Examining a Curvilinear Relationship Between Communication Frequency and Team Performance in Cross-Functional Project Teams

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***Abstract*—The performance of a cross-functional team depends on the skillful and innovative combination of information and expertise from all team members. Communication is the medium through which team members share the information required for successful amalgamation. In this work, we postulate that both high and low levels of team communication can impede team performance, thus leading to a curvilinear relationship between team performance and team communication. To test this hypothesis, the relationships between face-to-face, e-mail, and telephone communication and team performance were examined for 60 cross-functional project teams. E-mail and face-to-face communication were curvilinearly associated with performance, but telephone communication was not. Further analysis of the communication frequency between colocations showed that e-mail is the only medium for which usage increased with distance.**

***Index Terms*—Cross-functional teams, e-mail, team communication, team performance.**

I. Introduction

CROSS-FUNCTIONAL team members are typically drawn from many different locations within an organization [13] and in some cases are geographically dispersed [8]. In order to achieve high performance, they must meld the many different frames of reference and, therefore, they must find ways to communicate on a regular basis [6]. In fact, a number of authors argue that increased levels of communication among team members (hereafter referred to as "team communication") is a key to better team performance [32]. There is reason to believe, however, that the relationship between team communication and team performance is not so straightforward. Like some other group processes and characteristics, e.g., stress [43] and size [11], the relationship between team communication levels and team performance may be curvilinear [18]. In this work, we examine the relationship between levels of team communication and team performance. In examining this relationship, we highlight three communication media that are widely used by cross-functional teams today: face-to-face; telephone; and e-mail communication [16]. This approach allows us to test the generalizability of our curvilinear team communication hypothesis across different media.

The relationship between the communication frequency and performance is frequently explored in the literature [4], [38] under the general assumption that communication frequency is linearly related to performance [2], [28]. In addition, communication frequency can be seen as an indicator of the information processing activities of team members [33], [35]. Thus, high-communication frequency can result in more information being exchanged between team members with the greater exchange requiring more information processing. At some point, such exchanges may overload the capabilities of team members and inhibit their performance [17]. Similarly, low-communication frequencies may not supply enough information to team members and may not facilitate the innovative combination of information and expertise, required for high performance [13]. Consequently, we postulate that both high and low levels of team communication can impede team performance, thus leading to a curvilinear relationship between performance and team communication.

The contribution of this research is the empirical examination of the idea that the communication frequency of cross-functional teams does not have a simple relationship with team performance. Rather, we examine the possibility that communication frequency is curvilinearly related to team performance. We examine this relationship for three commonly used communication media with different attributes [34], to reveal any particular differences between the structurally different media. To our knowledge, relationships of this nature have never been empirically tested.

II. Theory and Hypotheses

Our objective in this paper is to explore the relationship between communication and performance. To have a comprehensive measure of team performance we assess both taskwork, namely team goal achievement and team efficiency, and teamwork, i.e., team cohesion [21]. The underlying premise of previous research on the communication frequency-performance relationship is that frequent communication will increase the information exchange among team members and thus increase team performance, as the team members will be able to share more information [1], [2]. Additionally, frequent communication will increase group cohesion [5] because team members of a cohesive group will share the information resources better, will process more project related information,

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and will know more details about the project [36]. Thus, higher performance is expected to be "guaranteed" when the team members possess all the information possible [9]. Other studies also have demonstrated this linear relationship between communication frequency and performance. Katz and Tushman [28] showed that teams with gatekeepers communicated more externally, which led to improved project performance. Von Hippel's study [42] noted how important communication with key customers was regarding better product designs. Ancona and Caldwell [4] found that teams with more frequent internal communication had superior performance. Thus, a number of studies demonstrate that a positive linear relationship exists between communication frequency and team performance.

A number of other studies, however, show either no relationship between communication frequency and performance or a negative relationship. Allen *et al.* [3] failed to show any significant relationship between performance and communication frequency in R&D teams. Smith *et al.* [38] found that frequency of internal communication was negatively related to performance. Moreover, in this prior research, there is no evidence that the authors examined relationships between communication frequency and performance for curvilinear patterns. Thus, curvilinear patterns may underline some of these contradictory results. Together, these results suggest that the relationship between team communication and team performance may be more complicated than traditionally depicted, especially in cross-functional teams.

