Human Performance in Aerospace Environments: The Search for Psychological Determinants

Robert L. Helmreich and John A. Wilhelm[1]

The University of Texas at Austin

Running Head: Human performance

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Abstract

A program of research into the psychological determinants of individual and crew performance in aerospace environments is described. Constellations of personality factors influencing behavior in demanding environments are discussed. Relationships between attitudes and performance and attitudes and personality are also reported. The efficacy of training in interpersonal relations as a means of changing attitudes and behavior is explored along with the influence of personality on attitude change processes. Finally, approaches to measuring group behavior in aerospace settings are described.

Effective performance in aviation and space is of the utmost importance as human error threatens both lives and critical missions. Similarly, with access to space a precious and scarce national resource, it is essential that each individual's contribution be optimal. That these are not abstract concerns has been well documented. Flaws in decision making, outright errors, and interpersonal conflict have been observed in both the U.S. and Soviet space programs (Helmreich, 1983; Bluth, 1981; Rogers, 1986). In aviation, analyses of aircraft accidents and incidents indicate that the majority of civilian accidents result from failures in crew coordination and that lack of technical proficiency, equipment problems, and environmental factors such as severe weather are of secondary importance (Cooper, White, & Lauber, 1979). An inescapable conclusion to be drawn from these data is that the selection, training, and management of crewmembers for these environments are open to improvement.

The issue is made more complex by the fact that most aerospace activities require not only competent, individual performance but also the effective coordination and collaboration of teams and groups. It is safe to say that if our knowledge of psychological determinants of individual performance is limited, that regarding the determinants of group behavior is even less advanced. The present program of research addresses these issues through basic, theoretical investigations conducted and validated

in applied, operational environments. The appropriateness of studying flightcrew behavior as a model for the reactions of work groups in demanding environments including space has been well described by Foushee (1984). Although civilian and military air transport currently serves as the primary setting for investigations, the strategy also includes research in other domains including scientific and managerial performance and psychological determinants of health. Foushee and Helmreich (in press) have discussed the central issues surrounding the performance of flightcrews. These are described here under the headings of personality and behavior, attitudes and behavior, training and its limitations, and capturing group processes.

Personality and Behavior

Psychology has long recognized the importance of individual differences as determinants of variability in behavior. Assessment of characteristics such as intelligence, psychomotor skills and specific aptitudes has a long history of validation and use. However, issues of aptitude, technical training, and qualification are not relevant to this discussion as the research subjects have all successfully passed through selection and training processes and are serving as flightcrew members in civilian and military organizations where their technical performance is subject to regular, formal evaluation. In other words, the focus is on variations in the performance of crews who

meet or exceed regulatory requirements for proficiency.[2]

The most controversial aspect of the research surrounds the role of personality factors as determinants of performance and behavior. While laymen have long recognized the central role of personality in human interaction, many research psychologists have questioned the concept because empirical evidence relating personality traits to observed behavior has been weak and often conflicting (Jones, 1985; Mischel, 1968). Indeed, in the specific area of aviation, decades of research have failed to establish consistent links between personality and pilot performance (Helmreich, 1986). Nonetheless, a long-standing collaboration with Janet T. Spence exploring the structure of men's and women's personalities has been extended into this domain.

The results obtained in predicting the performance of pilots, as well as those in other demanding professions such as scientific research, have proved to be robust (Helmreich, 1982; in press; Helmreich, Spence, Beane, Lucker, & Matthews, 1980; Spence & Helmreich, 1983). Two core dimensions of the self have been isolated: instrumental traits relating to achievement and goal seeking including aspects of achievement motivation and expressive traits relating to interpersonal behaviors and orientation. Measurement of these attributes is achieved through psychometrically reliable, self-report instruments that assess both positive and negative aspects of these dimensions (Helmreich

& Spence, 1978; Spence, Helmreich, & Holahan, 1979). In the case of pilots, positive performance in command of jet transport aircraft with multi-person crews relates to high scores on positive, instrumental traits including a need for mastery of new and challenging tasks, and low scores on negative instrumental attributes including such traits as arrogance and hostility. Also positively related to performance is possession of high scores on expressive traits including sensitivity to others. The latter finding reflects the fact that operation of a complex aircraft is a group endeavor requiring the close coordination of a crew more than the skills of the lone pilot wearing a white scarf.

