ROBERT J. BECK, WILLIAM J. FITZGERALD & BIRGIT PAUKSZTAT
University of California, Irvine

INDIVIDUAL BEHAVIORS AND SOCIAL STRUCTURE IN THE DEVELOPMENT OF COMMUNICATION NETWORKS OF SELF-ORGANIZING ONLINE DISCUSSION GROUPS

Abstract. Four preservice teachers' online discussion groups of eight randomly assigned participants each were studied to analyze the contribution of individual and social factors in the development of communication networks. Participants shared observations and follow-up responses in five weekly rounds of data collection. Using a core-periphery social network analysis model (Borgatti and Everett, 1999), distinctive core and periphery sub-groups were found in each of the four listservs. As measured through quality assessments of individual observational messages, mean quality was higher in each of the core groups, but results were statistically non-significant. In two of the groups, mean quality of follow-up responses was statistically significantly higher in the periphery for messages sent and, in one group, for response quality messages received. Early submission of observations was highly correlated with number of messages received. Fitting the core/periphery model to data from three cumulative time periods, T1, T3, and T5 for each listserv, allowed us to check for consistency in group dynamics over time. For each listserv, it was found that the communications data progressively achieved a better fit with a core/periphery model.

1. INTRODUCTION

Several studies have shown that in unassigned, initially leaderless groups a stable influence hierarchy and role system will emerge and persist after initial instability (Homans, 1950; Bales, 1970). Strangers initially use observed status characteristics, such as age, gender, and race, to establish leadership and influence hierarchies, and later, according to Expectation States Theory, the structure may be adjusted to match the relevant skills of different members (Berger, Conner & Fisek, 1974; Arrow, 1997). Status hierarchies are important because team effectiveness has been related to cohesiveness and leadership (Johnson & Johnson, 1994). The study of self-organizing groups necessarily relies on groups that have no history or pre-assigned hierarchical structure. Random selection of participants to groups is one means of neutralizing prior associations and, hence, pre-organized lines of communication. The members of an on-line group are probably less likely to experience the dominance that may occur in face to face groups as dependent on observable status or on visual and aural behaviors signaling power and authority, such as raising one's voice. The purpose of this paper is to analyze a relatively ignored dimension of CSCL, the discovery of structures and processes in group self-organization during collaboration. Lipponen (2002) stated that "there exists little research on how students participate in networked mediated collaboration, and on the consequences of different types of participation patterns…" (p. 75) (although see Stevens, 2001; and Kaptelinin and Cole, 2001). Bielaczyc (2001) called for more attention to building appropriate social infrastructures around technical infrastructures.

MODELS OF STATUS HIERARCHY DEVELOPMENT

What factors contribute to the development of status hierarchies? Burt (1999) contrasts the "human capital" explanation – people who do better, and hence attain higher positions in a status hierarchy because of their personal attributes, such as knowledge, skill, and charisma, with the social capital explanation – people do better because they are better connected.

Gould (2002) used a comparable dichotomy in summarizing groups of factors that lead to interaction hierarchies. He specified an individualist or market framework in which outcomes are unequal because individuals vary in qualities that have locally meaningful importance, such as talkativeness or confidence. Differentiation occurs because people make different contributions. This was contrasted with a social structural framework in which outcomes are unequal because of the quality of social positions one occupies, largely independent of personal qualities. However, Gould has not been content to accept one or the other of these factors alone in explaining why hierarchies develop.

For Gould (2002: 1145), hierarchy is explained as "an emergent social process" without assuming that it is a reflection of underlying qualities (individual or social). Outcomes result from a more decentralized,

less purposive process. In this view, status rankings are stable because of the self-validating character of social judgments (1144). For example, "if one individual attracts slightly more positive judgments than others because of some intrinsic quality, then the social influence process will set off a cascade in which this small difference is inflated as people react to one another's reactions to its existence" (1149). Thus, "collective adherence to socially provided assessments reproduces and thereby validates those very assessments" (1148).

