A PROCESS-BASED MODEL FOR PRIORITY CONVERGENCE IN MULTI-PERIOD GROUP DECISION-MAKING

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ABSTRACT

Over the past three decades substantial research has been dedicated to the task of providing theoretical models for group decision processes. Unfortunately, many models remain grounded in single-period decision contexts. The current work investigates an extremely basic process approach to multi-criteria multi-period group decision-making. The time-series model considered incorporates factors relating to member influence over aggregated group decisions, the effect of past priorities on subsequent priorities and the cognizance / acceptance of performance optimizing task-criteria priorities over otherwise non-ideal ones. Quantitative values relating to criteria priorities are elicited for each period through paired comparisons. Empirical analysis of collected group task data is done through a three-stage evaluation of the model's performance. Results suggest that the time-series approach is consistent in evaluating changes in criteria priorities over-time. The model can provide a strong auxiliary tool for multi-period extensions of existing approaches to decision support analysis.

KEYWORDS: Decision Analysis, Group Decision and Negotiation, Multi-Criteria Analysis

1. Introduction

Extensive work has been devoted to modeling multi-criteria group decision (MCGD) problems. Work in recent years has been no exception. In general these problems have been associated with a number of features including the existence of conflict between alternatives, multiple competing performance criteria and a group decision environment (Hwang and Lin 1986). Two of the primary points stressed in recent MCGD research have been the introduction of alternate techniques for group preference aggregation (Bolloju 2001, Forman and Peniwati 1998) and the consideration of the implications of incomplete information in the decision process (Kim and Ahn 1997). A third point stressed in the literature has been the potential benefit of iterative techniques and applied decision support mechanisms for these processes, such that win-win solutions or other objectives may be structured for those involved (Teich, Wallenius, Wallenius and Zionts 1996, Teich, Wallenius, Kuula and Zionts 1995). Yet the empirical evaluation of such issues and the appropriateness of alternate MCGD techniques remains relatively limited (Easly, Valacich and Venkataramanan 2000, Iz and Krajewski 1992), particularly with regards to multi-period human decision processes. Ehtamo and Hamalainen (2001) provide a review of the literature that further emphasizes this gap.

Several traditional sources of influence can be considered within multi-period evaluations. One of the most intuitive is the relative power of group members on the iterative decision process. The use of decision weights as representations of member influence goes back to the early works of such authors as Harsanyi (1955), and Dyer and Sarin (1979), as well as the works of other more contemporary authors (Islei and Lockett 1991). The classical tenets behind the application of such schemes stem from assumptions relating to complex social forces within the group including individual member indifference towards alternatives or alternate sets of task criteria priorities. Another key element is the presence of convincing group leaders, either by virtue of charisma or overt dominance, which are in turn partial to specific alternatives (von Neumann and Morgenstern 1944). Furthermore, the same issues represent secondary determinants, or structural “faults” of groups, as described in Janis’s groupthink framework (Janis 1982).

The persistence of incomplete information is similarly cited by Janis (eg. insulation from outside experts) as an antecedent of the group think phenomena, with the issue of group cohesion serving as the binding determinant. Of course, the bane of groupthink lays in the formation and maintenance of a premature assessment of a preferred set of priorities inferior to an otherwise ideal set (Janis and Mann 1977; Aldag and Fuller 1993). However, group cohesion in general should not necessarily be interpreted entirely as a phenomenon to be avoided, particularly when the group facilitates information pooling (Festinger 1950; Stewart and Stasser 1995; McCauley 1998). Indeed, in the presence of incomplete information, cohesion may prove critical to efficient sequential improvements within decision processes, particularly in the absence of an overpowering leadership that misguides rather than improves the set of priorities effective for the group as a whole (Huber 1989; Fuller and Aldag 1998).

