Group Solution Assembly in Response to a Simulated Emergency

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Abstract

Recent research has argued forcefully and persuasively that to understand creative thinking it is necessary to investigate both convergent and divergent thinking processes. In the context of group decision making in emergency response, the link between these processes is particularly relevant, since stakes are high and, by definition, thinking must conclude with decision. This study investigates convergent and divergent thinking processes in the context of group decision making during the response to two simulated emergency events. The results suggest that level of event severity had little appreciable effect on these processes in one group's response to two non-routine simulated emergencies.

Keywords: Group decision, group creativity.

Introduction

Emergencies present unique opportunities for testing the limits of explanatory theories of human cognition and decision. By definition, emergencies occur at—and sometimes far beyond—the boundaries of human experience, where creativity and an ability to decide effectively against time constraint and in the presence of high stakes are highly valued (Kreps, 1984; Mendonça & Wallace, 2007). As emergencies increase in scale, they are likely to be addressed by multi-disciplinary groups. Yet very little research has been done into the link between cognition and decision making among personnel in emergency situations.

This study investigates how one group of professional emergency response personnel assembled solutions in response to two highly non-routine emergency events. Specific research questions address the impact of event severity on the relationship between alternative solutions considered by the group, recommendations of group members regarding decisions to be made, and finally decisions themselves.

Background

Group work is common in the response to large-scale emergencies, with members likely to be drawn from disciplines such as fire, police, health and hazardous materials management (Scanlon, 1994). Members of the group (typically called an Emergency Response Organization, or ERO) are expected to work collectively to consider various courses of action, make recommendations to a group coordinator on how to manage the emergency, and communicate decisions to field commanders about personnel and materiel resources to be sent to the scene of the emergency. There are various guidances available to express which of these resources are best suited to fulfilling response goals such as preservation of life and property (Federal Emergency Management Agency, 2005), and these may be drawn upon during the course of the response. Once resources arrive at the scene, they are managed by on-scene commanders, who communicate as necessary with the ERO.

Previous work has suggested that high levels of time pressure and event severity may cause EROs to choose familiar courses of action even when they do not match field conditions (Weick, 1993). As with various other groups, it is appropriate to consider the impact of external conditions on how the ERO responds to highly non-routine situations in order to gain insight into how groups think (or fail to think) creatively (Hinsz, Tindale, & Vollrath, 1997).

Creativity has long been viewed from a theoretical perspective as entailing both divergent and convergent thinking processes. Divergent thinking involves "multiple or alternative answers from available information," while convergent thinking involves deriving "the single best (or correct) answer to a clearly defined question" (Cropley, 2006). However, the vast bulk of the literature on creativity in groups has treated the two types of processes as distinct and, perhaps, separable (Kerr & Murthy, 2004). Yet as is clear from Weick's study and those of others (Cropley, 2006), convergent and divergent processes may operate in tandem. Accordingly, the research questions developed in the next section link divergent to convergent thinking processes in the context of decision making by EROs.

Research Questions

The objective of this study is to examine solution assembly by a multidisciplinary group as it responds to two simulated, highly non-routine emergencies, each of a different level of severity. Consistent with Social Decision Scheme Theory (Stasser, 1999), the design of the study follows from the view that group decision is best investigated as the joint product of task structure, practices of the group, and properties of the environment. The task of the group here is to make joint decisions about which resources to allocate to an emergency scene. The practices of the group are aligned with the conventions of EROs. The

environment is one characterized principally by time constraint and event severity.

The analysis is organized around five research questions. The first question pertains to divergent thinking processes:

Question 1: To what extent do the recommended uses of resources for given response goals deviate from convention? Groups are expected to be less likely to consider unconventional uses of resources (e.g., using pumper trucks for controlling access to the incident location) when event severity is higher (Weick, 1993; Kerr & Tindale, 2004).