A number of studies have shown the influence of behavior on hierarchy formation (Lee and Ofshe 1981; Shelly and Troyer 2001, 2002). According to expectation states theory (Berger and Conner, 1974; Berger et al 1977; Fisek et al., 1991), social expectations arise from status characteristics of group members and interaction dynamics. In a self-fulfilling way, these expectations advantage those actors who possess the valued status characteristics, or who distinguish themselves by the quality of their contributions early on in the interaction (Gibson 1998; Okamoto and Smith-Lovin 2001; Shelly and Troyer 2001, 2002). Those actors who have gained such advantage will now be treated as higher status individuals, and a stable hierarchy emerges. To identify communications processes that contributed to the development of hierarchies, we drew on social network analysis.

SOCIAL NETWORK ANALYSIS

Social network analysis is an interdisciplinary approach whose goal is to understand social organization and social behavior by focusing upon the relations between actors (e.g., individuals, firms, groups).

> "Social network analysts seek to describe networks of relations as fully as possible, tease out the prominent patterns in such networks, trace the flow of information (and other resources) through them, and discover what effects these relations and networks have on people and organizations. They treat the description of relational patterns as interesting in its own right - - e.g., is there a core and a periphery? - - and examine how involvement in such *social networks* helps to explain the behavior and attitudes of *network members* – e.g., do peripheral people send more email and do they feel more involved?" (Garton, Haythornthwaite and Wellman, 1997: 2).

The fundamental units of analysis in social network theory are the relationship between actors. Relations among actors in a network are investigated to discern the nature, direction and strength of their ties. Analysts are interested in emergent global patterns in these exchanges that create and sustain work and social relationships. Ties may be analyzed according to relations of content, direction, and strength. Content refers to the nature of the resource exchanged (e.g., knowledge building communication) while direction refers to patterns of sending and receiving communications resources in network activity. Strength is usually operationalized as the frequency of communications (Garton, Haythornthwaite & Wellman, 1997).

Recent studies of teamwork and collaborative learning have provided important insights into the effects of patterns of communication on learning processes and on group task performance. It has been reported that patterns of giving and receiving elaborated help are critical components of teamwork skills (Webb, 1993). Giving explanations helps senders of messages to reorganize and clarify material (Bargh & Schul, 1980); receiving explanations can be beneficial by filling in gaps of understanding or correcting misperceptions and strengthening connections between new information and previous learning (Mayer, 1984; Wittrock, 1990).

Social network analysts can utilize a core-periphery model to see if empirical data are consistent with a communication hierarchy. An ideal core-periphery structure is one containing a "core" that is maximally connected to itself (i.e., members exchange frequent communications with each other) and a "periphery" that does not communicate with itself, but whose members may or may not communicate to some degree with the core. An algorithm developed by Borgatti and Everett (1999) attempts to fit empirical data to this idealized structure via matrix permutation, and the resulting two-mode partition is the best fit obtained between the actual data and this ideal structure. If empirical data indeed have such a core-periphery structure, the fit between the ideal structure and the partition of the observed data will be relatively large.

AN INTERACTIVE MODEL OF INDIVIDUAL BEHAVIORS AND SOCIAL STRUCTURES IN THE DEVELOPMENT OF CHOICE STATUS HIERARCHIES IN SELF-ORGANIZING GROUPS

In our model, we assume that status hierarchies develop because group members evaluate each other's contributions non-randomly. Further, it is assumed that high-status actors prefer to communicate with other high-status actors and that low-status actors prefer to communicate with high-status actors (cf. Gould 2002; Homans 1950). This results in the emergence over time of a group of core actors and a group of peripheral actors. The members of the (higher status) core are thus expected to exchange a large number of messages with each other. Members of the (lower status) periphery, in comparison, are expected to communicate only little with each other. Instead, we expect that low status actors will send a high number of messages to members of the core, but without receiving many messages from these core members in return, resulting in an asymmetrical relationship between core and periphery (Gould, 2002).

If personal attributes of individuals were relatively important factors in determining an individual's status (as indicated by her or his membership in the core), then we would expect significant differences in individual attributes of members of the core and of the periphery. For example, core members would be expected to send messages that are longer and of higher quality, or to distinguish themselves by the relatively early submission of their communications (cf. Arrow 1997; Gibson 1998; Kickul and Neuman 2000; Okamoto and Smith-Lovin 2001; Schmid Mast 2001; Shelly and Troyer 2001, 2002).

On the other hand, membership in the core may result not from personal attributes of individuals, but from the communication behavior of the group members. For instance, core members may also be those who are socially active in initiating and sustaining exchanges with others (Dann et al., 2000; Freeman, 1978/79). Eventually, core members may develop strong ties to each other because they recognize each other as well connected and central in the communication network.