In cross-functional teams, team members come from different functional departments. They possess knowledge about nonoverlapping aspects and stages of the project and they do not view the stages and aspects of the project and the information they have in the same way [40]. These differences can lead to varying interpretations of the same information that need to be communicated and combined for the team to perform effectively [15]. Too much information sharing and processing within a team, however, can overload members' processing capabilities and, thereby, inhibit their performance [15], [17]. In addition to information overload, frequent communication can impose a cost on team members in terms of the time spent communicating and, thereby, can cause delays in decision-making [38]. In sum, while communication is important for performance in cross-functional teams [32], there may exist thresholds for communication frequency, beyond which the costs to the team members are too high and performance decreases.

While very frequent communication can supply too much information and inhibit performance, infrequent communication may not supply enough information to achieve desired levels of performance. When team members do not communicate frequently in the team, they may not develop shared understanding of issues that are important to successful performance. Good team performance, therefore, requires a communication threshold, as communication is the source of information team members must share [25]. Consequently, both low and high levels of communication may lead to lower team performance, suggesting a curvilinear relationship.

Finally, we control for three factors that may impact both the communication frequency of the team and its performance, namely task significance, team size and the extent to which the team is colocated. Task significance is defined as "the degree to which the job has a substantial impact on the lives or work of other people, whether in the immediate organization or in the external environment" [20]. Highly significant tasks have been found to motivate employees to work harder to achieve their assigned goals. More significant tasks also may stimulate more frequent communication as motivated team members exchange information in pursuit of their goal [36].

Team size is defined herein as the number of fulltime members of the team [38]. It may affect communication and team performance, as team members from larger teams have fewer opportunities to participate in discussions than team members from smaller teams [23]. Further, the results obtained by Smith and associates [38] suggest that larger teams have more difficulty communicating, and, thus, have lower performance than smaller teams.

Similarly, the colocation of team members may affect both team performance and communication. Colocation in this study is defined as "bringing together personnel from different departments into the same physical location" [27]. Current research confirms that colocated teams have higher face-to-face communication frequencies and less use of other media such as e-mail and telephones [27], [41]. Colocated teams also have been found to have performance advantages that arise from being able to interact face-to-face [7].

Since task significance, team size and the degree of colocation could affect team communication and team performance, we control for these factors as we examine the communication frequency-team performance relationship. In conclusion, we hypothesize that a nonlinear relationship between team performance and communication frequency will be evident as follows.

A. Hypothesis

When controlling for task significance, team size and team colocation, team performance will have a curvilinear relationship with levels of team communication frequency such that low- and high-communication frequencies will be associated with lower levels of team performance while moderate frequency will be associated with higher levels of team performance.

III. Methods

A. Sample and Procedures

The sample consisted of 80 cross-functional teams from 25 corporate and government organizations. The industries represented included aerospace, automotive, public utilities, electronics, and communication. The teams included in the sample were working on a variety of product and process projects. Teams were identified through a high-level management contact within the firm. The potential respondents were identified through a liaison, established within each firm. These liaisons were mailed questionnaires, which they distributed to the project team members, the project team leader and the department heads of the team members. The completed questionnaires were returned in sealed envelopes to the liaison,

TABLE I
DESCRIPTIVE STATISTICS AND CORRELATIONS

Variable	M	SD	1	2	3	4	5	6	7	8	9
1.Task Significance	3.84	0.48	-								
2. Team Size	7.71	9.13	0.24	-							
3. Co-location 1	0.65	0.48	0.01	0.12	-						
4. Co-location 2	0.15	0.36	0.01	-0.11	-0.57	-					
5. Face-to-face Comm.	3.94	0.56	0.46	0.38	0.31	-0.03	-				
6. E-mail Comm.	3.86	1.01	0.22	0.11	-0.33	0.12	0.04	-			
7. Telephone Comm.	4.12	0.57	0.29	0.02	-0.21	0.14	0.17	0.36	-		
8. Goal Achievement	3.67	0.56	0.55	0.24	0.04	0.01	0.34	0.13	0.32	-	
9. Project Efficiency	3.07	0.64	0.28	0.08	0.04	-0.22	0.06	0.28	0.33	0.41	-
10. Team Cohesion	4.25	0.69	0.19	0.33	0.05	0.12	0.32	-0.09	0.28	0.32	0.11

who then returned them to the university research team. The overall response rate for all participants was 61% from the sample of 80 teams.