The next two questions explore the link between divergent and convergent thinking processes and decision:

Question 2: How does the set of considered courses of action impact decision quality? It is expected that, as the number of considered courses of action increases, better solutions become more likely (Kerr & Tindale, 2004). Event severity is expected to impact this relationship by reducing the number of considered courses of action, and thus the likelihood that a good solution will be found (Weick, 1993).

Question 3: How does the effort devoted to solution assembly change over time, as reflected in the evolution from considered courses of action to decisions? It is expected that effort will increase with time, until the point where CCAs begin to become infeasible, after which it will decrease. Increased level of severity is expected to increase level of effort, but not the trend. It is also expected that decisions will be made close to (but not after) the point at which resources begin to become infeasible.

The final two questions pertain to convergent thinking processes:

Question 4: To what extent do considered courses of action (CCAs) explain variability in recommendations of individual group members? CCAs are said to explain recommendations if resources included in CCAs tend to appear in recommendations. It is expected that frequency of mention of a resource will increase the likelihood that it is included in a recommendation. The effect is expected to be smaller as event severity increases.

Question 5: To what extent does the size of considered courses of action (as reflected in the number of resources used) mirror that of decisions actually taken? It is expected that the size of considered courses of action will parallel that found in decisions actually taken, since the decision by the group is meant to be a collective one. It is expected that event severity will have no appreciable impact on this effect.

Method

Experiment Design

The group was first presented with an overview of the session, then completed consent forms and background questionnaires. They next practiced using the computer-based system on a test case until all stated that they understood their task and how to use the computer-based system to perform it. They were then randomly assigned to the experiment conditions (here, the low severity Case 1 followed by the high severity Case 2). After each case, they assessed their performance. To conclude the experiment, they provided feedback via questionnaire response and informal discussion on the experience of participating in the session.

Participants

The five participants were emergency managers taking part in an incident management course at the U.S. National Fire Academy. One participant in the group served as group coordinator, with each one of the other participants serving as the representative of a particular emergency service: Police Department (PD), Fire Department (FD), Medical Officer (MO), and Chemical Advisor (CA). A summary of prior experience and qualifications of participants is given in Table 1.

Table 1: Background and Experience of Participants.

Role	Years with organization	Exercises	Emergencies
CO	27	>15	>2000
FD	15	too many to count	too many to count
PD	0.08*	>400	>46,000
MO	24	>30	>10,000
CA	26	>100s	>10,000

*23 years' experience in previous work

Setup

The group convened in a conference room, seated so that they could view each other face-to-face. Video cameras and microphones recorded their interactions (see Fig. 1).

Figure 1: Experiment Setup

The group was presented with two cases, developed from archival reports of prior accidents and supplemented by extensive discussions with subject matter experts at the emergency services division of a major European port. Case 1 concerned a cargo ship fire with subsequent oil spill; Case 2 concerned a collision between two ships with subsequent chemical emission. The cases were made non-routine by including plausible but rare constraints on the use of resources (e.g., CO_2 canisters that have to be escorted via police vehicles), availability of resources (e.g., some vehicles did not have drivers), and uncertainty in

information provided to the group (e.g., number of passengers aboard the ship was unknown).

The cases are summarized in Table 2. Case 2 was more severe than Case 1, since the event affected more people, and more goals needed to be met. Goals G1–G4 were given in Case 1 (C1), and G1-G5 were given in Case 2 (C2):

G1: control of access to incident location
G2: control of fire at incident location
G3: removal of trapped persons from danger
G4: treatment of injured persons
G5: control of chemical release.

Roughly the same number and mix of resources were available in each case, with up to three resources (denoted *a, b* or *c*) available at each site. For example, in C1, resource *Aa* was a an ambulance located at site *A*.

Table 2: Comparison of cases 1 and 2.

Element	Case One	Case Two
Sites	18	19
Resources	23	27
Goals	G1–G4	G1–G5

Information on the cases was presented through a computer interface (see Figure 2) with a map on the left side showing the location of available resources and panels with information about the status of the emergency on the right. A service representative learned about resources controlled by his/her own discipline by clicking on sites controlled by that service (indicated by icons on the map). Information about other disciplines' resources had to be requested verbally. The CO had access to all information. A log entry was generated each time the participants interacted with the computer-based system.