SOCIAL NETWORK ANALYSIS OF STATUS HIERARCHY DEVELOPMENT IN EXPERIMENTAL ONLINE DISCUSSION GROUPS

Online discussion groups present unique opportunities for research of the formation of communication hierarchies. In discussion groups such as those in the present study, the exchange of information is valued for its own sake, giving each member of the group access to information about a wide range of classroom situations and the ways in which other teachers solve various problems. In contrast to experimental task groups that are set up to study the emergence of hierarchies, such discussion groups are not given the objective to collaborate in the creation of an end product specified by the researchers. Task-oriented leaders who keep group members on task and on schedule, and who may assign different roles to other group members and coordinate their collaboration, are not required by design in discussion groups. Therefore, discussion groups are more likely to provide an environment that allows all participants to act on cues provided by the attributes of group members, their behavior, or to structural constraints such as emergent network position, rather than leading them to organize efficiently in order to fulfill certain tasks. This can be enhanced through setting experimental conditions in which, for example, each participant is asked to respond to a specific number of individuals in the group.

A second characteristic of discussion groups is that while participants respond to specific others, all messages can be read by any member of the group. In many problem-solving, product-oriented groups, communications may be one-on-one between two individuals, excluding others. In discussion groups the dialogue takes place within the "hearing" of all members of the group. In this way, group members have maximal information about individual attributes and behavior as well as on the emergent social structure of the group, allowing them to make informed decisions concerning to whom to send their next message.

2. METHODS

Task and procedure

Using the California Teaching Standards for the Profession as a framework, preservice teachers were set the task of observing and reporting in writing on activities in their mentor teachers' classrooms that exemplified one standard each week in five rounds of observations. In addition, the teachers were asked to follow up by responding freely to two or more of their Listserv members in each round.

Sample

Thirty-two multiple subject teachers in a 5th year credential program were randomly assigned to four initially unstructured groups of eight participants each. Twenty-nine of the participants were female and three were male.

Technology

Asynchronous email listserv discussion groups were used to communicate the teachers' observations of these standards and their follow-up responses to each other.

Data Analysis

Rubrics were developed for coding the observations and responses. One rubric was used to score the classroom *observations* about teaching standards. Three dimensions were scored :D1: Aptness (0-2 points); D2: Detail and context (0-2 points); and, D3: Reflection. Reflections were scored according to the following criteria: (3.1) interpretations about teacher's strategy or student outcomes; (3.2) interpretations explaining why a strategy was beneficial; (3.3) questions; (3.4) connections to other observations; or, (3.5) alternatives considered (0-5 points).

For the *follow-up responses to observations*, which were reflective in qualty, the scale used the same criteria as the Observation Reflection dimension.

All observations and follow-up responses were scored for quality by two independent raters. Alphas varied from .81-.93.

Research Questions

Q1. Is there a core and a periphery for each of the four groups as determined by a two-class partition of nodes? Corollary: Is there asymmetric reciprocity between the core and the periphery such that the periphery sends more messages to the core than the core sends to the periphery?
Q2. Does the core have higher mean observation quality scores than the periphery?
Q3. Does the core have higher mean response quality scores than the periphery for messages sent and received?
Q4. Does the core have higher rates of early submission than the periphery?
Q5. How early does the core develop and does it increase in strength and consistency over time?

3. RESULTS

Core-Periphery Analysis

Given our research hypotheses, we predicted that the communication choices across the five rounds would yield variability among listserv participants in aggregate communications activity. More specifically, we expected the overall pattern to be one in which a subset of participants were relatively active and preferred to communicate among themselves, while another subset of participants would be relatively inactive and would prefer communication with active members over inactive members. These expectations regarding group structure are intuitively consistent with a network-based ideal model of a "core -- which is maximally connected to itself, and a "periphery"- - which is not connected to itself, but may have some relatively weaker connection to the 'core.' Core/periphery models have been discussed and recently formalized (Borgatti and Everett, 1999), and incorporated into commercially available software applications for network analyses (Borgatti, et. al., 2002). While other network measures, such as degree centrality of participants, also address some aspects of our research questions, our choice of methodology more systematically and comprehensively

accounts not only for the frequency of communication for each participant, but also for the variations among participants in choices of communication partners.

