



## Human Performance Under Two Different Command and Control Paradigms

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# 1 Executive Summary

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## **What is this report about?**

This report is about subjecting commonly held beliefs about the benefits of Network Enabled Capability (NEC) to direct empirical tests. In this case, the assumption that NEC leads to increased tempo and effectiveness is considered.

## **Background and reasoning behind the work:**

The motivation for this report is based on a number of intriguing observations made previously during several large-scale simulated command and control (C2) exercises. A consistent observation was that NEC systems exhibit unusual, sometimes paradoxical behaviour. It is argued that this behaviour might provide several powerful clues as to how these systems are thought about, designed, procured, and the role of the human within them.

## **What was undertaken in the research?**

The Brunel University NEC test-bed enabled a traditional hierarchical command and control organisation ('classic C2') to be pitted against a network centric alternative on a common task, performed thirty times by two teams.

## **What was discovered?**

Time series analysis revealed that whilst the NEC condition ended up being slightly slower than its hierarchical counterpart on a simulated Military Operations in Urban Terrain (MOUT)-type task, it was able to balance and optimize all three of the performance variables measured (task time, enemies neutralized and attrition).

## **Military relevance of the work:**

This work lends weight to an alternate view of NEC. It is argued that a useful conceptual response is not to consider NEC as an end product comprised of networked computers and standard operating procedures, nor to regard the human system interaction as inherently stable, but rather to view it as a set of initial conditions from which the most adaptable component of all can be harnessed: the human.

## 2 Introduction

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This paper is motivated by a number of intriguing observations made previously during a large-scale simulated command and control exercise. The exercise had the explicit aim of testing a new method of working supported by a networked ‘infostructure’, commonly referred to as Network Enabled Capability (NEC; e.g. Ferbrache, 2003; Alberts, 2003; Alberts, Gartska & Stein, 1999). When the subsequent task analysis was scrutinised it was found that the techno-organisational system was exhibiting unusual behaviour. This is not to say the system necessarily performed sub-optimally, just that it performed differently.

Over time, the system became progressively more preoccupied with the ‘means’ to achieve a given end rather than the massing of objectives or ‘end states’, which is what is normally expected from NEC; indeed, what was expected in this case. Similarly, despite the provision of a networked information infrastructure, individuals and teams either used it in unpredictable ways or else adopted more familiar and presumably easier methods of working. To paraphrase Clegg (2000), what was witnessed were “people interpreting the system, amending it, massaging it and making such adjustments as they saw fit and/or were able to undertake” (p. 467). This creates a different interpretation of the results.

Drawing from the emerging world of networked technologies such as the internet (the world from whence NEC concepts seem to have been derived in most cases) it is possible to discern powerful new trends in which this form of human adaptability, far from being commanded and controlled out of existence, is instead actively exploited. From the sublime (e.g. the Human Genome Project) to the ridiculous (e.g. Wikipedia), these are both networked, highly distributed systems embodying the diffuse non-linear causality of peers influencing peers (Kelly, 1994; Tapscott & Williams, 2007; Viegas, Wattenberg & McKeon, 2007). In both cases, these are entities where the boundary between designers and users has become “highly blurred, highly permeable, or non-existent” (Scacchi, 2004, p. 6-7).

Under these ‘initial conditions’ highly effective and agile forms of organisational infrastructure ‘emerge’ rather than are created. To use Toffler’s (1981) or Tapscott and William’s (2007) phraseology, the participants in the motivating case study behaved rather like ‘prosumers’, individuals who see the ability to adapt, massage, cajole and generally ‘hack’ a new technology as a birthright (p. 32). It is for precisely this reason that people are still needed in such complex environments (Shorrock & Straeter, 2006), indeed, human adaptability is inevitable (Hollnagel, 1993).

From this emerges the notion that perhaps a more useful way to look at NEC is not to see it as an end product or an entity that ‘is’ something, but rather as a process, something that ‘becomes’ (e.g. Houghton et al., 2006). It seems possible to go even further, to argue that an alternative conception of NEC is not something that can be called a finished article, but rather as the initial conditions from which the most adaptable component of all, the humans in the system, create the end product most useful for their particular set of circumstances. Even then, this adaptation may prove fleeting and highly context dependant.

