Assessing command and control teams' performance and agility

Per Wikberg
Swedish Defence Research Agency, FOI
wikberg@fo.se

Dennis Andersson
Swedish Defence Research Agency, FOI
dennis.andersson@foi.se

Björn Johansson
Swedish Defence Research Agency, FOI
bjorn.j.e.johansson@foi.se

ABSTRACT

Crisis response organizations and military units must be agile and able to adapt to dynamic situations. The ability to adapt includes command and control agility, organizational adaptability and individual adaptability. An exploratory study of these adaptability traits were undertaken during a naval exercise. The exercise scenario was designed to progressively become more challenging, suggesting decreased performance and adaptability over time. The study objectives were to develop a data collection approach for adaptability traits and to investigate association between these traits and performance. Data collected from four command teams were evaluated in terms of response rate and item variation. Principal component analysis was used to explore latent structures and relationships. The results indicate acceptable survey response rates and trends showing a decrease in organizational adaptability and C2 agility over time while individual adaptability increased. The analysis also identified five partially independent components in the latent structure.

Keywords

Command and control, Agility, Adaptability, Performance assessment

INTRODUCTION

In routine emergency management such as traffic accidents responders are usually well acquainted with most responding agencies' standard operating procedures. Coordination is almost implicit and need for collaboration low (Berlin & Carlström, 2008). However, coordination is much more complicated in unexpected crises or major disasters such as Hurricane Katrina (Koliba, Mills, & Zia, 2011). Such crisis response operations are characterized by surprise, uncertainty and a need for collaboration and improvisation among entities in order to coordinate actions in time and space (Curnin & Owen, 2013; Curnin, Owen, Paton, Trist, & Parsons, 2015). The theory of command and control (C2) agility predicts that organizations who can adapt their way of exercising C2 in dynamic situations stand a better chance to handle the variation associated with such crises and disasters (NATO STO SAS-085, 2014).

This paper presents findings from an exploratory study of adaptability and agility during a Swedish naval exercise in 2016. The study is part of a research program with the aim of developing and adapting approaches to assess future naval operational Command and Control (C2) capability, including identification of relevant measurable factors reflecting maritime adaptability as well as finding valid and reliable methods for collecting data with respect to personal integrity, workload, security policy and other practical restrictions. In a series of naval exercises, different methodological approaches have been successively explored and developed (Wikberg, Johansson, and Andersson, 2016).

The objectives of this study are 1) to identify opportunities and challenges in data collection from command team members for adaptability assessment in a maritime operations setting, and 2) to gain understanding of how to assess command teams' performance by investigating how different adaptability traits are associated with performance. These research objectives have been studies specifically in the context of the Swedish navy, for which a particular challenge is that of obtaining repeated measures from command teams during distributed

operations since their work environment is too confined to allow the use of dedicated observers for on-site data collection while at the same time the communication environment only allows for limited non-mission-critical communication.

Command and control in the Swedish Navy

Swedish naval C2 are based on the principle of *mission command* (Försvarsmakten, 2016). Mission command is the principle in which details about how to solve a task are decided by the commander responsible for the execution (U.S. Army, 2012). Consequently, commanders in the Swedish navy give orders in terms of goals and assign resources, allowing subordinate commanders to autonomously decide how to fulfil the superior commander's intent.

During operations the Swedish Navy implements mission tailored *task organizations* (TaO) which are separate from the regular peace time *type organization* (TyO) with flotillas and regiments. The TaO consists of up to four organizational levels (Försvarsmakten, 2010):

- *Task Element* (TE). A TE consists of a vessel and/or unit.
- *Task Unit* (TU). A TU is a set of TEs and designed to solve designated tasks within the task groups overall mission.
- *Task Group* (TG). A TG is a set of TEs and TUs designated to solve a maritime operational task.
- *Task Force* (TF). A TF is the command normally executed at the highest navy command level, the *Maritime Command Component* (MCC). The TF can for example be a combination of TGs from the fleet, amphibious units, helicopter units and logistics.

Adaptability and agility

Adaptability can be viewed as the ability of a system to change - which is also sometimes referred to as agility (Hoffman and Hancock, 2017; Alberts and Hayes, 2003). This broad definition covers aspects such as changing processes, culture, equipment, tactics, leadership etc. The scope of the research program is assessment of C2 adaptability and the focus of this explorative study is performance and agility among Swedish navy command teams. Successful C2 agility connects and orchestrates organizational units and capabilities during adverse events, allowing for organizational adaptability. As humans are a main source for adaptability, we can also approach C2 agility and organizational adaptability from the individual point of view. By assessing the traits of C2 agility, organizational adaptability and individual adaptability, a holistic evaluation can be made.

C2 agility – approach to coordinate actions

C2 in military organizations has been studied from an agility perspective, defining agility as *"the capability to successfully effect, cope with and/or exploit changes in circumstances"* (NATO STO SAS-085, 2014). An assumption is that no single C2 approach is perfect for all kinds of situations. Instead, each type of mission corresponds to an optimal C2 approach, organizations, or collectives of organizations, who encounter a broad range of mission types must maintain a level of flexibility to adapt their C2 approach, i.e. maintain an adequate level of C2 Agility (Johansson, Wikberg, and Andersson, 2016; NATO STO SAS-085, 2014; Vassiliou Alberts, and Agre, 2014).

A conceptual tool for describing C2 agility is the *C2 approach space* (NATO STO SAS-065, 2010), a three axis model presenting the C2 approach in terms of *distribution of information*, *allocation of decision rights* and *patterns of interaction*. The appropriateness of a C2 approach can be evaluated in the light of the situation and problem in which it is applied – *the C2 problem space* (Alberts and Hayes, 2006). Sometimes each involved entity might act separately, with required coordination handled at the top command level (referred to as *de-conflicted C2*). More complex and unpredictable situations may require entities to collaborate on multiple levels concurrently (referred to as *collaborative* or *edge C2*). The ability to recognize the need to change C2 approach and to perform the change is what constitutes the C2 agility (NATO SAS-08, 2014). Consequently, agile C2 systems are expected to be projected onto different locations in the C2 approach space as the situation changes.