The efficient and repeated elicitation of group member views can also directly impact learning and convergence in group decision processes, approaching either an ideal or non-ideal group consensus (Salo 1995). Its particular importance to group decision processes, in contrast to one-time group decisions, relates to the types of analysis needed to assess the nature of underlying effects and relationships. While decision making can be studied from a structural-modeling standpoint, such efforts in their pure form are typically restricted to attempts at relating final alternative selections to single-stage explanatory inputs. Process-based approaches (eg. time-series analysis, event analysis or sequence-focused content analysis) on the other hand attempt to trace processes through their duration, perhaps foregoing the breadth of independent factors under consideration in place of the depth of processual understanding gained with regards to a subset of such factors. In his recent work, Svenson (1996) indeed claims that process perspectives on human decision-making are essential in the explanation of human decision-making regularities. According to this author, existent theory seems to suggest the prevalence of a number of relevant levels of decision-making that may be observable throughout such process-based approaches.

At a base level are the effects of sub-conscious rules, analogous to Klein's "recognition-primed" specifications, which emerge predominantly from prior experience (Klein 1989; Shiffrin and Schneider 1977; Svenson 1992). Analytical analogies naturally arise with regard to autoregressive models, in which future indicator values of preferences are based largely on those prior to them. Another level cited by Svenson involves the specification of a preference within a range of options at any given point within the process, though again research to date has been predominantly restricted to the end-decision evaluation (Svenson 1996). Nevertheless, such a level in group processes suggests the generation of some form of group consensus as well as the potential convergence of member preferences towards a more narrowly defined and accepted range of priorities. Lastly, the search for a promising set of priorities based on step-wise indications of idea performance-maximizing priority schemes, though almost entirely devoid of investigation in the academic realm, has been suggested as a particularly relevant issue with regards to the group process (Fischhoff, 1996).

One of the salient points with regard to the current work is the distinction between information-based and norm-based effects on both individual member priorities and group priorities regarding task criteria throughout the decision process. Keeney alludes to these two effects by considering the effects of alternative-focused as opposed to value-focused thinking (Keeney 1988; Keeney 1992). Essentially, the first can be interpreted as a disposition towards the consideration of any alternate set of priorities in general, as opposed to a strict dependence on recognition-primed alternatives, for example. Value-focused thinking however alludes to the ability of group members to favor the influences of performance-based indications of a more ideal set of priorities vis-à-vis the prior group consensus, as opposed to the group consensus alone.

While alternative-thinking is critical as a means to consider options that may or may not be ideal, value-thinking represents the channeling of appropriate resources in order to "make *better* decisions" (Keeney 1994). It therefore encourages a progression towards ideal priorities during the process, rather than a convergence upon relatively non-ideal beliefs of mislead groupthink. Similar distinctions between informational and normative influences have also been made within the MCGD contexts (Bryson 1996;

Huang, Raman and Wei 1993; Tan, Wei and Watson 1993). One of the aims of the current work is to help reconcile the void present in the process literature, through the empirical testing of a process model based on these same tenets.

2. Model Foundation and Structure

The present investigative model has its foundations in a relatively simple and mechanical approach to individual decision processes, with extrapolations to group settings. Rather than deny the existence of a multitude of behavioral components active in this process, these foundations assume a priori that complex mechanisms are at work. The concentration here however is not on the dependency upon such antecedents themselves, an issue delegated to future research, but rather the interaction of certain issues already deemed relevant within many decision processes (eg. consensus, individual priorities, decision weights, etc.).

The model builds upon two propositions, the first of which may be summarized as follows:

> *Proposition I*: Given complete information regarding the characteristics and overall performance criteria inherent to a task, and in the absence of normative biases, rational individuals will act to maximize their overall performance by taking actions strictly dependent on this knowledge, regardless of past priorities.

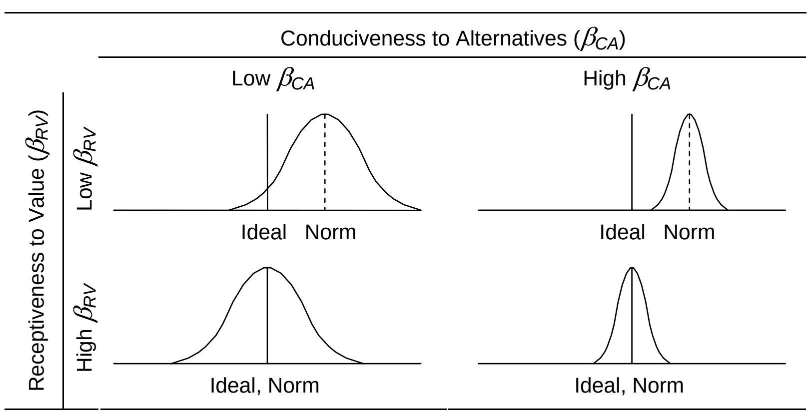
The foundation for this first proposition is provided by the allusions of Keeney with regards to value-focused thinking extrapolated to the presence of complete information (Keeney 1992). In such scenarios, alternative-focused thinking is dominated by value-focused thinking and recognition-primed priorities are irrelevant (Klein 1989). In a natural extension, groups of such individuals working together towards a common goal will act equivalently given such circumstances. However, as complete information is seldom a reasonable characterization of real-world decision processes, a variant of this first proposition must necessarily be considered.