Recently, the personality factors measured have been expanded to include aspects of what has come to be known as the Type A Personality (Jenkins, Zyzanski, & Rosenman, R.H, 1971). The "Type A" is usually described as a driven individual with high levels of ambition, time urgency, impatience, and aggressiveness. Earlier research has suggested that Type A individuals may be both prone to coronary heart disease and more successful vocationally (Friedman & Rosenman, 1974; Matthews, Helmreich, Beane, & Lucker, 1980). Our new formulation of the construct yields two moderately correlated factors that have been labeled Achievement Striving (AS) and Impatience/Irritability (I/I) (Pred, Helmreich, & Spence, in press). Looking at the two factors in relation to behavioral criteria has shown a consistent

pattern of outcomes: Achievement striving is related to positive performance including scientific and academic attainment but is unrelated to negative health outcomes (Helmreich, Spence, & Pred, in press) while Impatience/Irritability is associated with a variety of health complaints including poor sleep quality, headaches, and digestive and respiratory upsets but is not correlated with performance (Spence, Helmreich, & Pred, in press). These two factors correlate moderately with the instrumental and expressive traits described above and increase the predictive power of the battery.

Important findings regarding personality and flightcrew performance were obtained in a recent dissertation by Thomas Chidester (1986). Chidester replicated the finding that instrumental and expressive attributes were related to both technical and managerial aspects of flightcrew performance. He also found that Achievement Striving was a positive predictor of performance and that the Impatience/Irritability dimension was related to a variety of health complaints among flightcrew members.

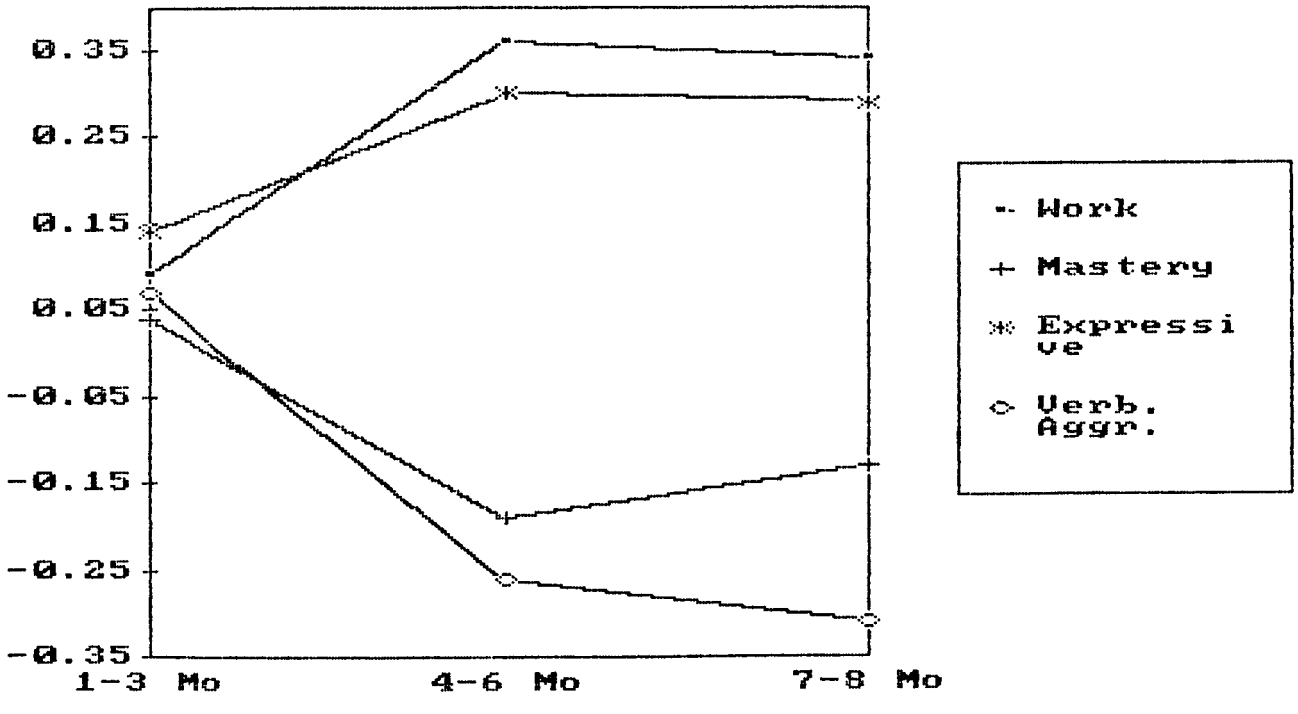
An intriguing question arising from these data is why significant and replicable relationships between personality and performance are being found when the consensus in the pilot selection literature is that personality and performance are unrelated. One possible resolution of this seeming paradox may