Organizational adaptability – detect and manage unexpected events

Improvisation theory state that organizational improvisation is "an adaptive response to unexpected or unanticipated situations that are outside the boundaries of what an organization has prepared for" (Trotter et al., 2013, p. 476). An organizations ability to adapt and respond to an unexpected crisis depends on number of

factors such as *capabilities*, unique skills that an organization performs, *capacity*, how many resources or trained personnel an agency has and *proficiency*, how well an organization performs each task (Pfeifer, 2005). An organizational unit, cut off from communication with higher command or other functions for coordination, can still adapt successfully to a situation if it is capable, proficient and has enough capacities. Consequently, an organizations ability to change concerns more than C2 agility.

Two organizational abilities are critical in order for an organization to change successfully to the demands of a situation. *Ability to detect abnormal events*, concerns the ability to predict, monitor, and understand changes in the environment. This is a prerequisite to response as the system must have the ability to predict or detect deviations and threats to make conscious decisions on countermeasures. *Ability to deal with abnormal events*, concerns the ability to cope with deviations when they occur and the ability to withstand damage and use resources in a flexible manner (Johansson et al., 2016). Presumably, these abilities varies over time and between different situations.

Individual adaptability – requirements on the role

In contrast to the C2 and organizational view on adaptability, a different perspective is based on the assumption that different types of situations require different forms of adaptive behavior by the individuals. Pulakos, Arad, Donovan, & Plamondon (2000) defined adaptability as involving *creative problem solving*, *coping with uncertainty*, *learning new tasks and skills*, *adapting to teamwork and collaboration*, *changing and developing new procedures*, and *adapting across cultures*. The definition is based on analyses of workplace challenges and suggestive for a method for job analysis. Consequently, the role for the individual in an organization may require different types of individual adaptability skills. Hart and Oprins (2015) have taken this notion one step further and outlined an approach aiming at an instrument to measure the adaptive behaviors in relation to organizational requirements, and individual preferences. According to the theory, the organization's performance can thus be increased by successfully matching individuals' adaptability profiles with role adaptability profiles. One could expect that these requirement varies over time during a crisis response operation.

METHOD

The study was undertaken as an exploratory case study during the last 5 days of the 10 day SWENEX 16 exercise. The study was planned in conjunction with the Navy's exercise planning, in close collaboration with the exercise evaluation cell (EXEVAL).

Scenario

SWENEX 16 was a live exercise that took place between November 14 and 23, 2016, in the Baltic Sea north-west of Gotland (Figure 1).

Figure 1. Area of exercise for SWENEX 2016.

Around 2,000 individuals, 20 large vessels and several small assault and patrol crafts were engaged in the exercise. In addition, helicopters and jetfighters from the helicopter flotilla and the Airforce participated. The naval WaO consisted of one TF organized into five TGs: Surface TG, Submarine TG, Amphibious TG, Helicopter TG and Logistics TG. The TF was commanded by the Maritime Command Component (MCC) at the Armed Forces Headquarters. The Navy's exercise objectives included training of naval command and control, and coordination and cooperation with other maritime actors.

The exercise scenario background was a tense security situation. For the major part of the exercise the Navy prepared and executed a maritime security operation in a context were a foreign power acted to limit Sweden's

military engagement in the area. During the exercise, the situation deteriorated and hostility escalated. Due to the increased tension and some incidents, the Task Force gave orders on Monday November 21 to the TG:s to change the operation into coastal defense. On Tuesday 22 the situation turned into open conflict and vessels were sunk on both sides. The opponents primary goal was however not to invade Sweden. Instead main actions were directed towards a third country. Political negotiations made it possible to reach a cease fire agreement on Wednesday 23.

Design

The study was designed as an exploratory case study.

The first objective, *to identify opportunities and challenges in data collection from command team members for adaptability assessment in a maritime operations setting*, was realized by testing a survey for periodic response by selected staff members in different TGs. The survey included 19 items related to the adaptability traits and two performance items. The feasibility of the survey was evaluated through response rate analysis and how items varied over days. The second objective, *to gain understanding of how to assess command teams' performance by investigating how different adaptability traits are associated with performance*, was realized through a principal component analysis (PCA) of survey data using a rotated solution in order to analyze whether there were any latent structures and relationships between the adaptability traits and performance.

Participants

Four of the five TG staffs participated in the data collection: surface (SuTG), logistics (LogTG), amphibious (AmphTG) and helicopter (HeliTG). These staffs were represented by appointed representatives from five different staff functions. Table 1 below shows the roles in each staff planned to provide data. Each row in the table denotes one TG staff, with the corresponding role prefix letter in parenthesis. The columns represent staff commander (Cmdr.), chief of staff (COS), and staff functions with the staff number in parenthesis[1]: intelligence/security (2), operations (3), logistics (4), plans (5) and communications/signals/IT (6). The roles in the table marked with an x are those that were tasked to contribute to the data collection. SuTG N3 and N5 are marked with / to denote that the staff functions for planning and operations in SuTG were merged during the exercise, and consequently these have been treated as one role in the analysis. Further, AmphTG S3 has been marked L1-3 to highlight that this role was represented in three different command posts L1, L2 and L3 and consequently corresponds to three roles. Consequently, 21 roles were expected to provide data. As the exercise was a 24/7 live exercise lasting several days, each role could be manned by different individuals in some of the TGs. However, no comparison was done on the individual level. Consequently, only role and TG were registered as identifiers in the survey.

Table 1. TG staff roles. Each role marked x was included in the data collection. Roles marked with / were merged and manned by the same individuals and consequently included and represented as one data point. AmphTG S3 existed as three command posts, each representing one intended point for data collection.

	Role						
TG staff	Cmdr.	COS	Intel. (2)	Ops. (3)	Log. (4)	Plan. (5)	Comms. (6)
SuTG (N)		x	x	/		/	x
LogTG (N)		x	x	x	x	x	x
AmphTG (S)	x	x	x	L1-3	x		x
HeliTG (A)	x				x	x	

Data collection

The survey together with instructions was distributed as part of the Navy's exercise plan. The exercise management organization at each TG then secured distribution to participants. Responses were collected from the roles identified in Table 1 at the end of each watch during the period from the evening of November 18 until the morning of November 23, 2016. In each response to the survey, the participants were asked to assess the situation during the completed watch. A digital file with the response was be submitted to the EXEVAL upon

[1] according to the continental staff system, also known as the great general staff system, see: https://en.wikipedia.org/wiki/Staff_(military)

completion and subsequently handed over to the analyst.