> *Proposition II*: Given incomplete information, rational individuals will attempt to maximize their overall performance by acting upon an aggregation of what they *perceive* to be the mechanisms inherent to the task and the available information regarding these mechanisms. Future perceptions of such individuals will depend not only upon the past priorities of the individual, but also upon both the conduciveness of the individual and the task environment to changes in perceptions (and hence preferences) and the sources that positively and negatively influence such changes.

Through the observation of performance responses to their actions, and a willingness to react and learn even marginally from such insights, individual perceptions will theoretically embody the true task mechanism with time. Though of course the amount of time required to attain this level of cognizance may vary greatly. In group settings, perceptions based on incomplete information will be influenced not only by the observation of performance indicators but also by the group consensus. Hence the effects of recognition-primed priorities and alternative-focused thinking inclusive of normative forces become relevant as well, as they are in reality.

Here, issues relating to Janis's groupthink phenomena again come to light (Janis 1982; Janis and Mann 1977). The decision dynamics characteristics of groups will depend both upon the extent to which individuals affect the group aggregate and the influence that the aggregate has on the future perceptions, as well as the tendency for perceptions to be affected by such influences. Again, with continued exposure, existing theory suggests that perceptions will inevitably converge upon the true task mechanism, with concurrent convergence in associated priorities (Keeney 1994). Here we similarly refer to a group member's priority level regarding a decision criterion as the importance that the individual places on that criterion relative to the other criteria considered.

Based on these propositions and the existent theory already presented, the form of the process model investigated implies that member *k*'s priority level regarding a specific decision criterion at some point in time *t* (P_{kt}) is a scalar function of the immediately previous recognition-primed priority level ($P_{k,t-1}$), the immediately previous group norm ($P_{G,t-1}$) and some ultimately ideal performance-maximizing priority level (Π_k) which is equivalent for all members of the group (ie. $\Pi_1=\Pi_1=..=\Pi_K$). Here it is assumed that member k is one of K individuals in a group of decision makers and that the various criteria under consideration each separately follows the same dynamic structure. Therefore only one criterion is depicted in the present notation. Given the theorized dependency on alternative-focused thinking, the total effect that group norms and information regarding the "ideal" specification should be mitigated by some factor, referred to here as the fractional (ie. ranging from 0 to 1) conduciveness to alternatives (β_{CAk}). A value of 0 would represent an unwillingness to adjust existing priorities, while a value of 1 would represent a willingness to base future priorities solely on the influence of the group or other sources of outside information (eg. indications of performance maximizing priorities provided by DSS feedback mechanisms). All other things being equal, the higher β_{CAk}, the faster convergence on some common set of priorities by the group members. Similarly, the tendency for the group to be cognizant of and respond predominantly to "ideal" alternative characteristics (value-focused thinking) rather than those of the norm, is depicted as the fractional receptiveness to value (β_{RVk}). In the present application, values of 0 imply a complete inability to recognize ideal task-criteria priorities and hence sole dependency on the group norm for subsequent influence on individual decisions. The opposite form of influence would be true for β_{RVk}=1. Figure 1 reiterates the conceptual role of these factors in group decision processes:



(Horizonal-axes: Priority level of criterion, Vertical-axes: Number of group members)

Fig. 1 - Conceptual Implications of β_{CA} and β_{RV} Effects for a Given Criterion

Here, normal distributions are used to represent the various preferences, as well as the prevalence of such priorities, embodied by the group, and the arithmetic mean is used in a simple depiction of the group aggregate. Obviously neither normality of priority distributions nor the applicability of arithmetic means need be appropriate in reality.