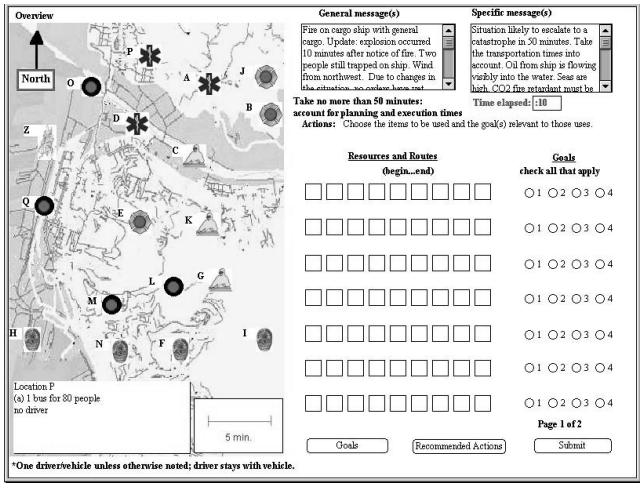

Figure 2: CO Interface to the Simulated System

Task

The group's task in each case was to allocate resources to the incident location in order to meet response goals. The group was told to account for decision execution time within a time budget of 50 minutes. Non-CO participants had to authorize the use of their resources and to specify the goals associated with that use (e.g., use of a pumper truck for the goal of fighting the fire). The CO then recorded the decisions of the group via the computer interface.

Because participants had to account for execution times, resources became infeasible if they were not used in time. Figures 3 and 4 show the number of feasible courses of action over time for each case. In both cases, the number of feasible alternatives diminishes rapidly following onset of the case. Event severity was constant. As a result, problem difficulty increased over time since fewer resources were available to meet response goals.

Upon completion of the experiment, participants rated the quality of their solutions with respect to the overall goals of the response. Independent external judges later rated the quality of each group's solutions with respect to each goal (responses were then averaged across each goal and judge).

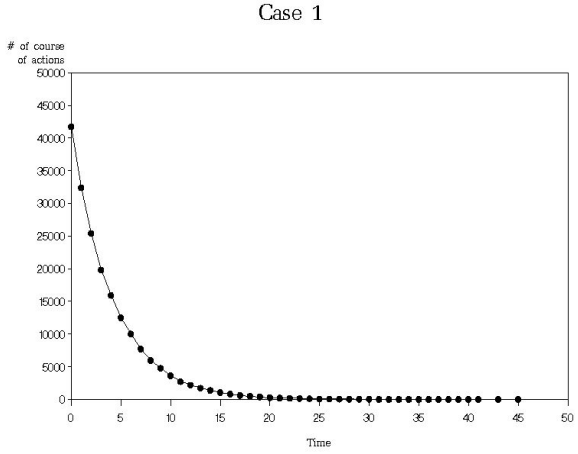

Figure 3: Feasible courses of action in case 1

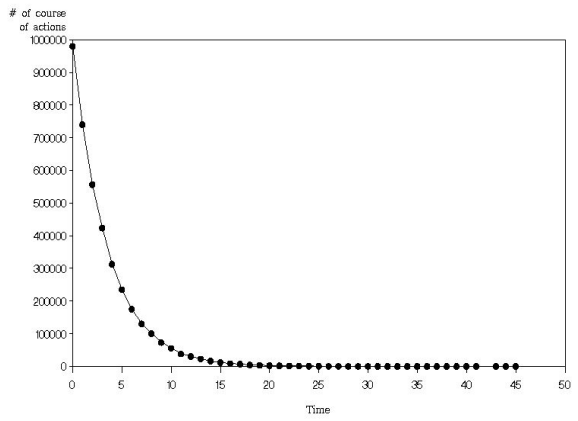

Figure 4: Feasible courses of action in case 2

Analytic Methods

Preparation of Data

Data were produced from the audio/video recordings and computer log files. Conversations among group members were professionally transcribed to show (i) *time* (mm:ss) of onset of each conversational turn, (ii) *role* of the speaker, and (iii) *content* of turn (see Table 3 for an excerpt).