rest in what we have christened the "honeymoon effect" of motivation on performance. In a recent study (Helmreich, Sawin, & Carsrud, 1986), correlations between components of achievement motivation and performance over time were examined. At the end of training there were no significant correlations between personality and performance in a sample of airline clerical personnel. With the passage of time, however, the correlations increased in magnitude, became significant, and stabilized. We have interpreted this as reflecting the fact that most individuals, when selected for a desired position, will exert maximum effort to perform well during training and probationary periods and this level of effort may mask the influence of personality on performance. It is not until after the individual has settled into the routine of the position and the "honeymoon has ended" that personality influences on behavior begin to emerge strongly. Looking at the literature on personality and pilot selection, it is notable that the criterion variable almost universally employed is performance in <u>training</u> or simply success or failure in training while in the present research the criteria involve the performance of experienced crews in <u>line operations</u>. The increasing magnitude of obtained correlations is shown graphically in Figure 1. As the figure indicates, two attributes, Work motivation and Expressivity become more positive correlates of performance and two, Mastery and Verbal

Aggressiveness become more negative after time on the job. The results for Mastery are particularly informative. This variable, from the Work and Family Orientation measure of achievement motivation (WOFO: Helmreich & Spence, 1978), reflects a need for new and challenging tasks. The job in question, operating a simplified reservations computer terminal, is a repetitive and mundane activity. Clearly, those high on this characteristic do not find this need met after considerable exposure to the work.

Insert Figure 1 Here

Another characteristic of research on personality/behavior relationships may have served to hide meaningful relationships. This is a tendency of investigators to concentrate on limited aspects of the total personality and to look at them in relative isolation. This restricted approach fails to consider the distribution of combinations of different trait intensities - in other words, it fails to look at the constellations of personality combinations that exist in "real people" in the "real world". For example, with what frequency are individuals with <u>both</u> highly instrumental and highly expressive personality traits found in the population or research sample. Thomas Chidester, Steven Gregorich, and the authors have been applying the technique of cluster analysis to determine the distributions of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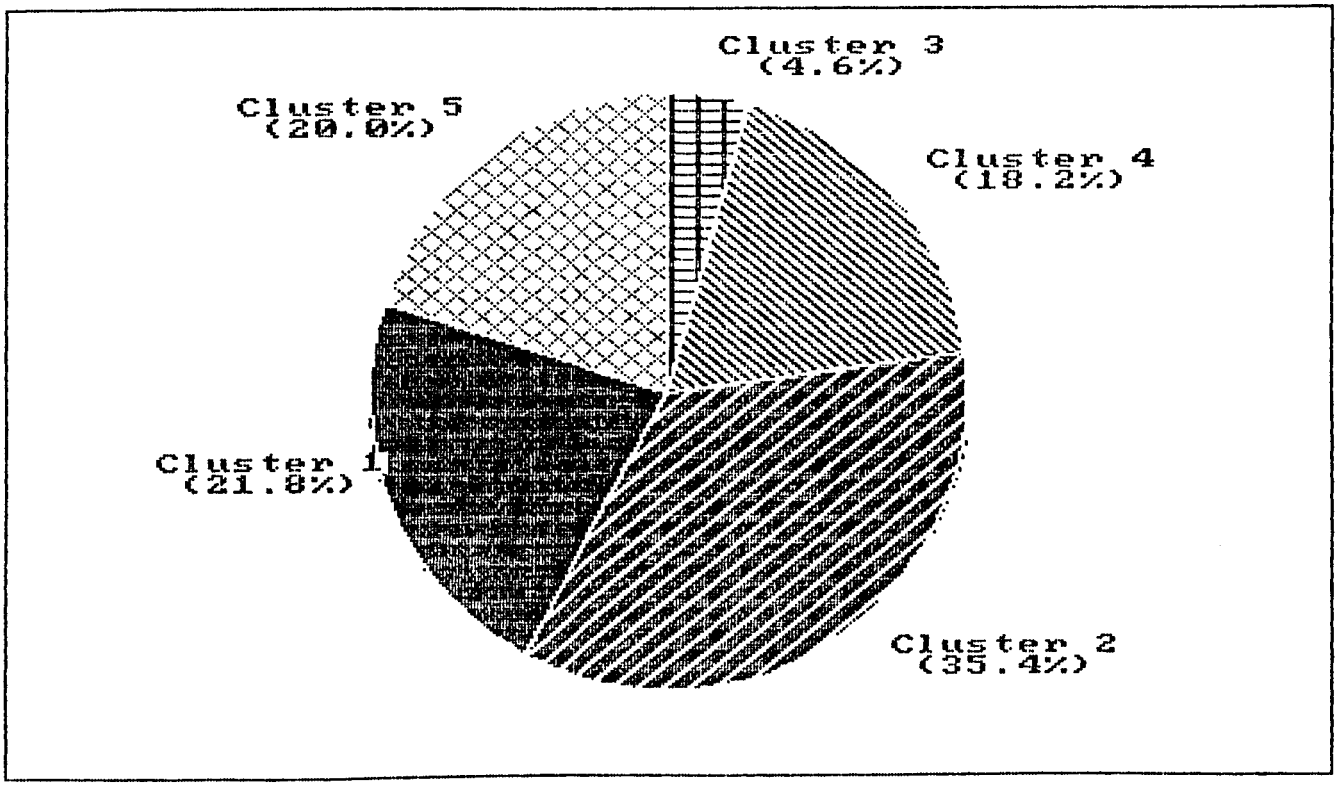
differing combinations of positive and negative personal attributes using the personality characteristics described above (Chidester, Helmreich, Gregorich, & Geis, in preparation; Romesburg, 1984). Depending on the research population, four or five relatively frequently occurring clusters of individuals with particular levels of instrumental and expressive attributes emerge from the analyses. These clusters reflect meaningful constellations of traits as they are distributed across individuals.