The questions were clustered into five themes, two for organizational adaptability (OA), one for C2 approach agility (C2A), one for individual adaptability (IA), and one for perceived performance. All questions were to be answered in a 7-degree Likert scale anchored at "1: not at all" and "7: to a very high degree" unless otherwise noted. The questions are listed together with each theme below.

Organizational ability to detect deviating events

The first set of survey questions refers to organizational adaptability and how much potential there is for the system to detect and understand a deviating event and to disseminate this information within their own system. These questions were based on a proposed tool for measuring C2 agility and resilience in socio-technical systems (Johansson et al., 2016).

Q1 To what extent have you had access to information about current threats?

Q2 To what extent have you had access to information about own (TF, TG) situation?

Q3 To what extent have you been able to disseminate important information on events related to current threats?

Organizational ability to deal with deviating events

Survey questions Q4-Q8 refer to the ability to cope with deviating events, including proactive measures proactive preparations and flexibility to allow system reconfiguration to better handle unanticipated deviating events. As for the previous set, these questions were based on Johansson et al.'s tool (2016).

Q4 To what extent have you been able to handle/resolve important events concerning current threats?

Q5 To what extent have you had different alternatives for handling important events?

Q6 To what extent have you been able to deviate from normal procedures/SOPs?

Q7 To what extent do you feel that there have been preparations to meet unexpected events?

Q8 To what extent do you feel that there is redundancy in your function?

C2 approach agility

The third cluster of survey questions refers to the ability of the system to maintain command functions within the frames of the designated mission space (NATO STO SAS-085, 2014). The items in this theme correspond to changes along the dimensions on which the C2 approach space is described in C2 agility theory: 1) ability to allocate decision rights, 2) ability to distribute information, and 3) ability to interact.

Q9 To what extent do you think the decision mandate has been allocated appropriately within your TG?

Q10 To what extent do you think that relevant information is distributed within your TG?

Q11 To what extent do you feel that it has been possible to coordinate within your TG?

Q12 To what extent do you feel that it has been possible to coordinate with units external to your TG?

Individual adaptability

The survey questions on individual adaptability refer to the characteristics of the working conditions defining which adaptable behaviors are required by individuals for their assigned work roles, based on the taxonomy of individual adaptability behaviors (Hart and Oprins, 2015). No item regarding adaption across cultures were included as the study only included Swedish naval officers.

Q13 To what extent has your work situation been characterized by coordination/collaboration with others?

Q14 To what extent has your work situation demanded crisis management?

Q15 To what extent has your work situation demanded creative problem solving?

Q16 To what extent has your work situation been characterized by uncertain and unpredictable situations?

Q17 To what extent has your work situation been characterized by the need to learn new equipment, systems or procedures?

Q18 To what extent has your work situation been characterized by high physical workload?

Q19 To what extent has your work situation been characterized by stress?

Perceived performance

To complement the questions on C2 approach agility and individual and organizational adaptability, the rating section of survey concluded with two questions on perceived performance, one regarding the respondent's own staff function in the context of the TG which the staff belongs to, and the other regarding the TG as a whole. These questions were answered on a 7-degree Likert scale anchored at "1: not at all" and "7: very well".

Q20 How well do you think your function has been able to perform?

Q21 How well do you think that your TG has been able to perform?

Analysis methods

All survey questions were worded in a way that high values indicated high levels of adaptability or performance, except those on individual adaptability which rated working conditions that are assumed to reduce adaptability and performance. The scale for these items was therefore reversed in order to homogenize the dataset so that indicated high values correspond to high adaptability/performance.

Response rate analysis

The survey data was scheduled for transmission to EXEVAL after the completion of a watch, once the duties of that role had been handed over to the next watch. This means that each role were planned to submit two data samples per day, except for the first and last day of the duration of the data collection period, given the assumption that there were two watches per role and day. In total each role thus constituted 10 data collection points, which with 21 roles means that the maximum number of responses would correspond to 210 samples. The response rate would then be calculated as the ratio between the number of actual responses and the maximum number of responses.

Exploratory response profile analysis

For the variance analysis of adaptability survey items, the mean value of collected responses per survey item per day was calculated. Each survey item was then categorized according to how the mean responses changed between days. Four different profiles were used for the categorization: flat, decreasing, increasing and varying (Figure 2). The classification of items were based on how much they deviated each day from their own total mean (M). The cluster of items with the relatively lowest daily deviation from their own total mean (M) were classified as *flat*, with the threshold for this variation selected after initial variance analysis of the dataset. The rest of the items were classified as *decreasing* if $M_{n+1} \leq M_n$, *increasing* if $M_{n+1} \geq M_n$, and *varying* in all other cases. The varying items were thereafter further classified depending on the number of local optima between the endpoints and their character. Variations with one local optimum were classified as *vary/hat* or *vary/dip* depending on whether the optimum was a maximum or a minimum. Items with two local optima were classified as *vary/increasing* or *vary/decreasing* depending on whether the initial and final derivatives were positive or negative. Items with more than two optima were manually inspected for approximate fit with other profiles, alternatively classified as *vary/wave* or *random*. Finally, all calculated profiles were manually inspected and reclassified where the coarse classifications were deemed too rough or slightly off-target.

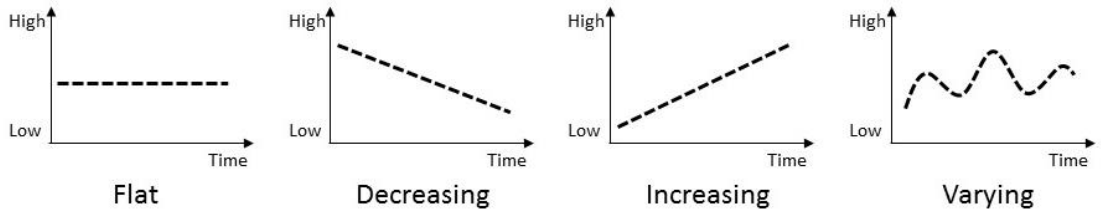

Figure 2. Each survey item was categorized into one of four moving mean profiles, based on the collected survey responses.

Principal component analysis

The 21 Likert scale questions from the survey were run through a PCA in order to analyze whether the manifest variables could be reduced to a set of fewer latent components. Initially, the Kaiser–Meyer–Olkin measure of sampling adequacy (KMO) (Kaiser, 1960) was calculated, with successive removal of variables with low measures of sampling adequacy (less than .50) until the KMO was considered good, i.e. above .70 (Sofroniou & Hutcheson, 1999). Further confirmation of the factorability was gained through Bartlett's test of sphericity (Bartlett, 1937).