Lastly, in the presence of predominant normative effects, and given the mechanisms involved in group consensus generation, the present model takes into consideration the decision weights (β_{DWk}) attributed to the individual members of the group. Rather than argue the adequacy of a new method for preference aggregation, the current decision weighting scheme simply implies that observable group actions reflect a linear combination of group member preferences. The coefficients of this combination are the fractional (ie. ranging between 0 and 1) decision weights for each member, the sum of which is unity. Operating in conjunction, for a given criterion, these issues can be expressed in vector notation for the group as a whole with the elimination of the group member subscripting (k):

$$\mathbf{P_t} = (\mathbf{I} - \boldsymbol{\beta}_{\mathbf{CA}})\mathbf{P_{t-1}} + \boldsymbol{\beta}_{\mathbf{CA}}(\mathbf{I} - \boldsymbol{\beta}_{\mathbf{RV}})\mathbf{P_{t-1}}\boldsymbol{\beta}_{\mathbf{DW}} + \boldsymbol{\beta}_{\mathbf{CA}}\boldsymbol{\beta}_{\mathbf{RV}}\boldsymbol{\Pi} \tag{1}$$

In vector notation $\boldsymbol{\beta}_{\mathbf{CA}}$ and $\boldsymbol{\beta}_{\mathbf{RV}}$ are sparse matrices containing β_{CAk} and β_{RVk} values along their diagonals and zeros elsewhere throughout, while β_{DW} is a vector depicting the relative power of group members (ie. decision weights). Here $\mathbf{P_t}$ represents instances of group member priority vector (of length k) at intervals t, and Π represents the scalar of the "ideal" priority level for the criterion under consideration. Hence we define the previous period's group norm for a given criterion, as a weighted average of individual priorities and use the term $\mathbf{P_{t-1}}\boldsymbol{\beta}_{\mathbf{DW}}$ for such representation. Under scenarios in which group members can be characterized by identical, or nearly identical, values of $\boldsymbol{\beta}_{\mathbf{CA}}$ and $\boldsymbol{\beta}_{\mathbf{RV}}$, the respective matrices reduce to scalars, β_{CA} and β_{RV}, and the model is greatly simplified. This may be reasonable in well-developed organization settings in which group members, although differing in experience and opinion, have become acclimated to a specific corporate culture and process for decision-making. If such simplifications cannot be made, then the model becomes significantly more difficult to both characterize and test. For the empirical purposes of the current study, the assumption is made that the scalar reduction provides an adequate estimation for parameterization, given the group task setting.

3. Consideration of Model Characteristics

Beyond its grounding in existent theory, the structure of the group priority convergence model in itself provides certain appealing characteristics. First, in its general form, it is simplistic as far as behavioral time-series models are concerned. This of course does not suggest that it is all encompassing at the same time. However the basic development of behavioral models necessarily begins with an understanding of simple underlying issues, prior to the imposition of more complex relationships. Furthermore, the nature of the model offers certain reductions that facilitate its empirical parameterization and subsequent validation.

3.1. Alternative Priority Convergence

The first reduction possible is with regards to metrics of general convergence, either to the ideal or to some non-ideal set of task criteria priorities. Consider a standard calculation that attempts to account for convergence in terms of step-wise reductions in the variance of individual member preferences within the group. Let the Alternative-Convergence Rate (ACR) for a given criteria be the ratio of current to prior variance, represented as follows, with regard to the formulation in (1).

$$\mathrm{ACR}_\mathrm{t} = \frac{\sigma_t^2}{\sigma_{t-1}^2} = \left(\frac{\left\| \mathbf{P_t} - \overline{\mathbf{P}}_\mathbf{t} \right\|_2}{\left\| \mathbf{P_{t-1}} - \overline{\mathbf{P}}_\mathbf{t-1} \right\|_2} \right)^2 \tag{2}$$