The purpose of this paper is to take the anecdotal evidence observed in the field and try to recreate, if not the exact situation, then at least similar conditions in the laboratory. The advantage of this, of course, is the degree of control that can be imposed, control that was

almost entirely lacking in the case study example that motivates this report. Caution does need to be exercised. Paradoxically, too much control could conceivably prevent the emergence of the adaptive behaviour being sought, so a novel approach to experimental design needs to be adopted.

In the present study, what might be referred to as a classic hierarchical command and control organisation (i.e. so called 'Classic C2') was created within a simulated environment, then pitted against a peer-to-peer NEC counterpart, both of which contained live actors who had to operate within a complex, adaptive, high tempo scenario. Both conditions represent 'frameworks' that people undertake a common task within but different constraints apply to the different conditions. For example, there is relatively little in the way of rigid specification of experimental procedures in the NEC condition (the focus is on outcomes not actions), and the technological infrastructure is configured to facilitate peer-to-peer interaction. The opposite is true for the C2 condition. Here there is a high degree of 'scripting of tasks' and a more constrained technological infrastructure within which this occurs.

The research question focuses on the performance of the incumbents in the different organisations and how that performance changes as they adapt to their context. In a break from traditional human centred approaches whereby the interaction (and subsequent representations) are generally static (Lee, 2001; Woods & Dekker, 2000), instead it is assumed to be dynamic. There is a good basis for this. Patrick, James and Ahmed (2006) for one recognise the 'unfolding' nature of command and control in their particular 'process based' methodology. They state that, "A critical feature of command and control in safety critical systems is not only the dynamically evolving situation or state of the plant but also the fluctuating responsibilities, goals and interaction of team members" (p. 1396). The experimental design needs to take such factors into consideration.

In regard to human performance under different command and control paradigms, the central question is related as much to the outright relative performance of the two organisations, the 'short term' end product (and what is normally measured) as it is to the pattern of adaptation and how performance changes over time; the 'long term' end product. This being, in other words, the system that the users 'design for themselves' by undertaking whatever adaptations they feel able and necessary (factors that are not normally measured). Whilst the promise of NEC leads to better initial conditions for more effective adaptation to be anticipated, the 'model' needs to be run in order to find out.

## 3 Method

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### 3.1 Design

The experimental task is based around a simplified 'Military Operations in Urban Terrain' (MOUT) game called 'Safe houses'. The game creates a dual task paradigm. The first task involves a commander managing two live fire teams as they negotiate an urban environment en-route to a 'safe house'. The second task involves the commander managing the activities of ten further simulated fire teams within a much wider Area of Operations. The two tasks interact such that success in one does not necessarily connote success overall, it falls to the commander to effectively balance task demands under the independent, between subjects variable of command and control 'type', which has two levels: NEC and C2.

The study is longitudinal in nature. The two teams (NEC and C2) separately undertook a total of thirty iterations through the same dynamic task paradigm and a form of time series analysis was employed to reveal the underlying 'adaptive model' embedded in the data. Participant matching and task randomisation were employed to control for individual differences and task artefacts respectively. The dependant variables focus on performance and were as follows:

- Task completion time,
- Attrition,
- Enemies neutralised.

Good performance in terms of these task based measures equates to the shortest time taken to complete the task, all en-route Target Areas of Interest (TAI's) correctly located and effected, and a high ratio of enemy to friendly agents neutralised.

In general terms, prior research leads to the hypothesis that the simple organisation design (NEC) will allow the actors to perform more complex tasks, thereby exhibiting greater degrees of adaptability from initial conditions. This is compared to the more complex organisation (C2), which requires actors to perform a greater number of simpler, more scripted tasks, in which it might be anticipated that greater, more malevolent environmental dynamism and complexity will arise along with poorer agility and performance.

### 3.2 Participants

Two teams of five people took part in the study, one team worked under NEC conditions, the other C2. The roles occupied by the five members were identical across teams. In each team, three of the team member roles were occupied by experimental participants (all aged 21) who were recruited from Brunel University. The remaining two roles were filled by the experimenters. These roles were:

### **3.2.1 NEC System Operator (Experimenter):**

In general, the NEC System Operator dealt with the experimental aspects of the Commander's Primary Task as well as the NEC system itself. Thus the first experimenter effectively 'drives' the NEC command wall system, receiving requests to add/append data to the live maps from the commander and helping them to use the system themselves. The system operator also supplied strategic injects according to pre-set rules dependent on experimental condition and the state of game play. In the NEC condition, the experimenter also provides situational updates to all team members (ensuring that 'everyone' knows 'everything').