In Figure 1, we present the solutions to the core-periphery analysis for Listservs 1-4. Note that, given our research questions (Q1), we left to empirical discovery the extent of the communication between core and periphery (Borgatti & Everett, 1999).

Group 1

Fitness: 0.570
Blocked Adjacency Matrix

	1	2	3	4	5	6	7	8
	0	1	3	3	4	4	4	8
1 046		4	7	7	2	1		1
2 172	1		2	4	4	2		1
3 307	4	2		7	8	1		5
4 347	4	5	4		6	2		2
5 413	1	5	7	6		1		5
6 417	1		1	1	2		1	1
7 480	1	3		4				3
8 859	1	3	2	4	3	3		

Density matrix

	1	2
1	4.500	1.400
2	1.733	1.333

Group 2

Fitness: 0.672
Blocked Adjacency Matrix

	5	2	7	4	6	1	3	8
	8	2	8	5	8	1	5	9
5 840			5	4	2	2		
2 222	2		3	4	3	2	1	1
7 873	3	3		7	4	4	2	
4 539	2	4	4		3	3	1	
6 846	5	6	5	4		4		2
1 146	3	1	2	4	2			2
3 536	1							
8 932	2		2		2	1	1	

Density matrix

	1	2
1	3.650	1.467
2	1.267	0.667

Group 3

Fitness: 0.650
Blocked Adjacency Matrix

	5	6	4	8	3	1	7	2
	3	7	3	8	3	1	8	1
5 361		6	4	4	1	5	5	1
6 796	3		1	3	1	2	2	
4 315	5	4		2	5	1	3	1
8 863	5	6	1		2		1	2
3 302	4	2	6	2		2	3	
1 110	1	3			1		2	2
7 840	4	1	2	1	1	2		1
2 111	2	1		5		2	1	

Density matrix

	1	2
1	3.667	2.000
2	2.125	1.417

Group 4

Fitness: 0.737
Blocked Adjacency Matrix

	3	2	6	1	5	4	7	8
	34	24	64	14	45	38	68	75
3 3418			7	1	3	1	2	2	2
2 2458	3			8	2		1		
6 6448	6	11			3	1	2	4	1
1 1475			1	2				1	2
5 4515	1	1	1		2				2
4 3875			2	1	1		4		
7 689C	2			4	1		1		1
8 7515	2			2	2	3	2	2	

Density matrix

	1	2
1	6.000	1.600
2	1.267	1.200

Figure 1. Core-Periphery Structures by Listservs 1-4

The results indicate some evidence for core-periphery structures in the communication data across all listservs. The size of the cores varied as follows: Listserv 1 = 5 members; Listserv 2 = 5 members; Listserv 3 = 4 members; and Listserv 4 = 3 members. In Listservs 1 and 3 the members of the periphery sent more messages to the core than vice versa; whereas, in Listservs 2 and 4 the members of the core sent more messages to the periphery than vice versa. Thus, Gould's asymmetric hypothesis could not be supported across all listservs.

Mean observation quality scores in core and periphery

The results of the core-periphery analysis enabled us to compare mean observation quality scores between members of the core and the periphery for each listserv. The results are displayed in Table 1.

OBSERVATION SCORES (D3)

LISTSERVE	n Core	Mean Core	n Periph	Mean Periph	P Value
1	25	0.92	15	0.53	0.073
2	25	0.96	14	0.64	0.146
3	20	0.65	20	0.70	0.416
4	15	0.80	25	0.36	0.067

Table 1. Observation Scores (D3) in Core and Periphery

While mean scores were higher in the core for members of Listservs 1, 2 and 4, there were no significant differences at .05 or less. It was concluded that individual attributes as measured by observational quality scores were not a factor in the development of the core-periphery hierarchy.