For each criterion, this value is therefore a scalar. In Eq. 2, $\overline{\mathbf{P}}_{\mathbf{t}}$ is the arithmetic mean of each criterion's priority for the group as a whole (ie. not actually the group norm which is assumed to be mitigated by member power), and the square of second order norm differences equated to scalar variances. Substituting in Eq. (1) for the $\mathbf{P_t}$ values in the numerator, and canceling out the terms common to all group members, namely the previous group norm and ideal attribute effects, we arrive at:

$$\mathrm{ACR_t} = \frac{\sigma_t^2}{\sigma_{t-1}^2} = \left(\frac{(1-\beta_{CA})\left\| \mathbf{P_{t-1}} - \overline{\mathbf{P}}_{\mathbf{t-1}} \right\|_2}{\left\| \mathbf{P_{t-1}} - \overline{\mathbf{P}}_{\mathbf{t-1}} \right\|_2} \right)^2 = (1-\beta_{CA})^2 \qquad (3)$$

In other words, when group members can be characterized by identical, or nearly identical, values of β_{CA} and β_{RV}, the ratio of current to prior group member priority variance is a constant described by the group's conduciveness to alternatives (β_{CA}). With regards to empirical investigations, this form is ideal as we can gather information directly regarding alternative-focused thinking directly from time-monitored observations of individual group preference changes. Such a technique is employed in the empirical study to be discussed.

3.2. Value Priority Convergence

A similar tactic can be taken with regards to metrics representative of group member priority convergence to the performance maximizing set. We begin by defining the Value-Convergence Rate (VCR) as the ratio of the squared deviations of group preferences from the ideal.

$$\mathrm{VCR_t} = \frac{\Delta_t^2}{\Delta_{t-1}^2} = \left(\frac{\left\| \mathbf{P_t} - \mathbf{\Pi} \right\|_2}{\left\| \mathbf{P_{t-1}} - \mathbf{\Pi} \right\|_2} \right)^2 \qquad (4)$$

Here Δ_t is used to distinguish deviation terms from those used in Eq.s 2 and 3. As with ACR_t, for each criterion, this value is a scalar. Again, by substituting in Eq. (1), and rearranging terms, we derive the following relative simplification:

$$\mathrm{VCR}_t = \frac{\Delta_t^2}{\Delta_{t-1}^2} = \left(1 + \frac{\beta_{CA}(1-\beta_{RV})\left\|(\mathbf{P_{t-1}} - \mathbf{\Pi})\right\|_2 \beta_{DW}}{\left\|\mathbf{P_{t-1}} - \mathbf{\Pi}\right\|_2}\right)^2 = (1+\beta_{CA}(1-\beta_{RV})\beta_{DW})^2 \qquad (5)$$

This metric is entirely dependent upon issues relating to group dynamics, and at no point dependent on individual priorities. However, rather than simply being dependent upon the group member conduciveness to alternatives, the Value-Convergence Rate is dependent upon both the group's receptiveness to value and the active decision weights. The presence of this confound reveals that an estimate of β_{CA} alone, as discussed earlier, is insufficient to determine β_{RV}. In particular, estimates of the decision weights are needed before any reasonable consideration of this issue can be made.

The estimation of decision weights however can be relatively straightforward if it is assumed that time-monitored group decisions represent, as before, a linear combination of time-monitored individual priorities. Given this assumption, the decision weights can be assessed by a simple least square fit with the restriction that all weights must be non-negative and that their sum is equal to unity. Such an approach is taken in the analysis of the present empirical study.

4. Experimental Design and Validation

MCGD environments suitable for the examination of priority convergence phenomena are those in which {1} group decisions involve tradeoffs between alternatives, each characterized by a comparable yet distinct set of attributes, {2} overall task performance measures, and changes thereof, reflect group decisions and that these measures are unambiguously presented in immediate response to group decisions, and {3} individual priorities, can be assessed both prior and subsequent to the task (as well as within the interim if possible).

4.1. Issues Relevant to Model Validation

Given the potential for using a GDSS (Group Decision Support System) environment for monitoring group and individual decision-making, a plan was developed for the empirical verification of the priority convergence concept and associated model. The test hypotheses of interest stemmed from a variety of mechanical and conceptual cornerstones of the model. As a first, the lone dependency of the Alternative-Convergence Rate on the group's conduciveness to alternatives suggests that the parameter can be measured almost directly given the appropriate empirical setting. The first hypothesis makes immediate use of this relationship in order to verify the generally positive dependency of ACR upon (β_{CA}). For statistical testing purposes (i.e. the rejection of hypotheses) we state this hypothesis in the opposite direction of our expectation:

H1a: Rates of Alternative-Convergence for a given criterion, indicative of the group's conduciveness to alternatives and hence alternative-focused thinking, should differ significantly over time.