Table 3: Excerpt of conversation transcript.

Time	Role	Content
10:54	FD	I want to send E to Z, the two closest pumpers
10:59	MO	Ea and Eb.
11:06	CO	Well, what we have two pumpers at E.
11:15	PD	What kind of goals that may be?
11:18	CA	I think it is control of fire.

A illustrative record from the computer log is shown in Table 4. At 07:52, FD sought information about resources at site *E*. At 14:50, MO made a recommendation that resources *Ea* and *Eb* each be used in achieving goal 2. At 29:22, CO submitted the decision to send resources *Ea* and *Eb* to the incident location (*Z*) to help achieve goal 2.

Table 4: Sample records from log file.

Time	Participant	Event
07:52	FD	E
14:50	FD	Ea, 0100
14:50	FD	Eb, 0100
29:22	CO	Ea, Z, 0100
29:22	CO	Eb, Z, 0100

Encoding of Data

The transcripts and log files were encoded to enable measurement of the four main constructs in the study:

- Considered course of action (CCA): a CCA is an ordered sequence of activities involving at least one resource and at least two sites. Resources in each CCA were identified, along with the sequence in which they were used and any corresponding goals. The two CCAs at 10:54 in Table 3 are encoded as (*Ea*, *Z*:0100) and (*Eb*, *Z*:0100), since both refer to goal 1.
- Recommendation (REC): a REC is an entry in the log file by a non-CO participant in which a resource is associated with a goal. The REC at 14:50 in Table 4 is encoded as (*Ea*: 0100).
- Decision (DEC): a DECis a course of action as recorded in the log file by the CO. The DEC at 29:22 in Table 4is encoded as (*Ea*, *Z*: 0100).
- Decision Quality: as mentioned previously, decision quality was assessed by judges and participants .

A coding instrument was developed for identifying CCAs from the transcripts and was found to be reliable (Cohen's κ=0.78).

Results

The values of the main study variables are first briefly reviewed, followed by presentation of the results for the six research questions. All statistical tests were performed at α=0.05.

As shown in Table 5, more considered courses of action (CCAs) were made and more goals associated with those CCAs in Case 2 (C2) than in Case 1 (C1). The number of resources (res) and goals per CCA was approximately equal in both cases.

Table 5: Total, mean (std. dev.) for main measures.

Case	1	2		1	2	
CCA	93	111	*CCAs*	2.43 (0.56)	2.30 (0.70)	*res/CCA*
	19	26	*goals*	0.20 (0.52)	0.23 (0.59)	*goals/CCA*
REC	12	10	*RECs*	3.00 (2.71)	2.50 (1.73)	*RECs/P*
	20	17	*goals*	1.67 (0.78)	1.70 (0.95)	*goals/REC*
DEC	10	13	*DECs*	2.70 (0.67)	2.31 (0.85)	*res/DEC*
	16	25	*goals*	1.60 (0.70)	1.92 (0.95)	*goals/DEC*
J Eval	–	–	–	3.75 (1.04)	3.20 (1.64)	*1=agree, 7=disagree*
P Eval	–	–	–	2.60 (1.95)	3.20 (1.79)	*1=agree 7=disagree*

Both the number of RECs and the number of goals associated with those RECs were nearly mirrored across the two cases, as was the number of RECs per participant (P), and the number of goals per REC.

The number of decisions (DECs) in both cases was approximately equal, though more goals were associated with those DECs in C2 than in C1. Resources and goals per decision were also approximately equal. The number of DECs in both cases represents an order of magnitude reduction from the number of CCAs.

Solutions were rated on a 7-point scale, where a 1 indicated agreement with the statement that the goal(s) had been attained, and a 7 indicating disagreement. Judges (J) and participants (P) ratings for quality of C1 and C2 DECs were not appreciably different, though it should be noted that judges ratings for C1 solutions were more clearly lower than those of participants.