The teams were retained in the sample if they had data from at least one third of the team members, the team leader and one third of the department heads identified for that team. Thus, subsequent hypothesis testing was conducted using a sample of 60 teams (630 respondents) from 18 companies. Data was included from an average of 71% of the team members per team ($M = 6.00$ team members per team), team leaders for all teams and an average of 66% of the department heads identified for each team ($M = 3.4$ department heads per team). The teams in the sample, based on the data provided from the team leaders have an average of 7.71 ($SD = 9.13$) full time members, 5.98 ($SD = 3.21$) different functional areas, 3.08 ($SD = 1.40$) different organizational levels and different degrees of colocation. The majority of the teams (39 teams) were at the same site; nine teams were in the same city, but at different sites; and 12 teams were in different cities or countries.

B. Measures

All the hypotheses were tested at the team level. Aggregation was completed following the guidelines of Klein, Dansereau, and Hall [29]. Questionnaires were worded using the team as a referent [10]. Between-team variability [24] and r_{WG} [26] were examined where appropriate to ensure the proper aggregating of the data to the team level. Less than 1% of the data were missing, and, therefore, we conducted a mean replacement at the item level [39]. Minor differences were revealed after the examination of the means, standard deviations and correlations before and after the replacement. Table I provides descriptive statistics for all measures.

1) Team Communication: Measures of team communication were developed following the work of Smith *et al.* [38]. For each communication media (face-to-face, e-mail, and telephone), we computed a mean score at the team level, i.e., the scores reflect the average frequency with which the team uses a particular medium. In this research, we were concerned with the overall pattern of communication activities, for which self-report measures have been argued to be reliable [4]. Team members were asked to describe how frequently they used different communication media ($1 =$ never, $5 =$ often). The internal team ***face-to-face communication*** was assessed using a two-item measure, including both formal and informal communication [41]. The questions were worded so that face-to-face meetings and casual interactions were assessed in different items. The between-team variability on face-to-face communication was significant ($F = 2.88, p < 0.0001$) with a median r_{WG} of 0.80. The frequency of ***e-mail communication*** was assessed with one question. The between-team variability for e-mail was significant ($F = 7.57, p < 0.0001$) with a median r_{WG} of 0.71. Similarly, ***telephone communication*** was assessed by one question with significant between-team variability ($F = 2.33, p < 0.0001$) and a median r_{WG} of 0.69.

2) Project Performance: Performance was assessed via three widely accepted indicators of project effectiveness: project goal achievement; staying within estimated cost goals; and staying on schedule [12], [19]. Department heads responded to 12 items asking them to rate how each project was performing on these three aspects of performance ($1 =$ disagree, $5 =$ agree). A factor analysis with varimax rotation was performed and it resulted in a two-factor structure with one item having a cross-loading greater than 0.40 on both factors. After this item was dropped, the structure was a clean two-factor representation, accounting for 100% of the shared variance in the remaining 11 items.

For hypothesis testing, a six-item measure of ***goal achievement*** assessed the degree to which the project was expected to be able to overcome all technical hurdles, meet its technical objec-

TABLE II
COMMUNICATION FREQUENCY-PERFORMANCE: RESULTS OF REGRESSION ANALYSIS. $N = 60$ TEAMS, $*p < 0.10, **p < 0.05, ***p < 0.01$

Independent Variables	Dependent Variables		
	Goal Achievement	Project Efficiency	Team Cohesion
Task Significance	0.633***	0.377*	-0.002
Team Size	0.007	0.0002	0.023**
Co-location 1	-0.071	-0.043	-0.023
Co-location 2	-0.118	-0.569**	0.256
Face-to-face	2.484**	1.343	1.012
E-mail	0.795**	0.939**	0.793
Telephone	-1.527	-3.009	2.133
Face-to-face ^{2}	-0.326**	-0.200	-0.104
E-mail ^{2}	-0.129**	-0.127*	-0.154**
Telephone^2	0.215	0.409	-0.207
R^2	0.467	0.338	0.3769
Adj. R^2	0.358	0.203	0.249
Significance of F	0.0003	0.0162	0.0054

tives, meet its business goals and provide the expected commercial value to the company ($\alpha = 0.89$). Between-team variability was significant ($F = 2.48, p < 0.01$) with a median r_{WG} of 0.94. ***Project efficiency*** was assessed with a five item measure, showing the extent to which the project was more costly than expected (reverse scored), had kept its actual costs within estimated costs, was too slow (reverse scored) and was on time in terms of project schedule ($\alpha = 0.77$). Between-team variability was significant ($F = 2.25, p < 0.01$) with a median r_{WG} of 0.83.

