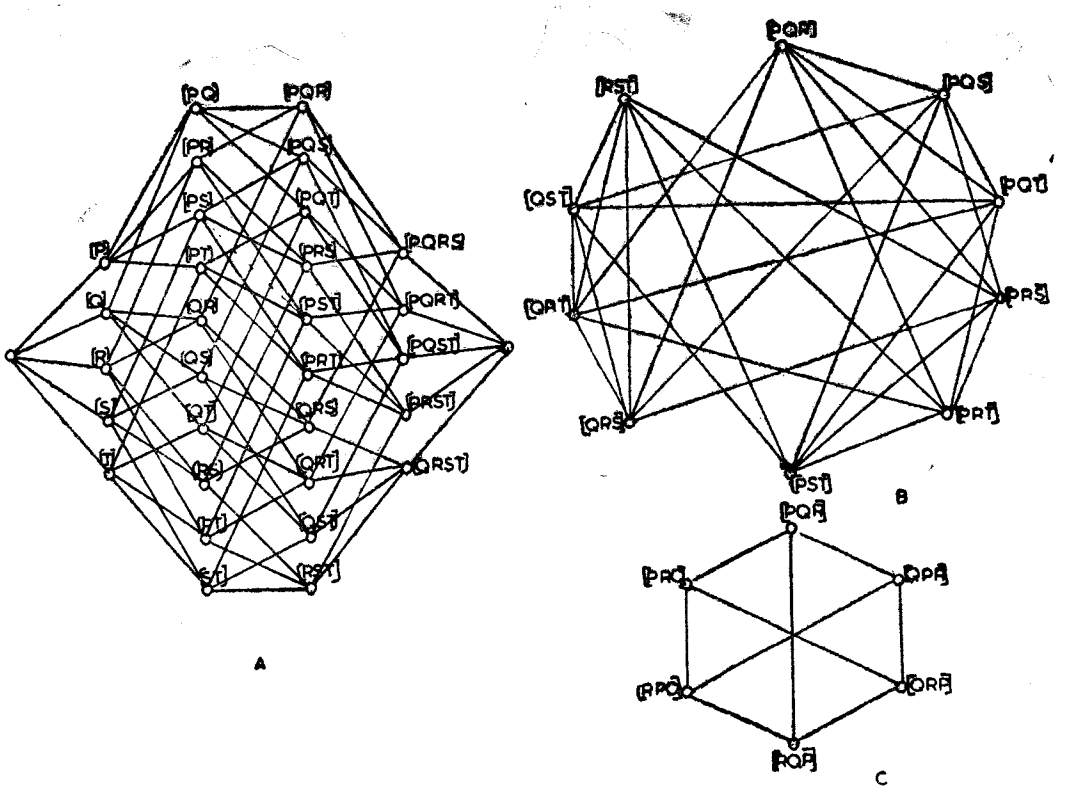

Fig. 6 : Three iterative structures of group communication networks. (A) A simple combinational network for a group of five individuals. (B) A simple network of all combinations of three individuals of the group. (C) A network of simple permutations.

median centres. The *zero-one variable* λij specifies whether or not group member j is assigned to the member in the centrally positioned location i.

The basic principles of this alogrithm in the context of a social group are as follows :

a. select location for each of the centrally positioned members in the groups considered.
b. assign members of groups to their (nearest) centrally positioned members.
c. compute a new central position for each of these groups of points, and
d· iterate over steps b and c until a set of stable groups emerges.

Now, the application of the mathematical formulation of Cooper to these groups to find a solution for the networks of communication is easy. Nevertheless, a few words are in order in so far as the applications are concerned :

a. It is indeed possible to introduce refinements on the alogrithm discussed above. Cooper himself has developed this into a much more flexible system than the procedures described above would allow.
b. The basic types of combinatorial problems represent the fundamental elements of a large number of *extremal graph-theoretic* problems. They are themselves of considerable importance in their own right, and have many planning applications in a variety of

simple netwerk problems. Group communications networks fall clearly within these networks, no matter how complex or simple they may appear to be.

c. The difficulties of solving group communication network problems are extremely great. This is particularly so when many complications incur the necessity of manipulating *real-valued* variables. Hitherto, only a few and highly simplified versions of these problems have ever been subjected to numerical analysis, and this, via the application of extremely *primitive heuristic* methods. Nevertheless, it is clear from a content analysis of literature that multiple travelling salesman problems and their generalizations are of great relevance in the analysis of many different kinds of complex networks.

d. All problems, whether their basic entities are *discrete-valued or real-valued,* which exist in some geographic area, are more or less influenced in their structural development by the effects of space. Indeed, in group process, the effects of space are of dominating infiuence via the element of distance.

e. While it is frequently not difficult to specify in theory what the conditions for optimality within some problem may be, it is in practice often difficult to attain such conditions. Three important dimensions of group interaction which may make it difficult to achieve an optimal solution are :

-the spatial structure of the network system being studied,

-its temporal functions and development, and

-the system adjusted in various ways to make it compatible with existing and foreseen developments in related systems.

There are many more problems and the space does not permit to deal with them in full. And as such this work represents only an elementary contribution to the effective analysis of realistic combinatorial systems in geographic space.