An innovative dissertation by Gibson (1987) demonstrates the utility of this approach. Gibson's study included examination of relationships between personality factors and ratings of managerial performance using performance ratings provided by supervisors, peers, and subordinates in a national airline. Cluster analyses based on the instrumental and expressive trait dimensions gave five readily classifiable groups. One of these clusters nicely defined the "average" manager. Individuals in this group scored as average on both positive and negative instrumental and expressive dimensions. Three other clusters were marked primarily by the elevated presence of one or more negative personality dimensions and/or low levels of positive characteristics. For example, one group showed high levels of arrogance and hostility combined with low achievement motivation. Another cluster was defined by slightly higher achievement

motivation and moderate levels of arrogance and hostility. A fourth group had average achievement motivation but high levels of verbal aggression and negativity. The last cluster was composed of individuals with high levels of the positive achievement motives and expressive traits and low levels of the negative attributes. Figure 2 shows the relative frequency of these clusters in the population of managers in this organization. Figure 3 shows the average performance ratings of the five groups where the ratings are expressed in terms of Z-scores. It is striking that the group with the "average" personality received average ratings with a mean z of approximately zero. Each of the groups characterized by one or more negative attribute dimensions received below average ratings. On the other hand, the group defined by high positive and low negative attributes received positive mean ratings for performance. In summary, the results obtained using these conceptual variables and the cluster analytic approach to determining their joint occurrence in research samples would appear to have considerable theoretical and practical utility. Another application of the cluster analytic technique will be discussed in the following section.

Insert Figure 2 and Figure 3 Here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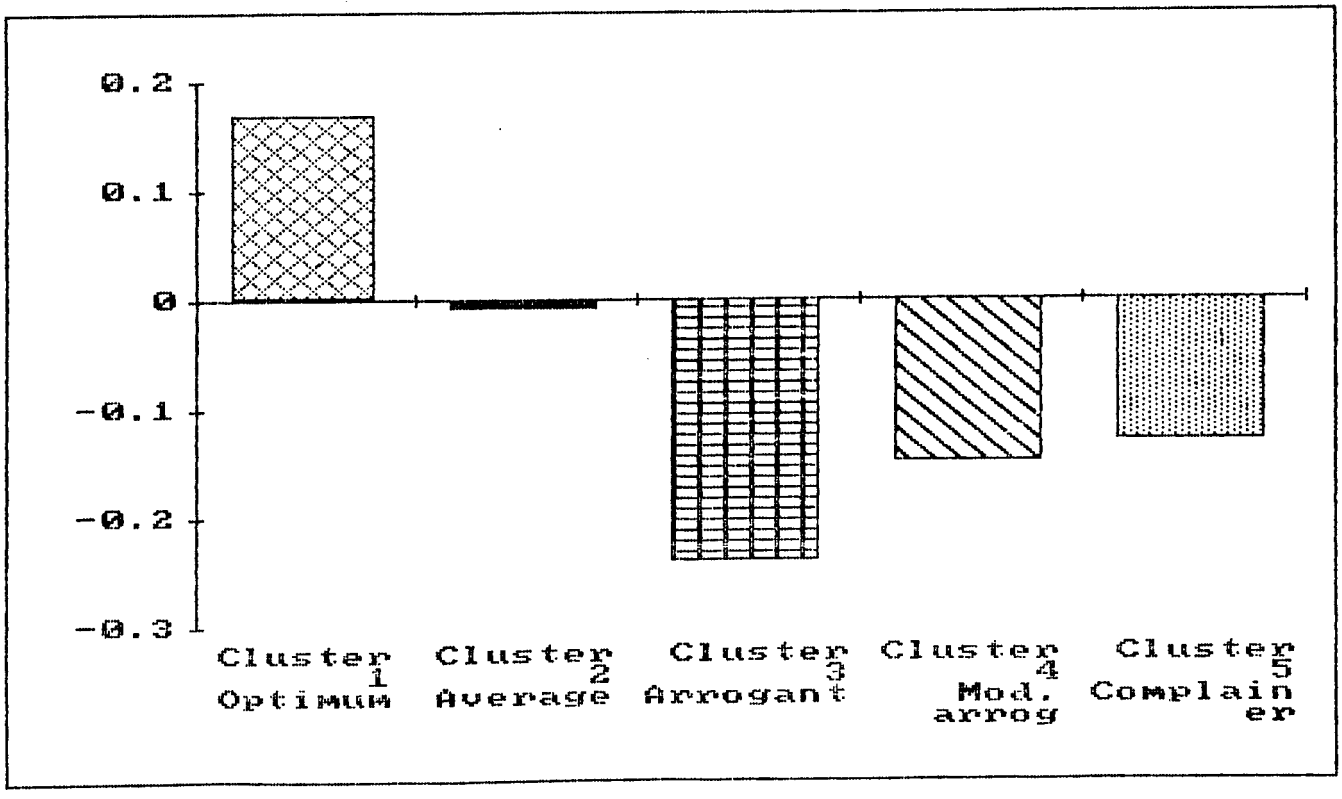
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Cluster 4 Mod. arrog
Cluster 5 Complainer