### **3.2.2 Commander (Participant):**

The incumbent of this role was in charge of both fire teams (within the Primary Task), providing guidance and strategy as required. They were also responsible for the larger strategic Secondary Task.

### **3.2.3 Fire team Alpha (Participant):**

This participant was located within the live battlespace and communicated to the commander, and depending on experimental condition, the other fire team as well. This was facilitated by an XDA device (a 'next generation' brand of Personal Digital Assistant) and MSN Messenger™. The XDA device also enabled the fire team to be live tracked and represented on the commander's command wall representation of the battlespace.

### **3.2.4 Fire team Bravo (Participant):**

This participant had the same role and capabilities as fire team Alpha.

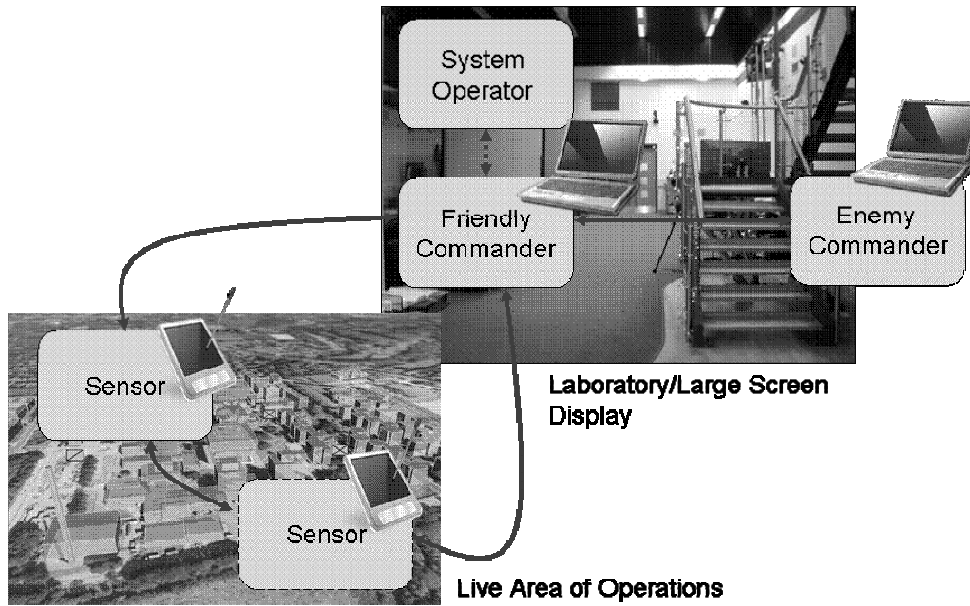
### **3.2.5 Enemy (Experimenter):**

This individual, like the NEC system operator, was another member of the experimental team but located away from the battlespace and from the friendly commander. They were in charge of playing the enemy commander (to the best of their abilities) in the Secondary Task, thus they controlled enemy actions in a 'wizard of oz' fashion.

## **3.3 Materials**

### **3.3.1 Command and Control Microworld:**

Figure 1 presents a visual representation of the command and control microworld within which the Safe houses game was implemented.



**Figure 1 – Command and control microworld**

The system operator and commander were co-located in Brunel University’s BIT Lab. Both sat with a clear view of the command wall, which contained a Google Earth™ representation of the virtual battlespace, with the position of the fire teams represented by an icon derived from Global Positioning System (GPS) data (thus positional tracking of the fire teams was live). This visualisation window was supplemented by a planning window, which contained a map based representation of the same environment with a grid square coordinate system. The planning window allowed the system operator and commander to add, delete and move objects as required by the primary and secondary tasks, which were then instantaneously represented on the main visualisation window. The planning window was populated by the experimenter (before the condition commenced) with all the required TAI’s and enemy icons according to a preset template randomly selected for that trial. The commander and system operator had separate work stations and their own computer, and communicated purely through text based means (using MSN Messenger™).

Both fire teams (Alpha and Bravo) were located in the Brunel Battlespace, away from the co-located commander and system operator. The fire teams carried an XDA mobile phone device. This permitted them to be live tracked using GPS. The XDA device also allowed each fire team to communicate with each other as well as, although depending on experimental condition, the commander in the control centre (via MSN Messenger™). Fire teams could add icons into their own version of the digital map, which would then simultaneously appear on each other’s screens and the main visualisation window in the control centre. The digital map shown on the fire teams’ XDA screens was also used for navigation purposes.