To have a comprehensive measure of team performance, a third dimension, ***team cohesion***, was added to reflect teamwork [21], [31]. Cohesiveness, assessed by the team leader, was measured using Seashore's [37] three-item scale ($1 =$ disagree, $5 =$ agree) with minor modifications to the text ($\alpha = 0.96$). The measure had significant between-team variability ($F = 2.28, p < 0.0001$) with a median r_{WG} of 0.89.

3) Task Significance: Following the work of Denison *et al.* [13], a five-item measure ($1 =$ agree, $5 =$ disagree) with minor modifications to shift the item referent to the team, was developed to assess the extent to which the team members perceive the task on which they were working to be important for them and for the organization. Team members were asked to describe the task by indicating how excited and challenged they were to be working on this team and how important the team work was to their own careers, to their department and to the company. The measure had significant between-team variability ($F = 3.77, p < 0.0001$), with a median r_{WG} of 0.89.

4) Team Size: Team size was estimated as the number of full-time team members participating in the team.

5) Colocation: Two dummy variables, ***colocation1*** and ***colocation2*** were developed to represent the three colocation categories described previously.

IV. RESULTS

Before testing the hypothesis, we examined the zero-order correlation relationships between the control variables and the criteria to be examined in hypothesis testing. As can be seen in Table I, each control variable is correlated with at least one dependent variable. Therefore, the control variables were included in all analyses.

The hypothesis predicted a curvilinear relationship between performance and communication (Table II).

The hypothesis was tested by regressing the performance variables on the control variables and six communication variables (three linear and three squared terms) [23]. When both the regression models and the squared terms are significant, a curvilinear relationship is present [30]. All three regression models are significant, with e-mail showing a consistent curvilinear relationship across all three team performance measures

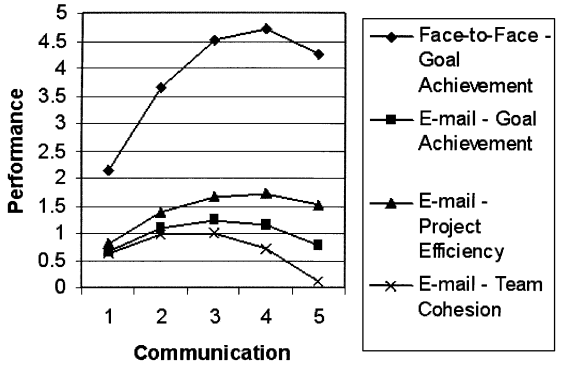

Fig. 1. Relationship between performance and communication frequency.

in the hypothesized form of an inverted U. This indicates that low- and high-communication frequency corresponds to lower levels of team performance while moderate frequency corresponds to higher team performance. Face-to-face communication is curvilinearly related to goal achievement, showing the predicted inverted U form of the relationship. Thus, support for the hypothesis is evident.

The four significant relationships are plotted in Fig. 1. We can see that the optimal relationship between communication frequency and team performance appears to occur at different frequencies for face-to-face communication and e-mail. To determine if the point at which face-to-face communication begins to degrade team performance is actually higher than the optimal point for the other media, the first derivative for each regression equation was taken and then the equations were set equal to zero and solved, yielding the following results: the optimal communication frequency (on a 1–5 scale) for the face-to-face communication-goal achievement model is 3.81; for the e-mail-goal achievement model, it is 3.10; for the e-mail-project efficiency model, it is 3.69; and for the e-mail-team cohesion model, it is 2.57. These results suggest that the team can engage in more frequent face-to-face communication, as compared to e-mail, before the frequency of communication begins to create information overload and performance starts to decline.