The factor extraction for the PCA used oblique rotation (direct oblimin method) and the Kaiser criterion to determine a baseline for the number of generated components, i.e. retaining components with eigenvalues greater than 1 (Kaiser, 1960). The number of components was thereafter validated against a scree plot to confirm whether the number should be increased or decreased.

Potential links between the latent components were analyzed by using the component correlation matrix. Once identified, the final set of components were named based on the interpretation of the corresponding manifest variables. The latent components were then analyzed by content in order to estimate whether they should be divided into subcomponents.

RESULTS

The results in this section are presented, grouped per analysis method: response rate analysis, response profile analysis and factor analysis.

Response rate analysis

One of the four TGs were unable to respond to the periodic surveys due to force majeure. Data were obtained from each of the remaining three TGs, as detailed in Table 2 below. The actual activity during nights was lower than anticipated which resulted in responses once per day instead of the initially expected two. In addition, no responses were obtained for the last day, the 23th, due to a somewhat earlier completion of the scenario than expected. Consequently, data was obtained once a day for five days, with 13 responding roles instead of 21. A complete dataset thus corresponds to 65 responses instead of the originally planned 210. In total 46 responses were obtained, corresponding to a total response rate of 22% of the initially sought set of responses and 71% of the actually obtainable dataset given the operational circumstances. A large portion of the missing data stems from LogTG who were unable to respond to the survey on the 22th. All obtained responses came with complete answers on all questions except for one questionnaire which had omitted Q21. This single missing value was imputed with the mean value for the item since removing the entire response would undisputedly have negatively affected the dataset more.

Table 2. Number of responses per day and TG, followed by response rate based on the maximum obtainable sample rate adjusted after operational circumstances.

	18	**19**	**20**	**21**	**22**
SuTG (4)	4	4	4	4	4
HeliTG (3)	3	1	2	3	2
LogTG (6)	4	4	4	3	0
n (N=21)	*11*	*9*	*10*	*10*	*6*
Response rate	*85%*	*69%*	*77%*	*77%*	*46%*

Exploratory response profile analysis

A daily mean was established for each survey item Q1-Q21. The response profile analysis was conducted on data from all five days, despite the drop in response rate for day 5. Because of this difference in N, a complementary analysis was conducted on the SuTG alone, since this TG was the only to achieve a perfect response rate for all sample occasions. This complementary analysis was used to clarify whether any notable effects on the last day pertain from actual differences in work situation or if they are more likely to depend on sampling. The left portion of Table 3 displays the average of daily means (M), average standard deviation (SD), maximum negative deviation of daily means from average mean (Dev_-), maximum positive deviation of daily means from average mean (Dev_+), and finally the profile classification for the total dataset. The right portion of the table displays the same statistics for the dataset corresponding to SuTG only. The far right column displays an overall profile classification based on the two preceding analyses. The Dev_- and Dev_+ values are expressed in

portion of the total average SD (1.373 and 1.393 respectively).

Table 3. Overview of categories of response profile for the different survey items. The left portion corresponds to the dataset including all TGs, while the right portion concerns only SuTG for which a perfect response rate was obtained. Each set is summarized with a detailed profile classification of the answers. The right-most column corresponds to a more generic profile classification based (flat, decreasing, increasing and indeterminate).

		All TGs					SuTG only					Profile class
		M	SD	Dev_-	Dev_+	Profile	M	SD	Dev_-	Dev_+	Profile	
Org adaptability	Q1	4.98	1.329	-83.5%	34.6%	Vary/Decr	4.75	1.297	-89.7%	89.7%	Decr	Decr
	Q2	5.01	1.241	-110.1%	38.9%	Vary/Decr	4.60	1.369	-114.8%	64.6%	Decr	Decr
	Q3	4.36	1.877	-26.2%	17.5%	Flat	4.30	1.598	-75.4%	50.2%	Vary/Hat	-
	Q4	4.36	1.518	-38.2%	24.9%	Vary/Decr	4.90	1.435	-82.5%	43.1%	Vary/Decr	Decr
	Q5	4.50	1.258	-73.1%	28.1%	Vary/Hat	4.45	1.409	-68.2%	57.4%	Vary/Hat	Decr
	Q6	4.70	1.360	-51.1%	21.7%	Vary/Hat	4.85	.718	-78.9%	28.7%	Vary/Hat	Decr
	Q7	4.43	1.084	-23.4%	41.4%	Vary/Decr	4.65	1.141	-46.7%	43.1%	Vary/Decr	Decr
	Q8	4.39	1.933	-40.6%	22.5%	Vary/Hat	4.30	2.140	-39.5%	32.3%	Decr	Decr
C2 agility	Q9	4.94	1.069	-11.7%	17.7%	Flat	5.05	1.168	-21.5%	14.4%	Flat	Flat
	Q10	4.52	1.055	-37.6%	21.9%	Vary/Decr	3.90	1.041	-28.7%	25.1%	Flat	-
	Q11	5.25	1.105	-79.2%	30.1%	Vary/Decr*	4.75	1.038	-89.7%	35.9%	Vary/Decr	Decr
	Q12	4.61	1.553	-93.2%	36.3%	Vary/Hat	4.45	1.777	-68.2%	75.4%	Decr	Decr
Ind adaptability	Q13	2.65	1.323	-32.8%	86.2%	Vary/Incr	3.30	1.600	-39.5%	68.2%	Incr	Incr
	Q14	5.67	1.551	-57.1%	43.7%	Vary/Dip	5.60	1.529	-61.0%	28.7%	Vary/Dip	Incr
	Q15	2.91	1.463	-33.6%	55.4%	Vary/Dip	3.50	1.640	-71.8%	71.8%	Vary/Dip	Incr
	Q16	3.09	1.448	-21.2%	29.8%	Flat	3.35	1.898	-43.1%	46.7%	Vary/Decr	-
	Q17	4.22	1.755	-23.1%	44.9%	Vary/Incr	5.45	1.380	-32.3%	39.5%	Vary/Incr	Incr
	Q18	5.77	1.167	-19.9%	23.1%	Flat	6.20	.790	-68.2%	39.5%	Vary/Decr	-
	Q19	4.33	1.702	-56.0%	73.4%	Vary/Dip	5.00	2.031	-71.8%	35.9%	Vary/Dip	Incr
Perf	Q20	5.46	.944	-33.8%	14.7%	Vary/Hat	5.35	.895	-43.1%	28.7%	Decr	Decr
	Q21	5.36	1.099	-13.9%	10.4%	Flat	5.20	1.365	-14.4%	21.5%	Flat	Flat
	Avg	5.36	1.373				4.66	1.393				