### **3.3.2 Command and Command Paradigms:**

The NATO SAS-050 model of command and control (NATO, 2006) was used to design command architectures that exhibited appropriate NEC and C2 characteristics as shown in Table 1.

**Table 1 – NATO SAS-050 Model of Command and Control was used to design NEC and C2 command organisations with the appropriate characteristics**

	NEC	C2
DISTRIBUTION OF INFORMATION	BROAD: fire teams are provided with regular situation updates from the system operator (in addition to being able to interact directly with their counterparts). 'Everyone' knows 'everything'.	TIGHT: the commander is the only individual with an overall view of the situation. The fire teams had a local view of their immediate location but in all other respects work in isolation. 'Everyone does not know everything'.
PATTERNS OF INTERACTION	DISTRIBUTED: all team member roles can speak to each other independently (there is no communications hierarchy).	HIERARCHIAL: the fire teams could speak to the commander but not directly to each other.
ALLOCATION OF DECISION RIGHTS	PEER TO PEER: collaborative working encouraged and facilitated by effects based instructions and communications infrastructure.	UNITARY: autonomy, authority and discretion rested with the commander.

### 3.3.3 "Safe houses" Game (Primary Task):

The goal of the primary task (that of the live fire team in the Brunel battlespace) was to:

*"Execute a concentrated and simultaneous operation to disrupt a named suspect by searching his house in order to gather evidence to disrupt and dislocate enemy force elements within that Area of Operations"*(MoD, 2005).

Practically, this involved the fire team choosing and negotiating a route through the urban battlespace in order to correctly locate and effect the safe house, dealing with Target Areas of Interest (TAI's) en-route, with each team having to collaborate by providing cover for each other.

Both fire teams start from the same location. The location of the safe house, the final destination, is randomised for each trial but with distance from start point controlled. The Area of Operations (AO) for the primary task is scattered with numerous Target Areas of Interest (TAI's) so that an equal number of TAI's will be encountered 'en-route' (and regardless of route chosen).

Firstly, each of these 'en-route' TAI's has to be correctly located by one of the fire teams. Correct location of a TAI is judged to have occurred when the fire team takes up position at the same grid coordinates as the TAI. Missing out a TAI by failure to locate it will result in the offending fire team being removed from the mission and having to return to the start point for the remainder of the trial.

Secondly, assuming the en-route TAI has been correctly located, the fire team then has to 'effect' it in order to make it safe for the other fire team to continue on their route. Although the location of the TAI is known by the fire team and commander a-priori, what is not known is what form the TAI actually takes and the most appropriate way to 'effect' it. This can only be judged by the fire team who are on the ground and are able to make that assessment based on a number of simple local characteristics. These are as follows:

- If the TAI was located on a building over three stories high then a ‘yellow effect’ will neutralise it (signified by the relevant fire team using their XDA to place a yellow icon on the appropriate grid coordinate).
- If the TAI was located on a building less than three stories high, then a ‘blue effect’ will neutralise it (signified by a blue icon being placed).
- If the TAI was located in a busy thoroughfare with retail outlets then a ‘pink effect’ will neutralise it (signified by a pink icon).

After confirmation that this information has been received, the relevant fire team will hold in this position, providing cover for the other fire team as they make their way to the next TAI. This ‘leapfrogging’ effect continues until, finally, the safe house itself is located and effected in the same way. It should be pointed out that in the NEC condition this leap frogging is facilitated by the fire teams being able to communicate directly with each other via their XDAs, in the C2 condition, however, communication (and instructions) have to pass through and/or come from the commander.

In order to further encourage the need for communication and interaction there is also a degree of built-in ambiguity in the positional data. This means that part of the adaptive process of the entire team is to figure out ‘work arounds’ and modes of operation that enable these ambiguities to be resolved in whatever way is found to be most efficient.

The need for good time and accuracy performance is embedded in the game by two simple game-play expedients. As mentioned before, if the wrong location is chosen or the TAI is ignored then the fire team allocated to it fails the mission and has to sit out the remainder of the trial. If the right location but wrong effect is applied then the fire team’s attrition score, which acts rather like a ‘life score’, starting at five and meaning ‘full strength’ through to zero, meaning ‘neutralised and unable to continue the task’, is decremented.

