CREW CLIMATE AND PERFORMANCE: USE OF GROUP DIAGRAMS BASED ON BEHAVIORAL RATINGS

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A method of depicting crew climate using a group diagram based on behavioral ratings is described. Behavioral ratings were made of twelve three-person professional airline cockpit crews in full-mission simulations. These crews had been part of an earlier study in which captains had been had been grouped into three personality types, based on pencil and paper pre-tests. We found that low error rates were related to group climate variables as well as positive captain behaviors.

Importance of Studying Crew Climate

Although we are becoming adept at ascertaining the effects of instrument displays and computer interfaces on crew performance, there is a huge void in our knowledge of how to measure the effect of group climate, i.e., interpersonal interactions, on performance. Helmreich & Foushee (1993) state that research into group factors is difficult and time-consuming, and that as a result, there is not an extensive literature in the aviation environment on group/individual level factors. If major characteristics of interaction in groups could be known and compared, we could estimate the degree to which crew climate contributes to performance, and the extent to which other factors affect crew climate. These other factors could be, for example, the design of procedures, training for techniques on making suggestions, adequate pre-briefings, etc. Presented here is an approach, the group diagramming method, which has been successful in characterizing group climate in non-aviation settings. The goal of this paper is to apply it to aviation settings.

The Group Diagram

Description. The group diagramming method was first described in Bales & Cohen (1979). The group diagram displays group member behaviors on the following three dimensions: (1) positive/negative, (2) dominant/submissive, and (3) task-oriented/expressive. In a group diagram behaviors on the positive/negative dimension are plotted on the x axis and behaviors on the task-oriented/expressive dimension on the y axis. Dominant/submissive behaviors are portrayed by varying sizes of circles, with larger circles representing more dominant behaviors. Dominance scores are used as statistical weights in the analysis of group properties (Parke & Houben, 1985).

Examples. Two examples of group diagrams are presented below to illustrate the type of information group diagrams portray. The classroom behaviors in these diagrams were obtained through teachers' ratings on an instrument described below. Red circles depict girls' behaviors and blue circles depict boys.'

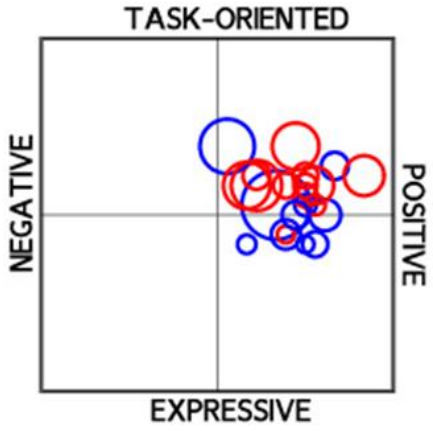

Figure 1. Unified classroom group, grade 5 (Parke & Houben, 1985).

Figure 1 shows a Unified Group, consisting of members who behave in the positive, task-oriented quadrant—with a few expressive behaviors (joking, non-task) to enliven the atmosphere. The defining characteristic of a Unified Group is the close *proximity* of the behaviors of the group members—all have been rated as behaving very similarly on the diagram plane. The statistic used to measure this proximity is the weighted average distance from the group's center of gravity (Parke & Houben, 1985). Proximity on the diagram plane has been shown by Fine (1986) to be related to greater enjoyment and less stress in the group, as rated by group members and observers. Fine also demonstrated a modeling and contagion effect. He introduced a dominant confederate in the second hour of his groups and showed that others moved towards the confederate in the diagram plane (as ascertained by self and other ratings, and coding of behaviors by observers). Hence the diagram plane is a dynamic space with clustering of behaviors (Parke & Houben, 1988). A repelling force was found on the dominance dimension, since there is a limited amount of group time, and one person's activity generally limits others'.

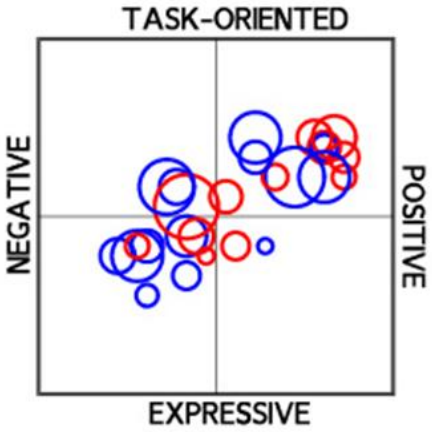

Figure 2. Polarized classroom group, grades 3-4 (Parke & Houben, 1985).