From this analysis, we can see that except for the e-mail-team cohesion model, the optimal communication frequencies are not at or near the middle of the employed communication scales. These optimal values make the curves appear less steep when going from low- to moderate-communication frequencies than when going from moderate to high frequencies, giving the impression of a larger effect on performance for low to moderate frequencies than for moderate to high-communication frequencies. An explanation for this seeming lack of symmetry (in a curve one might expect to be symmetric) could lie in the five point scale we employed to measure communication frequency. The scale may not provide a wide enough range of values above the optimal communication frequency point to capture the full effect of the curvilinear relationship. It is possible that our results would be more pronounced with a larger scale where much higher frequencies of communication could be portrayed.

The findings also indicate that e-mail is the only communication medium that exhibits a curvilinear relationship across all three performance indicators. As distance is a prevalent factor in choosing a communication channel [2] and e-mail is becoming a common medium for team communication, this strong finding made us further explore the use of e-mail. We conducted a supplemental analysis of variance, comparing the use of the media between the three levels of colocation. A significant MANOVA (Wilks Lambda 0.71, $F = 3.31, p < 0.005$) was followed by univariate tests (Table III). The univariate tests indicated significant differences in the communication frequencies for face-to-face communication and e-mail, but not for telephone communication. As one might expect, the communication frequency mean values show that colocated teams used face-to-face communication most frequently, while teams in different cities or countries most frequently used e-mail. It is also interesting to note that even for the teams located in the same building, their average use of e-mail is still fairly high and exceeds the optimal frequency of e-mail usage to promote team goal achievement and team cohesion.

V. Discussion

In the present study, we examined the communication frequency-team performance relationship for cross-functional project teams. We found important evidence that in cross-functional teams, communication frequency can have a curvilinear relationship to performance. Additionally, the present results also highlight differences between the usage of communication media and their relationship to three different types of performance indicators. This study demonstrates that e-mail is the only medium having a curvilinear relationship with team performance across all performance measures. Face-to-face communication is curvilinearly related only to goal achievement, while telephone communication did not have a curvilinear relationship with any performance measure. Further, when we compared the communication frequency across the different degrees of colocation, we found significant differences for the use of face-to-face communication and e-mail, but not for telephone communication. As one would expect, the more distance among the team members, the less frequently they communicate face-to-face. Instead, they communicate more frequently by e-mail when they are physically distant.

The current research extends the literature on communication in cross-functional teams in a number of ways. The most significant finding is a consistent curvilinear relationship between e-mail and team performance across a number of different performance measures. Several characteristics of e-mail may facilitate its potential to create information overload across all performance indicators. First, e-mail allows easy storing and retrieving of the exchanged information, which can be accessed any time. This aspect of e-mail may become a drawback, however, as communication frequency increases. As team members need to remember the approximate content of the message or the time when it was received in order to retrieve it, the time required for information search and retrieval actually may inhibit performance. Second, e-mail requires neither physical nor temporal proximity, so there are no restrictions on the actual frequency with which the medium is used. Each team member can send and receive an unrestricted number of e-mails per day and access all or a desired subset of team members at once. Again,

TABLE III
UNIVARIATE TESTS FOR CO-LOCATION AND COMMUNICATION FREQUENCY

Variable	Mean Teams located in the same building (s.d.)	Mean Teams located in the same city (s.d.)	Mean Teams located in different cities and/or countries (s.d.)	F value	d. f.	p-value
Face-to-face	4.07 (0.49)	3.89 (0.37)	3.56 (0.70)	4.21	2, 57	0.0198
E-mail	3.61 (1.08)	4.15 (0.89)	4.45 (0.52)	3.96	2, 57	0.0245
Telephone	4.03 (0.59)	4.32 (0.51)	4.26 (0.54)	1.41	2, 57	0.2522

this may promote information overload. Third, the length and the content of the messages are practically unlimited and the mechanics of using e-mail are extremely easy. Yet, the time required to compose an e-mail message, and to read and process the content of received messages, has the potential to create information overload and ultimately hinder performance. These characteristics of e-mail may explain why heavy usage of e-mail may actually begin to inhibit team performance. The present results clearly suggest that e-mail, as a communication medium in teamwork, should be used with caution.