Divergent Processes

In answer to *Question 1*, recommended use of resources deviated from convention, though level of severity does not appear to have impacted the extent of deviation. The question was answered by first identifying conventional resource:goal pairings, then tabulating the number of times resources of the various services were associated in RECs

with the goals in each case, as shown in Table 6 (conventional resource:goal pairings are shown in bold). For example, CA resources were associated with goal 2 (there are no conventional goals assigned with alternative resources). Since the number of available resources in the cases was unequal, a test was performed on the null hypothesis that the percentage of observed unconventional resource:goal mappings would be near zero (0.05) in each case (n=16 in C1, n=20 in C2). The percentage is 37.5% in C1 and 35.0% in C2, leading to respective p-values of each less than 0.001. Consistent with expectation, there is evidence of deviation from convention in the use of resources. However, contrary to expectation, there is no evidence of impact of level of severity.

Table 6: Resource:Goal combinations for RECs.

Case	*1*				*2*				
Goal	1	2	3	4	1	2	3	4	5
Role									
CA	0	**2**	2	1	1	0	0	0	**0**
FD	0	**2**	**0**	2	6	**0**	**0**	5	1
MO	0	0	0	**6**	0	0	0	**2**	0
PD	**3**	5	3	3	**16**	0	4	7	2
AR	1	3	0	0	5	0	1	5	1

Linking Cognition and Decision

In answer to *Question 2*, the number of CCAs had no appreciable impact on decision quality as assessed by judges or participants. As shown in Table 5, more CCAs were considered in C2 than in C1. While judges' ratings are higher for C2 than C1, the difference is minimal. The direction of change in participants' ratings is contrary to expectation, though again the values are not appreciably different.

In answer to *Question 3*, effort devoted to solution assembly does not appear to vary with respect to time between the low and high severity conditions. To answer the question, Figures 5 and 6 were compared, and two time series analyses conducted, as follows.

Figures 5 and 6 show the frequency with which CCAs and DECs of various sizes were observed in C1 and C2, respectively, as tallied at 3 minute intervals. For example, in the first interval of C1, each of the six observed CCAs involved 2 resources (no other CCAs were observed, and no decisions were made during that interval). DECs are shown in bold. The mean and 95% confidence interval for the mean number of resources in CCAs are also shown.

Level of effort is measured via the mean number of resources included in CCAs and DECs in each interval, since larger CCAs and DECs are expected to require more processing to assemble than smaller ones.

In C1 (see Figure 5), CCAs were generated through all intervals, with an approximately even split between CCAs with 2 and 3 resources, and some CCAs having 4 resources. There was no evidence of temporal dependency in level of effort, suggesting that—contrary to expectation—effort did not vary systematically over time. Decisions were taken in intervals 8 and 10, and contained 2 to 4 resources. Timing of initial decision was between 21 and 24 minutes, far beyond the point of greatest inflection in Figure 3.