Response quality scores

In Table 2, we present the findings for the quality of follow-up responses. For messages sent, there were two significant findings. In Listserv 1 the members of the periphery had a higher mean response quality score than the core ($p < .009$) while in Listserv 2, the members of the core had a higher mean response quality score ($p < .01$). For messages received, the periphery had higher scores in all listservs. However, only in Listserv 4

INITIAL RESPONSE QUALITY SCORES SENT

LISTSERVE	n Core	Mean Core	n Periph	Mean Periph	P Value
1	47	2.71	21	3.33	0.009
2	47	2.37	14	2.04	0.011
3	40	2.93	33	3.15	0.159
4	26	2.56	31	2.50	0.361

INITIAL RESPONSE QUALITY SCORES RECEIVED

LISTSERVE	n Core	Mean Core	n Periph	Mean Periph	P Value
1	50	2.87	18	2.98	0.346
2	43	2.19	18	2.56	0.071
3	45	2.96	28	3.14	0.210
4	29	2.38	28	2.68	0.034

Table 2. Initial response quality scores for messages sent and received

were these differences statistically significant ($p < .03$). Thus, while in some listservs members of the periphery sent or received high quality responses, the fact that the difference was insignificant suggests that these were not individual attribute factors contributing to the attraction of sufficient messages to achieve membership in the core.

Observation time of submission

Table 3 shows the time of submission of observations for each listserv, measured as the mean number of days that elapsed before the submission of the first observation for each standard by members of the core and periphery.

	OBSERVATION TIME (DAYS)				
LISTSERVE	n Core	Mean Core	n Periph	Mean Periph	P Value
1	25	5.56	15	11.07	0.002
2	25	5.76	14	8.79	0.043
3	20	2.20	20	3.85	0.035
4	15	4.20	25	10.92	0.0001

Table 3. Observation Submission Time for Listservs 1-4

As can be seen, submission time is a highly significant factor in determining membership in the core and the periphery. The listservs varied in how early messages were submitted. In Listserv 3, for example, both core and periphery members submitted their observations earlier than the participants in other listservs. Early submission time greatly increases the probability of receiving responses to observations.

Attempting to fit a core/periphery model to the aggregate communication data for a given listserv does not allow us to properly assess the evolution of communication choices over time. To take an initial look at group dynamics, we tested the core/periphery model on the communications data at the end of the first round (T1), the aggregate data at the end of the third round (T3), and compared both to the overall data (T5). This allowed us to check for consistency in group dynamics over time. For each listserv, we found that the communications data progressively achieved a better fit with a core/periphery model. In addition, we noted that the two most active participants for each listserv were already established as members of the core in T1 and remained there through T5. Both core/periphery partition size and membership showed only slight variation across time periods for some, but not all, listservs.

4. DISCUSSION

The study has begun to answer the question about the relative contributions of individual behaviors and social structure in online discussion groups. The results indicated that core-periphery membership is influenced by time of submission. While this might be considered an individual attribute in the sense of punctuality or dominance behavior, the early submission increased the probability one will get messages from the rest of the group. At least two members of the core in each group joined the core in the first round and stayed core members for the entire discussion. However, some core members did not become part of the core until the second time period and others drifted out of the core during the discussion, suggesting there may be an inner and outer core. Although the overall degree of reciprocity is high (on average, about 65% of all messages are

reciprocated, and only four persons have under 50% of reciprocal exchanges), core members in particular engaged in *repeated* reciprocal exchanges (30, 22, 22, and 22 messages for the most versus 0, 0, 4, and 2 for the least active member in each listserv), mainly with other core members. While early submission time and reciprocity appeared to be very important factors in social relations leading to distinctive core and periphery subgroups, an analysis of the most active and least active individual members of the listserv may point to individual factors that cannot be fully explained by the social structural factors.

Core actors exchanged *many messages* with *many different others*, while periphery actors exchange *fewer messages with fewer others*. The most active core member (defined here as the person with the highest total number of messages sent and received) in each listserv was involved in about 20% of the exchanges that occur in the listserv as sender or recipient (19.3%, 18.6%, 19.7%, and 22.8% in Groups 1-4, respectively). These members may be functioning as *hubs*. Barabási (2002) argues that nodes have relative fitness in competing for links and therefore have "preferential attachments" in searching for connections. For example, nodes tend to choose other nodes that are well connected, a characteristic that makes for high degrees of fitness. Those nodes that have very high fitness may become hubs or connectors and account for a high proportion of all ties in a network. Clearly, a strong factor in becoming a hub is early submission time. In contrast to periphery members, core members were among the earliest to submit their observations. The mean submission time (in number of days after the first observation for the standard was submitted) for the most active actor in each group was 4.6, .2, .6, and .8 respectively. In our study, the most active person or hub in each listserv was also in contact with all other members of the listserv, and both sent and received messages from six or seven of the others (In-Alter 7, 6, 7, 7, Out-Alter 6, 6, 7, 7). Counting only alter with whom three or more messages are exchanged ("partners"), the most active member of each listserv had 4, 4, 4 and 2 alter, most of them other core members.