Figure 2 shows a Polarized Group with two subgroups—one of members behaving in a task-oriented and positive manner, and another of members behaving in a negative, expressive manner—i.e. rebelling. The defining characteristic of a Polarized Group is that the group members' behaviors fall along a line. This characteristic is measured by an "index of polarization," ranging from 0 to 1, which compares the variance along the group's major axis (the weighted least square line fit through the group) to the variance among the minor axis, which is perpendicular to the major axis. The index of polarization of the group in Figure 2 is quite large—.91.

Research Goals

Our first priority was to determine whether behavior in cockpit crews varied enough so that differences between them would be portrayed in group diagrams. Our second goal was to ascertain whether any group variables were related to performance measures. Our third goal was to assess whether rating and coding the behaviors of captains and the other crew members increased our understanding of interaction in the crews. Yet a fourth goal, not addressed in this paper, was to make diagrams from act-by-act scores and arrive at a time-linked representation of behavior.

Method

Description of previous simulation. We re-examined a previous full mission 727-200 simulation with three person crews composed of professional airline pilots (Chidester, et al., 1990). The goal of this original study was to determine the effect of captains' personality on crew performance. To this end, 23 experienced professional airline captains were grouped into three types based on paper and pencil personality pretests. The types were: authoritarian (characterized by high levels of negative instrumentality and low levels of expressivity), skilled leader (characterized by high levels of instrumentality, expressivity, and achievement striving), and passive leader (characterized by high levels of negative expressivity and low levels of instrumentality and achievement striving). Crews headed by these captains participated in five experimental segments (legs) over two days. Segments 3 and 5 had difficult abnormal conditions in the last portion of the leg. Each abnormal condition called on different skills from different crew members.

Chidester et al. (1990) found that crews headed by passive leader captains made significantly more errors than crews headed by either of the other types of captains. It was unexpected that the crews of authoritarian captains made about the same number of errors as crews of skilled leader captains.

Current study. Three observers, blind to the category of captains, rated the video tapes of Segments 3 and 5 for 12 of the crews. These crews had been selected to be headed by four passive, four skilled leader, and four authoritarian captains, representing the extremes on the personality dimensions. The adjective list rating instrument used for the rating consisted of 26 behavioral items (tapping all possible combinations of the factors on the three dimensions described earlier) with a three point rating scale (hardly ever, sometimes, often) (see Parke, 1985). With this method, factor scores for all group members can be plotted simultaneously in three dimensions to create an easily interpreted group diagram. (The three observers also coded the video tapes act-by-act to aid in the development of a method for making diagrams based on act-by-act coding.)

Reliability. The average correlations of one rater with the average of the other two on each dimension were: .67 on the positive/negative dimension, .71 on the dominance/submission dimension, and .69 on the task-oriented/expressive dimension.

Results

Group diagrams reflected crew differences. Behavior in this sample of cockpit crews varied enough so that group diagrams could easily be distinguished from each other. Indeed, the metrics used to classify groups in other settings differentiated the pilot crews in terms of performance. Of the 24 diagrams (two segments per crew), 20 were Unified Groups or a Unified subtype. All of the flights with low or medium errors had crews that were Unified Groups. There were four flights with crews that were Polarized Groups and all were in the six highest error flights—only two of which were Unified.

Substantiating the findings of the earlier study which found that crews led by the passive captains made the most errors, the three highest error crews in this sample were headed by passive (and negative) captains. Figure 3 shows a group diagram for the crew with the highest error score. In the two highest error crews, the captains did not let the first officer fly during abnormal operations. Turning over the flying to the first officer is a way of dividing the workload in abnormal

conditions. It frees up the more experienced crew member to deal with abnormal operations while insuring that the plane gets flown. Both of these captains had first officers of similar or greater dominance ratings than themselves, and the captains appeared to be trying to retain control. For example, the first officer of Crew 7 (Seg. 5) said at the beginning of the abnormal condition, "Well, are you going to do everything, or are you going to let me help." The captain replied, "No. *I'll* fly the plane." Whether first officers can be too dominant or assertive in some cases is a current concern (Murray, 1999). Since many accidents have been related to the first officer's lack of assertiveness, there seems to be a fine line a first officer has to walk, depending on the captain's behavior.