Four adaptability trait items and one performance stood out as a cluster with a relatively lower deviation from their own total mean. None of these had max and min deviation in relation to the total standard deviation above 30%, hence this was selected as the threshold for flat response profile. Items above 30% were thereafter classified according to the predefined profile schema. All items in the full dataset had one or two local optima, except Q11 which had three local optima, although its first local maximum (the day 2 mean value) is only marginally higher than the day 1 mean value, and is consequently not treated as an optimum. The item, marked with an asterisk in Table 3, has thus been reclassified as if it had two optima, e.g. vary/decreasing in the AllTG dataset. The same analysis was conducted on the SuTG dataset, which identified one survey item as *increasing*, i.e. Q13 relating to collaboration. The *decreasing* profile corresponds to five items in the SuTG dataset, all relating to the ability to exercise C2 and the ability to handle abnormal events. This confirmatory profile classification on the SuTG dataset was consistent with the full dataset on most items, confirming trends on a more generic scale as either Increasing (both ratings are *Incr*, *Vary/Incr* or *Vary/Dip*), Decreasing (both ratings are *Decr*, *Vary/Decr* or *Vary/Hat*), Flat or Indeterminate (-). Figure 3-5 illustrates the varying profiles for the AllTG profiles.

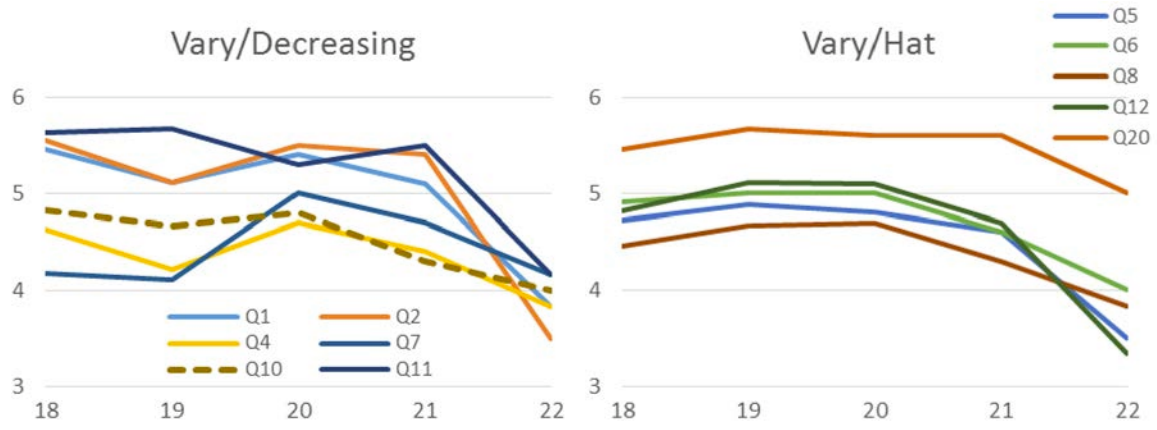

Figure 3. Profile graphs for survey items from the AllTG dataset that decrease towards the end of the exercise. Solid lines have been classified as *decreasing*, while dashed lines are classified as *indeterminate* due to mismatch with the SuTG dataset.

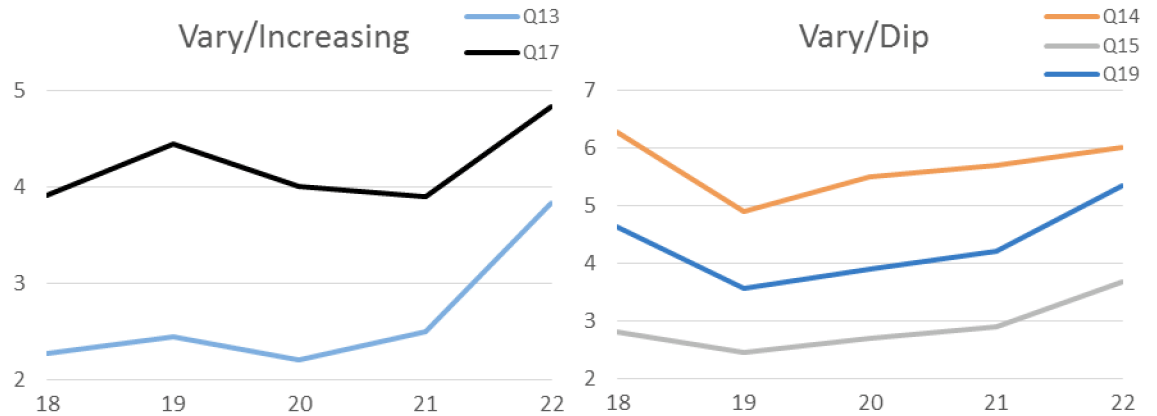

Figure 4. Profile graphs for survey items from the AllTG dataset that increase towards the end of the exercise. Solid lines have been classified as *increasing*.

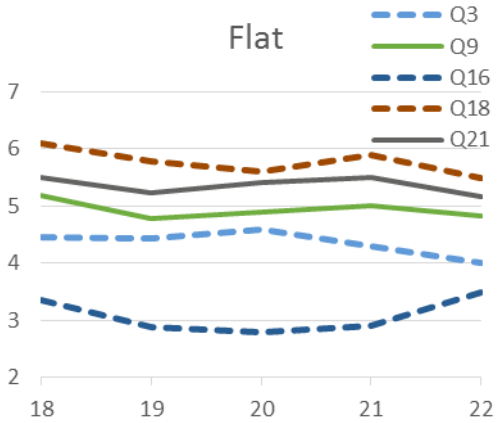

Figure 5. Flat profile graphs for survey items from the AllTG dataset that are relatively stable throughout the exercise. Solid lines have been classified as *flat*, while dashed lines are classified as *indeterminate* due to mismatch with the SuTG dataset.