Attitudes and Performance

The study of attitudes, attitude change, and relationships between attitudes and behavior forms a core topic in social psychology (e.g. McGuire, 1985). Keeping with this tradition, a central focus of the research has been on measuring attitudes relevant to individual and group performance, assessing the relationships between these attitudes and crew performance, and determining the effectiveness of training programs in changing these attitudes. Earlier NASA research had isolated certain flightcrew attitudes associated with effective and ineffective cockpit management (Cooper et al., 1979). Building on this research, a survey instrument designed to measure pilot attitudes regarding the conduct of flight operations was developed and has been administered to more than 5,000 crewmembers from civilian and military organizations (Helmreich, 1984). The attitudes measured fall into a number of topic areas including personal capabilities and reactions under stressful conditions, leadership strategies, interpersonal communication and crewmember roles and responsibilities. While couched in terms of crew behavior in aviation, the basic attitudes are relevant to many groups operating in demanding environments, including that of space. The measure was validated in a study showing strong relationships between crewmembers' attitudes and performance assessment (Helmreich, Foushee, Benson, & Russini, 1986).

Another highly significant finding emerged from comparisons of crewmember attitudes between organizations and between crew positions within organizations. Highly significant differences as a function of both factors were found on most attitudes. These results have several important implications. One is that that organizational cultures, even in a regulated environment, may influence attitudes. This suggests that efforts at attitude change need to address both the individual and the organizational culture to be maximally effective. Another is that if members of the same crew disagree significantly about how operations should be conducted, it is highly unlikely that such a crew will achieve the most effective coordination and performance. This is congruent with data regarding the causes of aircraft accidents (e.g. Cooper et al., 1979) indicating that, although the technical competence of crewmembers involved may be exemplary, team functioning frequently is not. Both civilian and military authorities have recognized this deficit and have rushed to initiate training programs to improve crew coordination in flight operations.

Given validation of the attitude measure as a predictor of crew performance (e.g Helmreich et al., 1986) and the demonstration of highly significant differences between and within organizations, it becomes feasible to utilize the attitude measure as one means of assessing the impact of training on crew

behavior. Preliminary research on this topic is described in the following section.

Training and Its Limitations

Those involved with training, whether of Astronauts and pilots or of scientists and managers, have a strong belief in its efficacy. In recent years, not only managers of aviation but also leaders of a variety of organizations have come to believe that training in teamwork and interpersonal communications can result in greater organizational effectiveness. The proliferation of such training in aviation has been well documented (Orlady, 1987). NASA has also acknowledged that deficits in crew coordination may impact the effectiveness of crews during spaceflight (Foushee, personal communication). Despite the commitment of substantial resources to training for improved group performance, little empirical evidence has been collected to support the veracity of this belief. Part of the present program of research is directed toward evaluating the impact of training in crew coordination on group behavior (Helmreich & Wilhelm, in press).

One of us (Helmreich, 1983; 1987) has argued that there are theoretical limits on the effectiveness of training programs as agents of change for human behavior. Given that human behavior is directed both by stable, personality traits and, more consciously, by attitudes regarding appropriate action, it can be

argued that training can influence one of these sources but not the other. Personality represents thoroughly internalized attributes of the self and to effect personality change requires strong interventions such as intensive psychotherapy. It is probably foolhardy to assume that relatively short training programs will alter personality driven patterns of behavior. On the other hand, those behaviors directed by attitudes are much more amenable to change. However, the interrelationships among attitudes, personality, and attitude change remain open issues (e.g. McGuire, 1985).