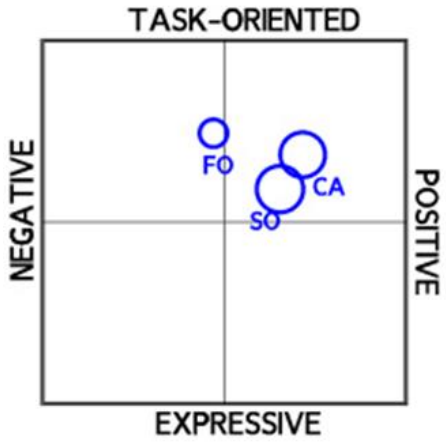

Figure 3: Crew 4, Segment 5. Crew with most errors: Polarized Group.

A group diagram of the crew that made the fewest errors is shown in Figure 4.

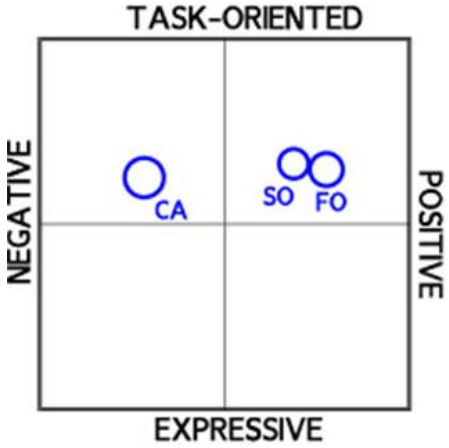

Figure 4. Crew 8, segment 3. Crew with fewest errors: Unified Group.

Group variables were related to performance measures. Making fewer errors was related to low average distance between behaviors on the diagram plane (r=.40, p=.05). Making fewer errors was also related to the group's center of gravity being positive (r=.54, p<.01) and expressive (r=.38, p =.07). Expressive behavior in these crews consisted mostly of joking behavior in the first portion of the two segments.

Additional insights were derived from rating the crew members' behaviors. Figure 5 shows the average ratings of the three captain types on the three behavioral dimensions used to make the group diagrams.

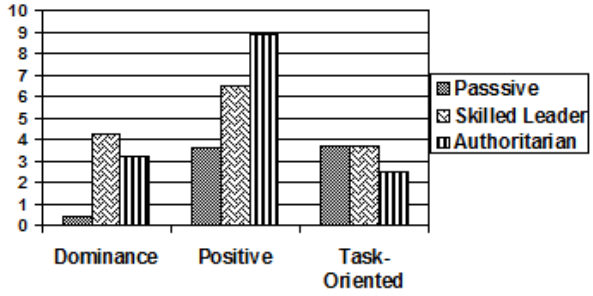

Figure 5. Captain's pre-test groupings and ratings of captains' observed behaviors (average of 3 raters).

As can be seen, the passive leader types were the least dominant and least positive of the captains, as would have been predicted. The skilled leader types were more dominant, and positive, again in line with expectations. Not in line with expectations, however, were the captains selected as authoritarian. They were rated as behaving the most *positively* of all the captains. The original characterization of these captains, it will be remembered, was "high levels of negative instrumentality and low levels of expressivity." Hence one cannot attribute the good performance of the crews headed by these captains to actual negative, instrumental (task-oriented) captain behavior.

The average rating each crew member received across all crew types is presented in Figure 6. It can be seen that in general, the second officers are more positive and less task-oriented (and more expressive) than other crew members.

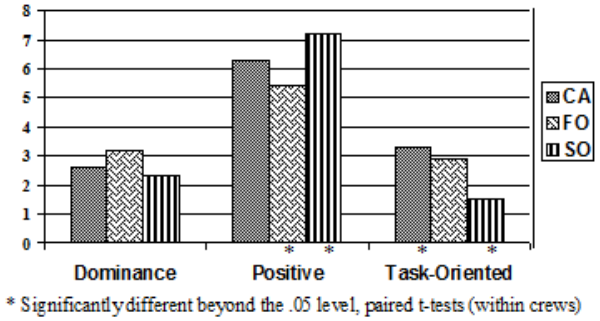

Figure 6. Average ratings of crew members.

Table 1 shows the average crew ratings received in the three types of captain-headed crews.