As seen in Table 3 and Figures 3-5, ten survey items relating to C2 agility and organizational adaptability were classified as decreasing, two were indeterminate and two flat. One additional decreasing survey item, Q20, corresponds to individual performance, and likewise Q21 pertaining to TG performance was categorized as flat. Five out of the seven individual adaptability items instead display a positive trend, increasing towards the end of the exercise. The other two survey items in this category were indeterminate. Finally, many items has a distinct change between November 21 and November 22 corresponding to when the operation changed to coastal

defense.

Figure 6 illustrates distribution of response profiles for each survey item in terms of deviation from the mean SD plotted against average daily SD. Through this chart it can be seen that Q9 and Q21 have low variance and high homogeneity among the responses, implying that there is indeed little change between the days in how the respondents answer these questions. Question 3 on the other hand shows a high daily average SD, implying a lack of agreement among the respondents. Since the flat profile is based on mean calculations, this could be a result of opposing changes that neglect each other in the mean analysis. The same type of analysis show that the indeterminate response profiles (Q10, Q16 and Q18) are fairly homogeneous, making them interesting for further analysis.

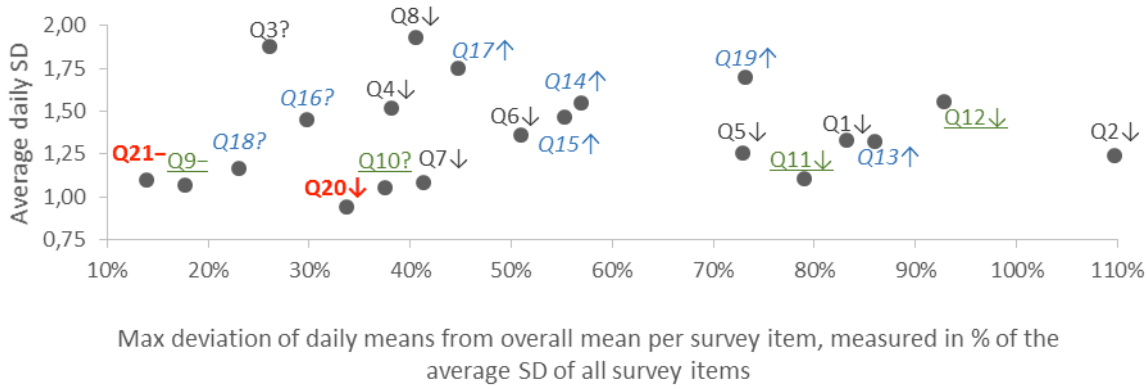

Figure 6. The maximum deviation of the daily mean from the total mean, for each survey item, plotted against the average of their daily mean standard deviations. Gray items relate to C2 agility, underlined green to organizational adaptability, italic blue to individual adaptability and bold red to performance. Each point has been labelled with their survey item number, suffixed by arrows representing whether their response profiles have been categorized as increasing (↑), decreasing (↓), flat (-) or indeterminate (?).

Q9 and Q21 have been confirmed to be stable. Figure 7 displays a plot of each individual's responses to Q9 for each day, juxtaposed with Q21. There is undoubtedly some variation among the answers, yet the responses are considered stable enough to retain the original estimation of their response profiles as flat.

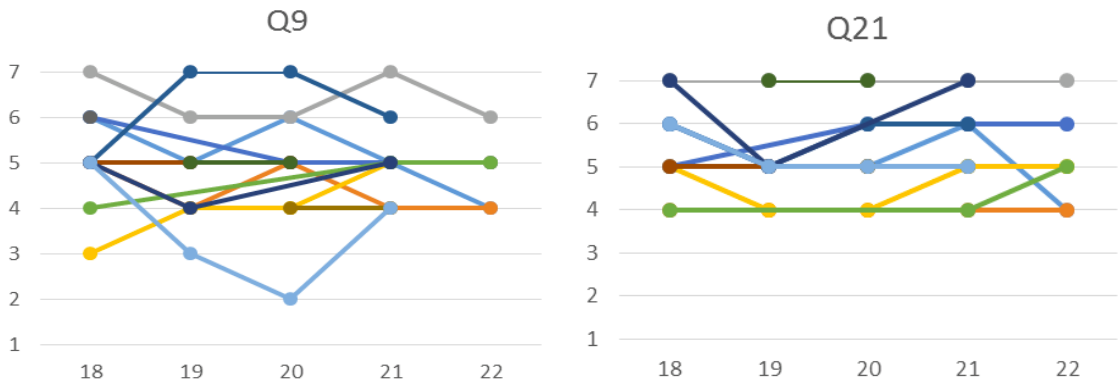

Figure 7. The daily responses for each respondent to Q9, juxtaposed with Q21.

In a similar manner as the flat profiles were analyzed more carefully, the items previously rated as indeterminate are displayed in Figure 8. Arguably Q18 could be seen as fairly stable up until the final day, during which those that did respond have lowered their assessments, thus the profile seems to be decreasing. Q18 is therefore changed to decreasing. Q3, Q10 and Q16 are all fairly stable among some of the respondents, although not necessarily in agreement. Since a few respondents have are spread their answers across the whole spectrum with opposite trends, while others have remained consistent in their ratings, the final verdict remains indeterminate for Q3, Q10 and Q16.