A lack of support for H1a would follow expectation emerging from Eq. 3. Likewise, the consistent nature of the Value-Convergence Rate (VCR) suggests the associated hypothesis. Again, this hypothesis is stated in contrast to our expectations purely for the purpose of statistical testing:

H1b: Rates of Value-Convergence for a given criterion, indicative of the group's conduciveness to alternatives, as well as the group's receptiveness to ideal priorities and the inherent decision weights associated with the group, should differ significantly over time.

A lack of support here would follow expectations based on Eq. 5.

Furthermore, as a simple form of validation regarding our assumptions and derivations of preference independent convergence rates and metrics for group dynamics, a second set of 8 hypotheses was posed. Rather than appear repetitive, simply stated again in the negative for testing purposes, Hypotheses 2a through 2h propose that the initial group preference means ($\overline{\mathbf{P}}_{\mathbf{1}}$) and variances (σ_1^2) should be significantly correlated with the convergence rates (ACR, VCR) and the derived group dynamic metrics (β_{CA}, β_{VR}). A lack of support for these hypotheses would suggest that significant relationships are not in general observable, which is well in line with the earlier assumptions used in model construction and manipulation.

Of additional interest to the researchers, though not explicitly dealt nor conflicting with the present model, was the potential effects that the within group variance of derived decision weights had on the convergence rate metrics. Specifically, based on Janis's groupthink phenomena, it was speculated that environments dominated by a single individual (i.e. groups with high variability in their decision weights) might in effect be characterized by a tendency to converge on that individual's preference set, and hence a tendency to rapidly converge on the non-ideal. The following hypotheses were constructed specifically to address such possibilities.

H3a: High levels of Conduciveness to Alternatives (β_{CA}) for a given criterion should be associated with high levels of variance in group decision weights (β_{DW}).

H3b: Low levels of Receptiveness to Value (β_{RV}) for a given criterion should be associated with high levels of variance in group decision weights (β_{DW}).

This last assumption is intended purely as demonstrative of the validity of the priority convergence argument, as well as to suggest the importance and applicability of the theory if valid.

H4: VCR should be a stronger predictor of overall performance than ACR.

4.2. Design of the Empirical Study

In implementing the empirical study, a GDSS environment was developed that allowed for monitoring and recording of group actions as well as resultant performance feedback. Each group, consisting of five senior undergraduate business students, were given a single personal computer on which the GDSS was set-up. All students had undergone extensive coursework on the use of the Excel environment in which the GDSS was set, and 93% had previous internship experience with firms affiliated with the university. No specific role assignments were imposed on the students within each group.

The task faced by the five member groups was one of selecting a one-week schedule of job assignments for 30 employees of a hypothetical service firm. Information relating to the specific skill sets of each employee and their preferred work hours within the week were made available to each group. Also available was information relating to hourly and daily demand for each skill-specific service provided. Student groups were expected to make improvements to the schedule (i.e. by alternate employee assignments) during each of 12 5-minute rounds. Within each round, members were expected to discuss the appropriateness of modifications, but by the end of each round only one complete schedule would be entered into the GDSS Excel spreadsheet.

Separate equally scaled (percentile) performance output for three criteria (labeled “Morale”, “Service” and “Profits”) were updated for each group at the end of each of the 12 5-minute rounds. The overall performance of each group was also updated at these points, though the exact nature of this non-linear relationship was never revealed explicitly. The ideal criterion priorities associated with overall performance maximization (ie. Π for each criteria) was 0.23, 0.34 and 0.53 for the three criteria respectively. In order to ensure that cognizance of the ideal alternative attributes depicted by this relationship was a non-trivial matter, the GDSS ensured that no single action could effect one of the three criteria without altering the others. Again the exact mechanisms that provided such complications were never revealed to the groups participating.