Plausible Hypotheses

We have thus far seen how individuals and groups are influenced by their physical environment. Personal space and individual territoriality have important consequences for group behaviour, and spatial arrangements in groups are important determinants of status, satisfaction, and performance. The methods and their extensions to group process analysis point out the immensity of the possibilities for spatial analysis of group process. It is now possible to list out some precise plausible hypotheses that have survived the test of empirical data. They are :

1. *The physical aspects of the environment interact with human individuals to help determine group process.*
2. *Individuals and groups assume a proprietary orientation towards certain geographical areas which they defend against invasion.*
3. *Individuals typically establish a personal space which influences most of their interactions with others.*
4. *Affective responses of individuals vary with the personalness of the situation, the intimacy of the person-other relationship, and the status of the person relative to the other.*
5. *Communication patterns in groups are determined, in part, by the spatial arrangements of individuals in the group.*
6. *Spatial arrangements influence the quality of group interaction.*
7. *Organizational development occurs more rapidly in a centralized than in a decentralized network.*
8. *A decentralized communication network is most efficient when the group must solve complex problems, whereas a centralized network is efficient when the group must solve simple problems.*

References

Altman, I. and W. W. *Haythern* (1967) : The Ecology of Isolated Groups, *Behavioural*, science, *12, 169–182.*

Bavelas, A. (1948) : A Mathematical model for Group Structures, *Applied Anthropology, 7, 16–30.*

Bavelas, A. (1950) : Communication Patterns in Task-oriented Groups, *Journal of the Acoustical Society of America, 22, 725–730.*

Baxter, J. C. (1970): Interpersonal Spacing in Natural Settings, *Sociometry, 33. 444–456.*

Carr, S. (1967) : City of the Mind, in *Environment For Man*, ed., W. R. Ewald, Junior., Indiana University Press (Bloomington), 197–231.

Clark, W. A. V. (1971) : A Test of Directional Bias in Residential Mobility, in *Perspectives in Geography 1: Models of Spatial Variations*, ed., H. Mc Connel and D, W. Yaseen, Northern Illinois University Press (Illinois), 1–29.

Cooper, L. (1964): Heuristic Methods for Location–allocation Problems, *SIAM Review, 6, 37–53.*

Festinger, L., S. *Schacter*, and K. *Back* (1950): *Social Pressures in Informal Groups*, Harper and Brothers (New York).

Franke K. G. and D. N. *Franke* (1975) : *Man and the Changing Environment*, Holt, Rinehart and Winston (New York).

Golledge, R. G. (1970) : *Process Approach to the Analysis of Human Spatial Behaviour*, Department of Geography, Ohio State University.

Hireta, K. (1953): Group Problem–Solving and Communication, *Japanese Journal of Psychology, 49, 547–553.*

Horton, F. E. and D. R. *Raynolds* (1971) : Action Space differentials in Cities, in *Perspectives in Geography 1: Models of Spatial Variattons*, ed., H. Mc Connel and D. W. Yaseen, Northern Illinois University Press (Illinois), 83–104.

Hudson, J. C. (1971): Some Properties of Basic Classes of Spatial Diffusion models, in *Perspectives in Geography 1: Models of Spatial Variations*, Northern Illinois University Press (Illinois).

Justice, M. T. (1969): *Field-dependency, Intimacy of Topic and Interaction Distance*, Doctoral Dissertation, University of Florida (Gainsville).

Karg, L. L. and G. L. *Thompson* (1965) : A Heuristic Approach to Solving Travelling Salesman Problems, *Management Science, 10, 225–248.*

Little, K. B. (1965) : Personal Space, *Journal of Experimental Social Psychology, 1, 237–247.*

Lyman, S. M. and M. B. *Scott* (1967): Territoriality: A Neglected Social Dimension, *Social Forces, 15, 236–249.*

Morton, R. K. (1950): The Social Psychology of Housing, in *Current Trends in Social Psychology*, University of Pittsburgh Press (Pittsburgh),

Moore, E. and L. A. *Brown* (1969): *Spatial Properties of Urban Contact Fields: An Empirical Analysis.* Research Report No. 52, Department of Geography, Northwestern University.

Mulder, M. (1960): Communication Structure, Decision Structure, and Group Performance, *Sociometry. 23, 1–14.*

Myers, R. K. (1969): *Some Effects of Seating Arrangements in Counselling*, Ph. D. Dissertation, University of Florida (Gainsville).

Rubensein, A. H, and C. J. *Haberstrol* (1964) : *Some Theories of Organization*, Richard D. Irwin (Homeweed, Illinois).

Russo, N. F. (1950)i Connotations of Seating Arrangements, *Cornell Journal of Social Relations, 1, 342-345.*

Shaw, M. E. (1954); Some Effects of Problem Complexity upon Problem-solution Efficiency in Different Communication Nets. *Journal of Abnormal and Social Psychology of Small Group Behaviour*, Mc Graw-Hill (New York).

Sommer, R. (1959) : Studies in Personal Space, *Sociometry, 22, 247-260.*

Sommer R. (1969) : *Personal Space : The Behavioural Basis of Design*, Prentice-Hall (Englewood Cliffs, N. J.).

Steidzer, B. (1950) : The Spatial Factor in Face-to-face Discussion Groups, *Journal of Abnormal and Social Psychology, 45, 552-555,*

Whyte, W. F. (1949): The Social Structure of the Restaurant, *American Journal of Sociology, 54, 302-308.*

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