Table 1: Average Crew Ratings
in Three Types of Captain-Headed Crews

	Dom.	Pos.	Task
Passive			
CA	.4	3.6	3.7
FO	4.2	3.4	4.4
SO	-.6	7.1	3.1
Skilled Leader			
CA	4.3	6.5	3.7
FO	2.4	4.2	2.5
SO	3.9	5.4	1.6
Authoritarian			
CA	3.2	8.9	2.5
FO	2.9	8.5	1.8
SO	3.7	9.2	-.2

The ratings for the crew led by passive captains confirms a previous finding on this simulation by Kanki et al. (1991), who found that the first officers made more commands, a type of dominance behavior, with the passive captains than any other first officer/captain pair. This would help counteract the lack of such behavior in the passive captains. Table 1 also shows that not only were the captains in the authoritarian crews the most positive, but that their crews, especially their second officers, were also the most positive and expressive of the crew types. In this regard, it is interesting that crew behaviors related to reduced errors were captains' positive behavior ($r=.41$, $p<.05$) and second officer's dominant and expressive behaviors ($r=.47$, $p<.02$; and $r=40$, $p<.05$ respectively). Furthermore, crew behaviors that were related to each other were captain's positivity and second officer's expressive behavior ($r=.56$, $p<.01$), and captains' and second officers' dominance ($r=.53$, $p<.01$) as well as their expressive behavior ($r=.46$, $p<.05$). These correlations might well be a result of chance configurations of crews. On the other hand, they raise the possibility that the second officers in the authoritarian led crews were affecting the behavior of the captains.

Even though the crew members were assigned randomly to the different captain types, it happened that the second officers for the authoritarian captains were all skilled leader types—leader types that in this case engaged in substantial positive and expressive behavior. In Fine's study (1986), behaviors in the positive/expressive direction were the most contagious of all. Although it seems surprising to suggest that behaviors of the most junior members of a crew may influence others, there is evidence that members who provide expressive behavior for a group are frequently low in status (Wagner & Berger, 1998). In some of the video taped segments of the authoritarian-led crews, the second officers indeed seemed irrepressible.

Conclusion

Group diagrams based on behavioral ratings reflected differences in crew climate and were related to performance measures. In addition, the ratings provided information on crew behaviors which helped explain anomalies in the original study. The results suggest that behaviors of all crew members contribute to crew climate in ways that affect performance. The findings themselves must be treated with caution, however, because of the small sample size and selection effects in the choice of captains. The method, however, has promise for ascertaining the effect of situational and training variables that may impact crew climate.

References

Bales, R. F., and S. P. Cohen (1979). *SYMLOG: A system for the multiple level observation of groups*. N. Y., N. Y.: The Free Press.

Chidester, T. R., B. G. Kanki, H. C. Foushee, C. L. Dickinson, & S. V. Bowles (1990). *Personality factors in flight operations: Vol. 1. Leader characteristics and crew performance in a full mission air transport simulation*. NASA Technical Memorandum #102259.

Fine, G. A. (1986). Behavioral change in group space: A reintegration of Lewinian theory in small group research. *Advances in Group Processes*, 3, 23-50.

Helmrich, R. L., & H. C. Foushee (1993). Why crew resource management? Empirical and theoretical bases of human factors training in aviation. In E. L. Wiener, B. G. Kanki, & R. L. Helmreich (Eds.), *Cockpit resource management*. San Diego, CA: Academic Press.

Kanki, B. G., M. T. Palmer & E. Veinott (1991). Communication variations related to leader personality. In *Proceedings of the Sixth International Symposium on Aviation Psychology* (pp. 253-259). Columbus: Ohio State University.

Murray, L., J. Eastman, J. Orasanu, M. A. Rodvold, & L. K. Tyzzer. Has CRM succeeded too well? Assertiveness on the flight deck. In *Proceedings of the Tenth International Symposium on Aviation Psychology*, pp. 357-360. Columbus, Ohio State University.

Parke, B. (1985) A field adaptation to the SYMLOG Adjective Rating Form suitable for populations including children. *International Journal of Small Group Research*, 1, 89-95.

Parke, B., & H. C. Houben (1985). An objective analysis of group types. *International Journal of Small Group Research*, 1, 131-150.

Parke, B., & H. C. Houben (1988). Analyses of subgroups and clusterings within groups: Attaining knowledge of the social interaction potential. *International Journal of Small Group Research*, 4, 143-158.

Wagner, D. G. & J. Berger (1998). Gender and interpersonal task behaviors: Status expectation accounts. In J. Berger & M. Zelditch (Eds.), *Status, Power, & Legitimacy*. New Brunswick, New Jersey: Transaction Publishers.