To provide performance incentives, five groups would compete throughout the full one hour duration of the task for a $50 cash prize. Before the formation of each 5-member group, the general task scenario was detailed and prior perceptions of the relative importance of each of the three criteria were independently keyed in by each group member, outside the confidence of the group as a whole. These ratings were derived through pair-wise comparisons of the three criteria. Similar priority information was gathered at the beginning of each successive round, while group consensus priorities and overall performance measures were collected at the end of each round. A final inquiry was made subsequent to the completion of the one-hour period, for a total of thirteen sets of preference data per individual and group, from which 12 rates (ACR and VCR values per criteria) could effectively be derived per group. One hundred groups were studied in this fashion.

5. Analysis and Results

Each group's convergence rate metrics were derived in accordance with their definitions in Eq. (2) and Eq. (4), as was the back-calculation of average values for β_{CA}, as described by Eq. (3). Ordinary least square fits were applied to the time series data to estimate the decision weights (β_{DW}) under consideration. In these fits, the individual priorities of group members served as independent variables whereas the group's common (consensus-based) set of priorities served as the dependent variable. As an additional check for the stability of the weights, least square fits based on the first seven time periods observed were compared against those based on the last seven time periods. In comparing the absolute differences in these estimates to zero (representing no change between initial and later figures), no statistical differences between the two sets of estimates were detected. This finding is not meant to suggest that changes in leadership did not occur during the task, but rather that most of these changes were apparently slim. In environments where leadership changes are significant adjustments to the use of the current model would be required, however in this case we felt justified to continue with our design of analysis.

The other key metrics required for testing our hypotheses were estimates of the receptiveness to value coefficients for each group and criterion (β_{RV}). Non-linear optimization by way of the Solver Add-in in Microsoft Excel and the availability of the β_{CA} and β_{DW} calculations, provided the means by which group values of β_{RV} were extracted (ie. from Eq. (5) or similarly (1)). All metrics appeared to be approximately normally distributed among the 100 groups and for all three criteria, with confirmation via Kolmogorov-Smyrnov test statistics. Other than the fact that the sum of all criteria priorities was equal to one by definition of the pair-wise data collection, no additional issues stemming from inter-relatedness were taken into account that would otherwise complicate this preliminary model investigation.

Since the model developed and subsequent calculations do not suggest that these metrics are subject to change over-time, tests for whether H1a and H1b could be rejected were required. In order to assess the time-consistency of the rate metric derived, and due to the relatively small number of observations per group, two time-variability tests were utilized. The first tested the existence of a marked absolute difference in the rates between the average of the first six and last six time periods monitored. The second tested for the existence of a marked absolute difference between the average of the middle six and outer six (first three and last three) time periods. Essentially the form of the compound ACR test metrics derived for each group were as follows (with vertical lines depicting absolute value calculations):

First vs. Last: $$\Delta ACR_{FL} = \left| \overline{ACR}_{t=1..6} - \overline{ACR}_{t=7..12} \right| \qquad (6)$$

Middle vs. Outer: $$\Delta ACR_{MO} = \left| \overline{ACR}_{t=1..3,10..12} - \overline{ACR}_{t=4..9} \right| \qquad (7)$$

The compound metrics derived for difference in VCR group values were of the same form. The results of t-Tests performed to assess whether these difference-indices were significantly non-zero are provided in Table 1. To increase the power of these tests, and the ones to follow, the data sets used in these comparisons include ACR and VCR values for all 3 criteria of all 100 groups (ie. 300 records total).

	Test: First – Last = 0	Test: Middle – Outer = 0
ACR	0.678	0.771
VCR	0.754	0.839

Table 1. P-values for the respective compound index t-Tests

As shown, the non-significant p-values derived suggest that in the absence of any mitigating forces outside the test environments the observed convergence rates are indeed relatively stable, hence rejecting the first two negative hypotheses (H1a and H1b) posed and supporting the assumptions that underlay these aspects of the model (ie. that the stability of ACR and VCR estimates is acceptable).

Correlations constructed for each of the pairs discussed in the second set of hypotheses are equally supporting, in as far as the simplistic theory driven basis of the model is concerned. These correlations are summarized in Table 2.