The present project casts some light on these issues. In several organizations where attitudes of crewmembers who have received training can be contrasted with those who have not, significant differences in a positive direction have been observed among those receiving training (Helmreich & Wilhelm, 1987). More evidence comes from a sample of Army pilots whose attitudes were measured both before and after training and from whom personality data had been collected (Chidester, in press; Chidester, et al., in preparation). Using the same cluster analytic approach discussed earlier, albeit with a somewhat reduced set of measures, personality factors were found to influence both initial attitudes and susceptibility to change on key dimensions. Figure 4 shows the effects for attitudes regarding the importance of group atmosphere. Those individuals

with the most positive constellation of instrumental and expressive personality traits both had more favorable attitudes initially and showed considerable positive attitude change. Those with the less favorable constellations were unaffected by the training.

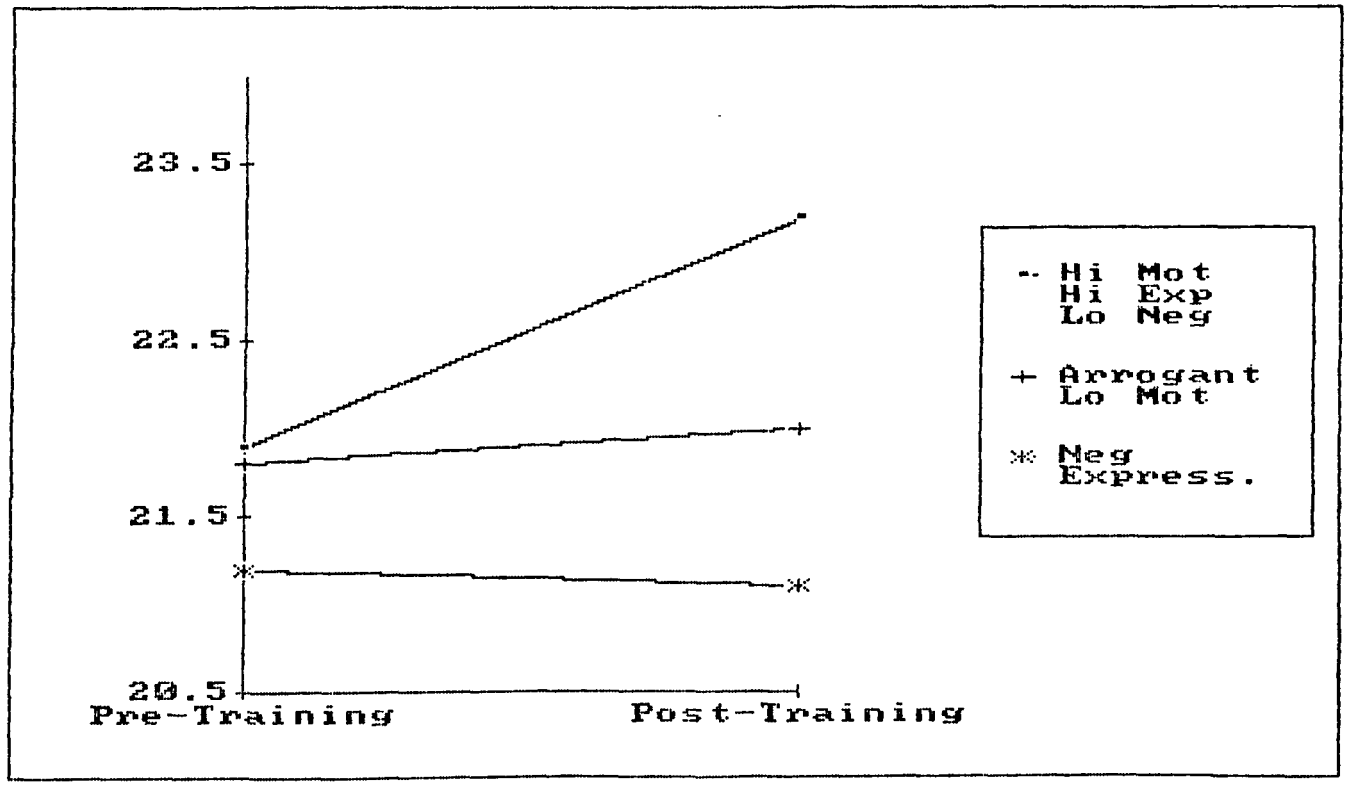
Insert Figure 4 Here

Figure 5 shows a very different pattern for attitudes regarding personal capabilities and reactions under stressful conditions. Here the personality types were quite similar in initial position and all showed significant, positive change as a result of training. Perhaps the data can be best summarized by noting that when personalities and attitude issues are involved, that it is possible to change some of the people all of the time and all of the people some of the time, but not to achieve universal change.