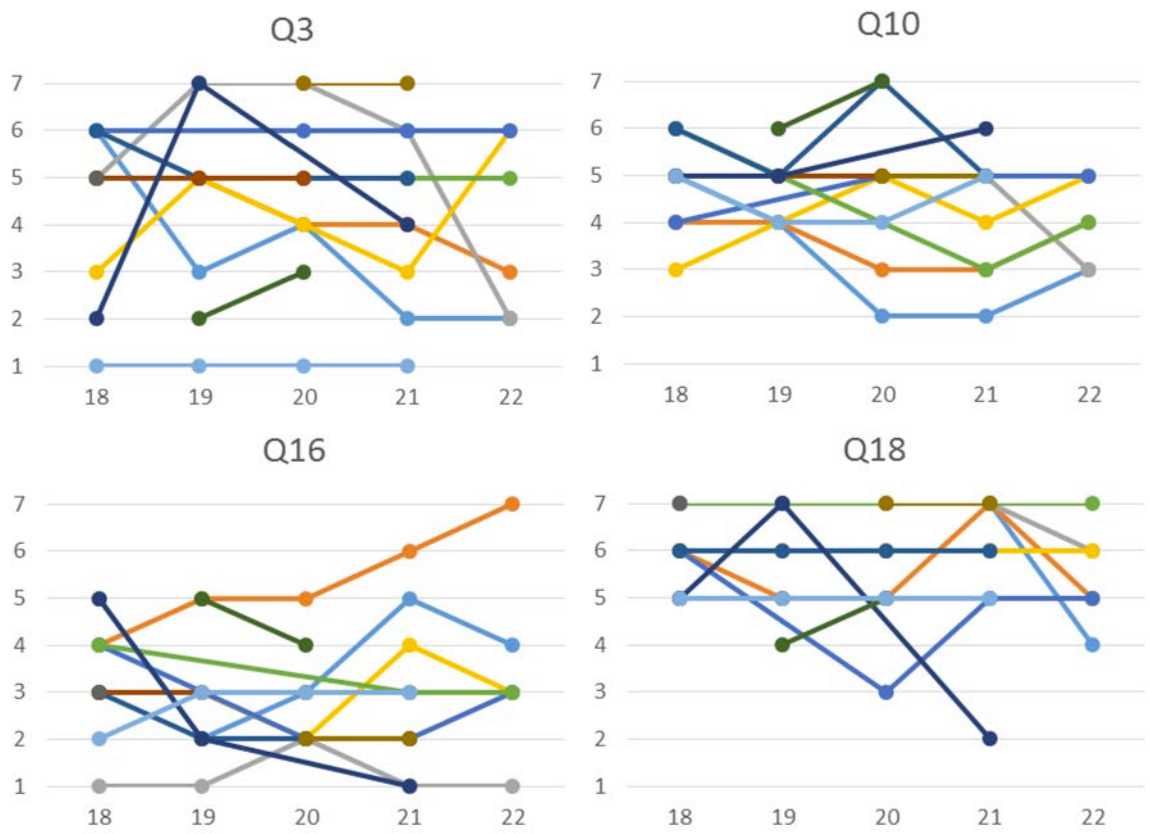

Figure 8. The daily responses for each respondent to questions rated as indeterminate (Q3, Q10, Q16 and Q18).

After alteration of the response profile for Q18, the distribution of response profiles per trait becomes as shown in Table 4. Individual adaptability is almost exclusively increasing towards the end of the exercise, whereas organizational adaptability is dominating the decreasing category.

Table 4. Final distribution of trait per response profile type.

	Response profile			
Trait	**Decreasing**	**Increasing**	**Flat**	**Indeterminate**
Organizational adaptability	Q1, Q2, Q4, Q5, Q6, Q7, Q8	-	-	Q3
Individual adaptability	Q18	Q13, Q14, Q15, Q17, Q19	-	Q16
C2 approach agility	Q11, Q12	-	Q9	Q10
Performance	Q20	-	Q21	-

Principal component analysis

The measures of sampling adequacy was initially investigated through the anti-image correlation matrix diagonals to detect the factorability of the survey items. The items *Q6*, *Q14* and *Q18* MSA less than the acceptable limit .5 and were thus excluded from the PCA. After exclusion of these items, the obtained Kaiser-Meier-Olkin measure of sampling adequacy (KMO) was .73, which was considered acceptable. Bartlett's test of sphericity χ^2 (153) = 520.49, p< .001, indicated correlations sufficiently large for principal component (PC) extraction. Five principal components with eigenvalues >1 (Kaiser's criterion) were generated which together explained 75.49 % of the variance in the data. An additional scree plot investigation showed inflexion at five components, confirming the choice of five components in the final model. The screened pattern matrix from the PCA is illustrated in Table 5, with cutoff set to .38 (roughly corresponding to 15% of the overlapping variance), suppressing any loadings below this threshold.

Table 5. The pattern matrix from the PCA with loadings weaker than .38 suppressed.

	Component				
Survey item	**1**	**2**	**3**	**4**	**5**
Q12. C2A: Possible to interact with external entities	.845				
Q20. Performance of function	.786				
Q21. Performance of TG	.751				
Q8. OA: Redundancy in function	.687	.505			
Q1. OA: Access to information about threat level	.667		.394		
Q2. OA: Access information about own situation	.557		.488		
Q15. IA: Creative problem solving	-.430				
Q19. IA: Stress		.796			
Q5. OA: Options to handle important events		-.614			
Q3. OA: Able to disseminate threat information			.968		
Q4. OA: Able to handle important events			.733		
Q7. OA: Preparations to meet unexpected events				-.837	
Q9. C2A: Allocation of decision rights				-.621	
Q17. IA: Necessary to learn new systems					.927
Q11. C2A: Possible to interact within TG					-.717
Q10. C2A: Distribution of relevant information	.462				-.494
Q13. IA: Collaboration with others	-.468				.472
Q16. IA: Uncertainty and unpredictable situations					.390
Total variance explained by component	37.56%	12.18%	10.86%	9.16%	5.72%
Accumulated variance explained by components		49.74%	60.62%	69.78%	75.49%

The component correlation matrix (Table 6) shows that all component pairs have none ($|r| < .15$), weak ($.15 \leq |r| < .30$) or low ($.30 \leq |r| < .50$) correlation. All pairs including component 4 fall into the no correlation category ($|r| < .15$). By contrast, the strongest component (1) has a low correlation with component 5 and weak correlation with component 3. Thus, the extracted components are fairly independent from each other.

Table 6. The component correlation matrix from the PCA.

Component	2	3	4	5
1	-.110	.231	-.137	-.381
2		-.159	-.011	.224
3			-.089	-.117
4				.122

The principal components have been listed again in Table 7, with assigned labels and a proposed division into sub-components that can help further explain their contents.

Table 7. The principal components of adaptability as measured, labelled and split into subcomponents.