	Initial Variance of Group Member Preferences (σ_1^2)	Initial Mean of Group Member Preference ($\left\|\overline{\mathbf{P}}_1\right\|$)
β_{CA}	0.005	-0.008
β_{CA}	-0.064	0.050
ACR	-0.041	0.046
VCR	0.083	0.059

Table 2. Bivariate correlations under consideration in H2a-h

None of these correlations were found to be significant at the 10% level, well in line with our intended rejection second set of negatively stated hypotheses (H2a-H2h). This suggested that the model's view that initial variance and priority conditions didn't have significant impacts on model parameter estimates was acceptable.

In evaluating the postulations of H3a and H3b, a similar approach was used. The results of correlations derived for the terms involved in the two hypotheses are provided in Table 3.

	Variance in β_{DW}
β_{CA}	0.062
β_{RV}	-0.189**

** - Significantly different from 0 at the p<1% level

Table 3. Bivariate correlations under consideration in H3a-b

Although the correlation between the variance in decision weights and group conduciveness to alternatives was insignificant, the correlation of this variance with receptiveness to value was, and in the hypothesized direction, lending partial support to our groupthink-driven hypothesis set (H3a and H3b).

Finally, we considered H4, in which the superiority of VCR (Value Convergence Rate), relative to ACR (Alternative Convergence Rate), as a predictor of end-performance was posed. At an R^2 of 0.335, VCR accounted for approximately 20% more variance in the final performance measure than did ACR (R^2=0.126). Furthermore, a step-wise regression in which the ACR term was added in the second step, after VCR was already present, showed no significant improvement in the model's F-statistic at the 10% level. In contrast, the addition of VCR in a second block (when ACR was already present) showed a significant increase in the model's R^2 at the <1% level. Taken as a whole, this seems to lend support to our final hypothesis (H4) as well. As stated before, the importance of this last finding lays in the capability of the model to provide consistency with the view that convergence on the group norm is not as important (in itself) as the ability of a group to converge on the task ideal, with respect to overall performance. If this could not be shown, the usefulness of the model in supporting both theory and basic intuition would be called into question.

6. Conclusion and Future Work

Empirical investigations into group priority aggregation and information usage in problem solving environments remains limited, particularly with regards to multi-period processes. To fill this gap, the current work has attempted to build upon past theory and research in this area to propose a simple and tractable approach to modeling multi-period group priority convergence. To add validity to the idea that simple time-series based models may be applicable in these complex settings, several hypotheses have been posed and tested through laboratory study. Overall, our empirical findings seem to provide substantial support for the theoretically based priority convergence model for group decision processes proposed.

According to our analysis, the model presented proves adequate in characterizing several classical features inherent to theory regarding multi-period schemes, as well as new perspectives on processual group dynamics. The measurements, as well as the associated derivations, required for the application of the current model are furthermore relatively mechanical thus providing ample room for elaboration and extensions into more complex and custom contexts. Future work should in turn emphasize potential latent and stochastic extensions of the priority dependencies of the model as well as attempts to apply the model in place of, or in parallel with, existing behavioral frameworks of group decision processes.

For example, based on research into performance feedback (Bachrach, Bendoly and Podsakoff 2001, Staw 1975) the manipulation of the validity of feedback (i.e. the use of false feedback) has the potential of effecting group behavioral phenomena, such as sportsmanship, civic virtue and others considered within organizational citizenship frameworks. A logical extension might be the consideration of the process impacts that such manipulations might have by evaluating direct effects of these manipulations on process indicators of the present model such as alternative- and value-convergence rates (ACRs and VCRs). By assessing whether performance feedback manipulations impact specific group citizenship attributes simultaneous to effects on convergence rates, research may be able to derive connections between group process differences, latent indicators of group dynamics and the potential for managerial manipulation in real world settings.

Along similar lines, the level of ambiguity associated with the task may be taken into consideration in future experimental manipulations. Since ambiguity in itself should be expected to have a direct impact on the overall rates of convergence on performance-maximizing priorities, it would be interesting to investigate the relationship between various forms of task ambiguity impact such rates. Beyond a certain point, additional information regarding the relationships between decision variables and performance measures may cease to be of assistance, and may in fact become prohibitive due to information overload. On the other hand, even small amounts of appropriate information may greatly enhance the speed at which priority convergence occurs among group members. With the growth in use of virtual group settings, as made available through developments in internet technologies, such studies could be of considerable support to information systems and knowledge management researchers as well as package developers.

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