The least active member of each listserv (defined here as the person with the lowest total number of messages sent and received) was only involved in about 5% of the exchanges (4.14%, 2.54%, 7.09% and 5.83%), which is only 25% of the activity of the most active core members described as hubs. For the least active actor in each listserv, submission time was clearly a factor. On average they submitted their observations 17, 13, 3.8 and 15 days after the first observation in each standard had been submitted by a listserv member. Note that in listserv 3, the observations were submitted almost at the same time by all persons. Moreover, the least active members had only a few persons to whom they send (4, 1, 5, and 5), and a few persons from whom they receive messages (1, 4, 5, and 3), which, as there is only partial overlap between these two networks, added up to a total personal network of 5, 5, 6, and 5 alter for the peripheral actors. None of the least active member in each listserv had any "partners", with whom they had three or more reciprocal exchanges. Peripheral members apparently sent messages to those who were less likely to reciprocate back to them.

There were no differences between members of core and periphery with regard to the quality of their observations. Differences in response quality were small: the mean RQS of core members in each listserv was 2.789, 2.196, 2.710, and 2.559. Periphery members of each listserv had a slightly higher mean RQS of 3.056, 2.412, 3.025, and 2.664. That periphery members both received and sent high quality messages in some listservs could indicate, respectively, that they were perceived as in need of high quality messages. Perhaps, they sent high quality messages in order to form connections with others. Given the differentiation of the core and the periphery in terms of submission times for observations, an alternative argument here is that members of the periphery had more time to learn from group communications as a whole and thus were able to produce higher quality responses; or, they invested more time in each message, i.e., quality instead of quantity.

These results have implications for the identification of individual and social factors contributing to role structures in groups, and these structures, in turn, suggest criteria for the design of computer-supported collaborative learning. In each listserv, there was a *core* formed of early submitters who had strong reciprocating partners from the core. Yet, in each core was a *hub* who was relatively distinctive not only in the total degree and share of messages in the core, but who also practiced relatively more diversity in selecting and reciprocating a large number of alters. We think that the choices of diverse numbers of partners by hubs, and to a somewhat lesser degree in all core members, constitute an individual factor that cannot be explained by time submission and reciprocity alone. Conversely, there were other individuals who were extremely peripheral, who appeared to invest in the wrong alters. Therefore, participants were not benefiting equally in

these groups, at least in terms of messages received as feedback. And yet a number of these peripheral members had high quality communications; thus, benefits from this collaborative process await further clarification.

Should hubs and peripheral members be identified, as such, to the participants themselves? In conventional discussion groups in formal education, it would be a commonplace for an instructional leader to encourage greater participation from those who had low levels of participation and to praise high performers who engaged several others in the group. Thus, core-periphery analyses could be used to assess individual performance in groups that had extended discussions. In these assessments, peripheral members and some core members could be encouraged to communicate more frequently and with a greater diversity of alters. Hubs should be praised for the strength and diversity of their engagement. Some feedback might be generic to the group: all actors should be active, reciprocal, and diverse in their choices of alters. The effects of such instructions could be measured through subsequent core-periphery analyses in which the collapse of such hierarchies might be predicted. And yet this might be problematic, given that hierarchy may be implicated in overall group productivity and the received wisdom that participants may learn in socially diverse ways. For example, peripheral members' quality might decrease as a function of their increased activity in communicating more, and with a greater range of alters. Still, it seems reasonable to try to encourage communications between high quality, but peripheral, individuals with core members, who have a greater propensity to reciprocate, if only to provide peripheral members with more feedback on their observations and responses. In online groups, no less than face to face, perhaps some adroit matchmaking could be encouraged between selected core and periphery members.

To reduce the effects of submission time, methodological changes are needed. This might be effected through instructions requesting observation submission at specific dates and that participants wait until all observations have been received before responding. Instructions also could reinforce the focus on individual behaviors by asking participants to respond to messages they found "interesting" or "useful." Retrospective surveys on why participants decided to send messages to whom also would clarify the importance of individual factors in choices.

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