#	Label	Sub-component	Content
1	C2 structure and performance	1.1. C2 interaction	Q12. C2A: Possible to interact with external units
			Q10. C2A: Distribution of relevant information
		1.2. Situation assessment	Q1. OA: Access to information about threat level
			Q2. OA: Access information about own situation
		1.3. Role importance	Q15. IA: Creative problem solving
			Q13. IA: Collaboration with others
			Q8. OA: Redundancy in function
		1.4. Performance	Q20. Performance of function
			Q21. Performance of TG
2	Mental workload	2.1. Individual stress	Q19. IA: Stress
		2.2. Organizational resilience	Q5. OA: Options to handle important events
			Q8. OA: Redundancy in function
3	Management of deviating events	3.1. Information management	Q3. OA: Able to disseminate threat information
			Q2. OA: Access information about own situation
			Q1. OA: Access to information about threat level
		3.2. Ability to act	Q4. OA: Able to handle important events
4	Planning		Q7. OA: Preparations to meet unexpected events
			Q9. C2A: Allocation of decision rights
5	Communication and individual uncertainty	5.1. Individual uncertainty	Q17. IA: Necessary to learn new systems
			Q16. IA: Uncertainty and unpredictable situations
		5.2. Communication and collaboration	Q11. C2A: Possible to interact within TG
			Q10. C2A: Distribution of relevant information
			Q13. IA: Collaboration with others

DISCUSSION

The operational circumstances around the study resulted in a slightly different exercise configuration than was originally expected. Half of the sampling opportunities and a substantial portion of the intended respondents all disappeared before the data collection could even begin and the obtained response rate was 22% of the maximum. With consideration taken to changed preconditions, the modified response rate was 71% from the remaining sample points, indicating that the challenges to collecting data in live navy exercises are generally not due unwillingness or ignorance among the participants, but rather a question of risk assessment and planning to compensate for short notice alterations of the operational setup.

Since surveys were repeated five times instead of the planned ten, the resulting granularity was only half of the initially intended thus making the analysis of the response profile error prone. Thus, there are many possible explanations for variations in the obtained results that cannot be ruled out. The approach of requesting data at the end of each shift must presumably be reconsidered in order to find an approach which generates more data.

Some other considerations regarding obtained data should also be put forward. There is no straightforward way of objectively deciding if a response profile is flat and the moving means approach must be used with caution. In addition, four of the items were classified as indeterminate as not enough data were available to explore the cause of the found variation. In addition, the scope of this study was on repeated measurement of command team members' perception of the situation. In an assessment of performance this should be complemented with other data. It is also important to note that the organizational adaptability trait in this study is limited to *Ability to detect abnormal events* and *Ability to deal with abnormal events.*

The exercise scenario was designed to progressively become more challenging, suggesting a decreased

performance and adaptability over time. The timing when the Task Force changed focus of the operation into coastal defense was visible in a majority of response profiles. The responses regarding organizational adaptability also largely correspond to expectations indicating a decreased ability to detect and deal with deviations. However, responses regarding individual adaptability indicated a trend of increased ability over time. In fact, only one of the surveyed individual items showed a decreasing trend in adaptability: Q18 on physical workload. Thus, despite increased workload and decreased organizational adaptability, individual adaptability seems to increase over time. The trend for C2 Agility is less conclusive with two decreasing, one flat and one indeterminate item.

A possible explanation for the difference between individual and organizational trends might be the scenario design. Although the situation got more complex and challenging at the Task Force level, the expectations on the different roles might have become clearer. The initial unclear but less threatening situation called for the individuals to prepare and a wider set of options. As the situation became clearer they were able to focus on a few main tasks instead of having to keep a lot of doors open although the organizational level challenges was tougher. The mission command approach implemented in the Swedish Navy might accentuate this effect. Each level has a high degree of responsibility to prepare for different options detail in an uncertain situation. When the situation clarifies each level is relatively free to decide on how to act without seeking permission from higher command.

Another possible and somewhat overlapping explanation is training effect. As work procedures settles, role tasks become more routine and knowledge of details of the exercise scenario evolves even if he study design tried to addressed this issue by not collecting data during the first part of the exercise. Yet another possible explanation is respondent bias as there might be a systematic difference in how one judge the organizational ability compared to how one judge one's own abilities and challenges.

Regarding the individual trait one should differ between role demands and the individual's adaptability. In this study, the items related to individual adaptability have been used to obtain response profiles on how respondents perceived the situation. As such the obtained results reflects the different requirements on the role they had in the command team rather than individual ability to adapt. Thus, the results indicate that role requirements regarding adaptability are not constant. Instead they vary in a consistent way over time but the variation is not necessarily positively correlated to other adaptability traits.

The exploratory analysis of latent structures found five partially independent components. The strongest component, C2 structure and performance, explains more than 37% of the variance and is characterized by C2 interaction, situation assessment, role importance and performance. The component is negatively loaded by collaboration and creativity on the individual level, which is in line with the opposite trends identified between individual and organizational factors.

The second component, mental workload, contains survey items relating to individual stress and organizational resilience, with stress and redundancy as the strongest positively loading items. As in the first component, the individual adaptability item, the presence of options for choosing an action loads negatively on this PC. In addition to the previous discussion on response trends, a hypothetic explanation for this negative loading could be that the mere existence of alternatives induces stress and perceived workload.

The third component is primarily about management of deviating events, including interpreting and disseminating information about the current situation, i.e. information management and sense-making. Additionally, there is a strong loading from the TGs ability of handling important events relating to current threats.

The fourth component is planning oriented, with loadings from allocation of decision rights and preparations for unexpected events. Since this component does not correlate with any of the other components it appears to have had little impact on adaptability and performance as a whole. This result may seem somewhat counter-intuitive, however, allocation of decision right and preparedness to meet unexpected events may still have an effect on performance in the longer perspective. A variation which was not captured in this data collection. Further, it may have been difficult for the respondents to reflect upon these questions in a valid way. For example, rating one's preparedness to unforeseen events requires a way to imagine these unexpected events, which is mentally challenging.

CONCLUSION

With the presented study we have explored how adaptability in a C2 system can be measured and related to performance. Due a cumbersome work environment, force majeure, and absence of on-site researchers, the response rate for the self-assessment reports did not meet initial expectations. Still, the response rate from the remaining possible dataset suggests that repeated self-assessment surveys are feasible for data collection in the

context of distributed exercises. An appropriate approach to obtain more data must be developed together with the navy to compensate for operational circumstances.

Through explorative analysis, a systematic difference was detected in how the respondents answered questions regarding individual adaptability versus organizational adaptability. The trend regarding C2 agility is less clear with two decreasing, one flat and one indeterminate item. This is consequently perhaps the most interesting outcome from the study. We have not been able to identify other studies reporting results on this topic and thus call for further investigation.

A PCA confirmed the existence of latent structures in the dataset, allowing us to cluster variables based on correlations. Five clusters have been identified, suggesting that communication and handling of deviating events can be directly linked to how the respondents assess their own performance. The relative importance of these components should be further investigated.

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