Insert Figure 5 Here

Attitudes, of course, are only surrogates for actual behavior. In the following section we will discuss the assessment of group behavior.

Capturing Group Processes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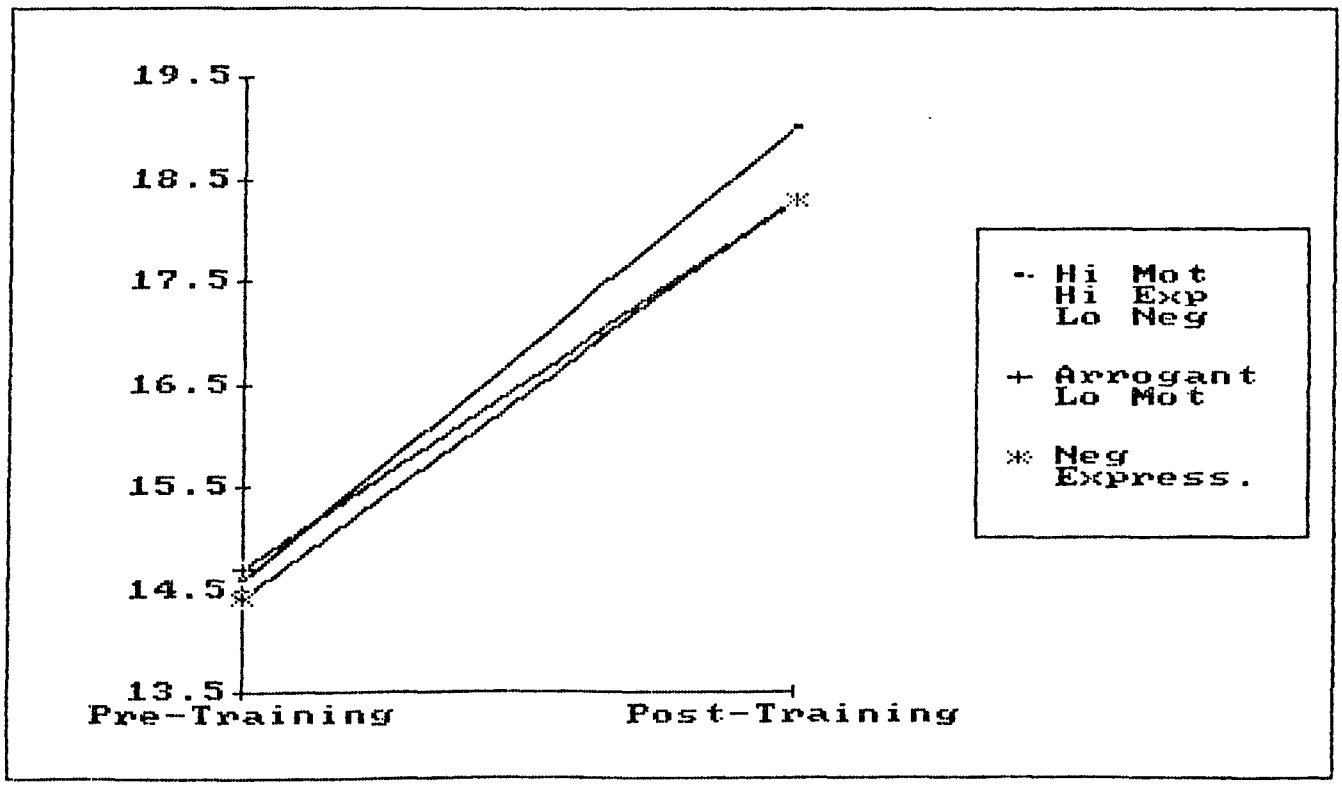
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Performance evaluation in American society is traditionally individualistic. Even judgments of group performance tend to focus on the contributions of individual participants and to ignore the fact that one combination of individuals may lead to very different outcomes from those achieved by a different combination of equally able members. While psychologists have long acknowledged that group performance is highly dependent on the psychological processes associated with group interaction, they have not proved to be much more sophisticated than laymen in understanding these processes. In defense of small group researchers, it should be noted that the situation, even in very small groups, is highly complex. Group members bring into the group varying constellations of personality which may result in different patterns of interaction and affect. Disentangling the causal patterns in verbal and non-verbal interchanges is also a daunting task requiring complex, time series analyses. Additionally, dissimilar processes may lead to equivalent performance outcomes. This array of impediments motivated many psychologists to abandon the study of group behavior (Steiner, 1973). Recently, however, there seems to be a resurgence of interest in group phenomena and efforts to apply a variety of methodologies and theoretical approaches (e.g., Hackman, 1987; Ginnett, 1987; Helmreich, in press; McGrath, Futoran, & Kelly, 1986).