A second finding of note is the curvilinear pattern that appeared when examining the relationship between face-to-face communication and goal achievement. The downturn in team performance when more frequent face-to-face communications took place may indicate confusion or conflict within the team about project goals. This confusion or conflict could provoke more face-to-face discussions and could hinder project performance. Since our data do not include information about the content of communication, we leave this question for future research. The results do indicate, however, that when teams engage in very high levels of face-to-face communication, project performance is likely to be in jeopardy.

The lack of relationships between communication and performance in several instances are also interesting phenomena for discussion. While face-to-face communication was related to a team's ability to achieve its business goals, as we have just discussed, it was not related to either team efficiency or team cohesion. With respect to efficiency, communication may not be as necessary for meeting budgets and schedules as it is to arriving at a common understanding of the team's goals. Cohesion, on the other hand, may not have a relationship with face-to-face communication in this sample, because the reported levels of cohesion were very high with low variability across teams ($M = 4.25, SD = 0.69$). Had cohesion been lower, or had we conducted a longitudinal examination, the relationship may have been different.

The lack of any relationship between telephone communication and team performance is intriguing. The telephone, although frequently used, appears to be a medium that does not have any impact on team performance. Nor, based on our *post hoc* analysis, is it a medium that is used to compensate for distance among team members. Thus, the role of telephone communication on cross-functional project teams is left unclear. We can speculate, however, that the advent of e-mail, with its convenience and mass distribution capabilities, may be displacing the telephone as the important medium for team communication. In fact, as our *post hoc* analysis shows, e-mail was increasingly used to facilitate team communication as distance between team members increased.

There are several implications for practice from these results. As this research indicates, e-mail must be used with caution. It results in a consistent curvilinear relationship with performance across all measures included in this study. Hence, team member usage of e-mail must be closely monitored to ensure that performance is not impacted by frequent messages. Additionally, team leaders and managers may want to aid teams by clearly identifying the team goals to minimize the amount of face-to-face and e-mail communication required to gain a common understanding among team members. Finally, cross-functional team members may need to be trained to manage the amount of information they exchange with various communication media. In sum, when establishing the preferred team communication channels and training team members, team leaders should keep in mind that more communication will not necessarily result in higher performance.

The results of this research suggest at least two opportunities for future research. First, objective and comprehensive assessments of communication are needed to further refine the curvilinear relationship we established in this research. Objective measures of communication, as opposed to the self-report measures used in this study, and more refined scales are necessary to precisely establish the threshold of communication

at which performance starts to decline. Comprehensive assessments of communication will provide the data necessary to conduct content analysis that will further clarify the type of information transferred over each communication media. Such analyzes may provide insights as to why various media have different relationships with performance.

Second, future longitudinal research is needed to determine the causality of the performance-communication relationship. The cross-sectional design we employed in this work does not allow us to rule out the possibility that low performance may cause low-communication frequency. For example, teams reporting low cohesion may decrease the frequency of communication transpiring among team members because they may be prone to disagreements and unpleasant interactions. Likewise, a highly cohesive team may not communicate frequently because the team members know each other well and do not feel the need to exchange a lot of information. We anticipate that goal achievement and project efficiency could similarly influence communication frequency. Such reasoning demonstrates the necessity of conducting longitudinal research to establish the directionality of the communication-performance relationship.

VI. Conclusion

The current study was designed as an empirical investigation to provide a more comprehensive understanding of the relationship between cross-functional team performance and communication frequency. Extending previous research on cross-functional team communication, we have shown that the relationship between communication frequency and team performance is not as straightforward as previously believed. The curvilinear relationship between communication frequency and performance we were able to establish requires reconsidering the way communication is used to facilitate team performance. This work also provides an interesting glimpse into the role e-mail plays in project teams and how it is related to various aspects of team performance. Future research on the communication frequency-team performance relationship appears justified, with special attention being paid to the new electronic communication media that are emerging in project work today.

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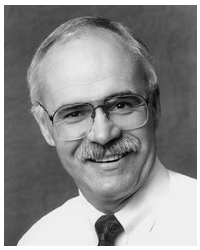

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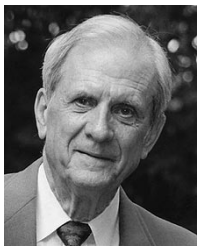

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