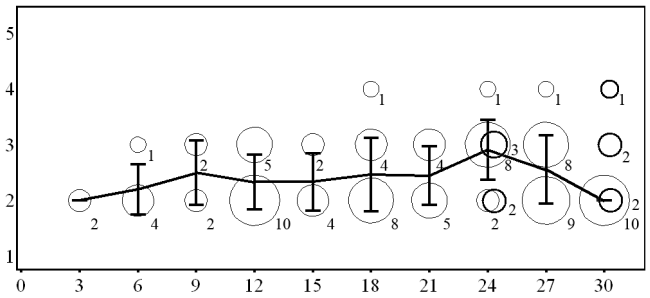

Figure 5: Frequency of occurrence of CCAs and DECs of sizes 2 through 5 in C1

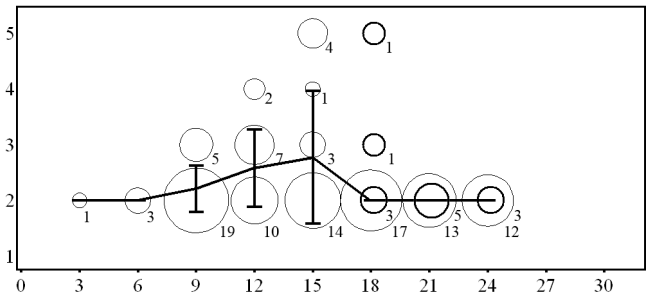

Figure 6:Frequency of occurrence of CCAs and DECs of sizes 2 through 5 in C2

In C2, CCAs were generated in intervals 6 through 8, and included 2 to 5 resources. There was no evidence of temporal dependency in the data, again contrary to expectation. Finally, decisions were taken in intervals 6 through 8, and included 2, or 5 resources. Thus, timing of initial decision under the higher severity condition was at 18 minutes—beyond the point of greatest inflection in Figure 4 but not as far as in C1.

In summary for Question 3, then, level of effort did not vary with time for either case, nor did level of effort increase along with level of severity.

Convergent Processes

In answer to *Question 4*, CCAs explain RECs only in the low severity condition (C1). To answer the question, a logistic regression model was fit to the data, with inclusion of resource in a REC as the dichotomous response variable, and number of times the resource was included in CCAs as the predictor variable. For C1 (n=23 resources), estimated parameter values in the model were significantly non-zero at p<0.10, suggesting that the likelihood of a resource being included in a REC increased with the number of times the

resource was included in CCAs. For C2 (n=27 resources), no estimated parameters values were significant, suggesting that a resource's inclusion in a REC was not affected by the number of times the resource was included in CCAs.

In answer to *Question 5*, the size of CCAs (as reflected in the number of resources used) does not mirror that of decisions. To answer the question, two empirical distributions were compared. The first distribution estimated the probability of i resources being included in a CCA; the other estimating the probability of i resources being included in a DEC (i=1,...,maximum number of resources in a the largest CCA or DEC, whichever was greater). An exact χ^2 goodness-of-fit test (Conover, 1999) was performed for each case, using a data table that represented the frequency with which a i resources were found in CCAs and DECs ($d.f.$=2 in C1 and 3 in C2). For example, in C2, four CCAs and one DEC contained five resources (see Figure 6, below). The null hypothesis of no association between rows and columns was retained for both cases, suggesting that the number of resources found in a CCA was independent of the number of resources found in a DEC. Knowing the size of CCAs therefore provides no indication about the size of actual decisions.

Discussion

The results of this study enable an exploration of the relationship between divergent and convergent thinking processes in group decision making by an emergency response organization. Level of severity did not have an impact on the extent of divergent thinking by the group, as indicated by the breadth of group members' thinking of how available resources might be used to achieve response goals.

In considering the link between cognition and decision, it is worth emphasizing the order of magnitude difference between options (i.e., CCAs) considered and decisions taken. In this light, it is perhaps not surprising that decision quality did not increase with number of CCAs, suggesting that further work is needed in investigating how CCAs are transformed into decisions. Time itself provided no explanation for cognition and decision patterns. Alternative approaches to explaining the link between cognition and decision should therefore be pursued.

Finally, with respect to convergent thinking, CCAs explained individual recommendations only under the lower severity condition. Moreover, the number of resources included in a candidate course of action did not mirror the number of resources in decision.

Conclusions

Decision making in emergency response is characterized by severity and time pressure, and a concomitant need to organize multidisciplinary groups to address highly non-routine situations. This study suggests that level of event severity had little appreciable effect on divergent and convergent thinking processes in one group's response to two non-routine simulated emergencies. Moreover, groups maintained a similar level of effort even as feasible courses of action were diminishing rapidly.

The results have offered some insights into the group processes that follow establishment of an ERO, but also into broader questions of the progress of creative decision making in groups. Future work in this area may benefit from the use of a wider range of levels of severity, particularly to uncover the impact of this factor on the timing of decisions.

Acknowledgments

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