Certainly, with regard to the training and evaluation of flightcrew performance, the focus until very recently has been almost exclusively on the actions of individuals (Helmreich, Hackman, & Foushee, in preparation). It is in this area that efforts of the present project center. Measures have been developed to use expert raters to evaluate both individual and full crew behavior and performance. Data collection assessing the performance of flightcrews in line operations and on segments flown in high fidelity simulators is underway at a major airline and is scheduled to begin with military transport crews. This effort also encompasses evaluation of the effectiveness of crew coordination training as it compares the behavior of trained and untrained crews (Helmreich & Wilhelm, in press). Although not enough data have been collected to draw conclusions about the behavioral impact of training, observers have demonstrated high reliability in coding crew behavior.

In contrast with the macro evaluations just described, a parallel effort is underway to refine coding schemata for micro-level analyses of crew communications. The goal of this approach is to employ time series analyses to capture processes and breakdowns in interpersonal communications and to relate these to global performance and to particular responses. Initial tests of the coding are in progress using Cockpit Voice Recorder tapes and transcripts from selected aircraft accidents in which crew

behavior and coordination were causally implicated. As part of the collaborative effort with other NASA investigators, it is planned to apply this type of coding and analysis to the behavior of crews selected and composed on the basis of personality constellations and flying the same programmed flight scenario which including both normal and abnormal conditions. This aspect of the research involves an experimental design which will allow stronger causal inferences.

Conclusions

While the ongoing investigation of determinants of crew performance has provided preliminary answers to some theoretical and practical questions, many more issues remain open. The data provide strong support for the critical role of personality factors as determinants of individual and group performance, for the existence of significant relationships between personality and attitudes and attitude change, for the influence of organizational and role factors on attitudes and behavior, and for the validity of linkages between attitudes and behavior. Great challenges remain in understanding the interplay of individual personalities in group dynamics and in capturing and interpreting the processes of group interaction and their relationships with performance. Some optimism about outcomes appears justified, in large part because the research centers on real behavior in meaningful settings and utilizes a variety of

methodologies to include individual, team, and organizational factors. Collaboration with other investigators including J. Richard Hackman and Linda Orlady from Harvard University, Robert Ginnett from the U.S. Air Force Academy, and Clay Foushee and Thomas Chidester from NASA, Ames Research Center, also brings additional perspectives and resources to bear on common problems.

The direct relevance of this research to space missions also remains to be demonstrated. However, the critical issues in aviation and space operations have many conceptual similarities and a persuasive case can be made that interpersonal relationships and personal adjustment may be major limiting factors in long duration spaceflight (e.g. Connors, Harrison, & Akins, 1986). Additional considerations will have to be addressed in settings such as a space station. Crews, for example, will be larger, more heterogeneous in background and orientation, will be isolated for longer periods of time, and may have multiple goals (for example, different scientific projects or scientific versus operational concerns) which can result in conflict over activities or the use of scarce resources. Despite situational differences between aviation and space settings, the influence of personality constellations on behavior in long duration spaceflight should be as great or greater than that in aviation because of these situational factors and the effects of personality on health should be more critical in an isolated and

confined microsociety. The methodologies for assessing group behavior and performance should also translate readily into space but need validation in this setting. An optimal strategy for NASA would seem to be targeting investigations of psychological issues in short duration spaceflight as a primary research goal while at the same time exploring them in real world analogs of long duration missions such as undersea habitats (National Academy of Science, 1987; Helmreich & Wilhelm, 1985).

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Figure Captions

Figure 1. Correlations of personality factors with performance index across time.

Figure 2. Relative frequency of personality constellations in airline managers.

Figure 3. Mean managerial performance ratings (z-score) for each personality cluster in airline managers.

Figure 4. Pre- and post-training attitudes regarding group atmosphere among U.S. Army pilots (higher scores indicate more favorable attitudes).

Figure 5. Pre- and post-training attitudes regarding personal invulnerability and stress among U.S. Army pilots (higher scores indicate more favorable attitudes).

Footnotes

1. Reprint requests should be addressed to Dr. Robert L. Helmreich, Department of Psychology, The University of Texas at Austin, Austin, Texas 78712.

2. Another aspect of the research program not discussed here is investigation of optimal predictors for the initial selection of aerospace crews. This work includes both personality factors and measures of cognitive function.