The attrition score is not just affected by accuracy but also speed and time. Five time activated attrition injects occur randomly throughout the 15 minutes allotted to the trial, these cause both fire team’s attrition scores to be decremented. As a result, the longer the fire team takes, the longer they expose themselves to the deleterious effect of the experimental injects. This combines with accuracy: the less accurate they were the lower the score.

What appears to be a relatively complex set of rules becomes considerably simplified as far as the experimental participants are concerned. The system operator (who is a member of the experimental team) undertakes all game play management tasks such as maintaining the formal record of ‘location accuracy’, ‘effect concordance’ (whether the right effect has been applied), the attrition score, enactment of the time based attrition injects, and communicates all of this to the commander as required.

### **3.3.4 Secondary Task (Commander):**

The commander’s secondary task is based on the following mission:

*“Execute a concentrated and simultaneous operation to disrupt named suspects by searching their houses in order to gather evidence to disrupt and dislocate the enemy force within West London”.*

Whilst the first task concerned the activities of a live fire team in a live environment, the secondary task of the commander is simulated and occurs in a much wider AO (the boundaries are six miles in either direction from the AO of the first task). This larger strategic mission relies on the commander playing a competitive game against a simulated 'enemy', played by the experimenter acting in a wizard of oz fashion. Thus 'live' (small AO) and 'simulated' (large AO) elements were played simultaneously on the same NEC system.

While the live fire team progress towards their primary target within their smaller AO, wider enemy activity is taking place all around which, if permitted to continue, will eventually impinge on the primary task. Such impingement, under certain specified conditions, will mean that the primary task fails regardless of the efficacy of the fire teams. The onus is thus on the commander to manage both tasks effectively.

In the commander's wider area of operations there were 15 enemy elements/icons dispersed randomly around the environment. These icons were placed according to a random script for that trial by the experimenter acting in the 'enemy' role.

Enemy icons, due to the asymmetry of most MOUT-type situations, were free to move across the battlespace at will (no area is restricted to them). The commander had 25 friendly force icons/elements all massed in a defined 'green zone'; this was their starting position. Although more numerous, the friendly icons were not permitted to enter pre-defined 'sensitive areas'.

Apart from these constraints, the game plays like a virtual game of 'draughts' in which the grid square system of the map serves as a form of draughts board. Only one icon can be moved, one square at a time (in any direction), in enemy reaction, friendly counter action, enemy counter re-action, and so on in sequence.

If the friendly icon enters a grid square occupied by an enemy icon then the friendly icon wins. If the enemy icon enters a grid square occupied by a friendly icon, the enemy wins. The experimenter playing the role of the enemy updated the icons/map accordingly (and kept a record of the game score).

The enemy's objectives were to reach several other enemy safe houses dotted around the AO (one of which is the primary target for the live fire team). Every enemy icon that entered a grid square occupied by a safe house is safe and no longer available to be 'captured or neutralised', and thus was no longer able to contribute to an 'enemy captured/neutralised' score. As a result, the onus on the commander is to capture/neutralise the enemies before they reach a safe house, and preferably, neutralising the safe house before enemies start to reach it, hence the phrase 'disrupt' and 'dislocate'.

## **3.4 Procedure**

### **3.4.1 Training Phase (Day #1):**

The aims and objectives of the study were introduced in broad terms along with health and safety preliminaries and informed consent. Detailed instructions on the task were then provided to all participants, supplemented with demonstrations and hands-on examples. The experimenter then used the pre-populated command wall to begin the first full trial which was identical in all respects to the experimental trials but served as a

practice (both teams were measured subsequently as an internal check on concordance between them).

The fire teams were then equipped with the XDA and briefed by the friendly commander, with the help of the study team, as to the mission objectives. The start point of the study was Brunel University's BIT Lab: the study was timed from the moment the fire teams left. The commander was seated in front of their own laptop computer and the command wall. With all participants ready the practice trial commenced with help, facilitation and intervention from the experimental team as required. The System Operator managed the experimental tasks associated with the Primary Task (attrition scores, communications updates – where required and permitted - and timing). The Enemy commander played the friendly commander concurrently according to the rules of the game. After a maximum of 15 minutes (or sooner if the Primary Task was complete) the trial was halted, and the MSN transcripts were saved/archived along with those of the command wall's system logs

### **3.4.2 Experimental Phase (Day #2 Onwards):**

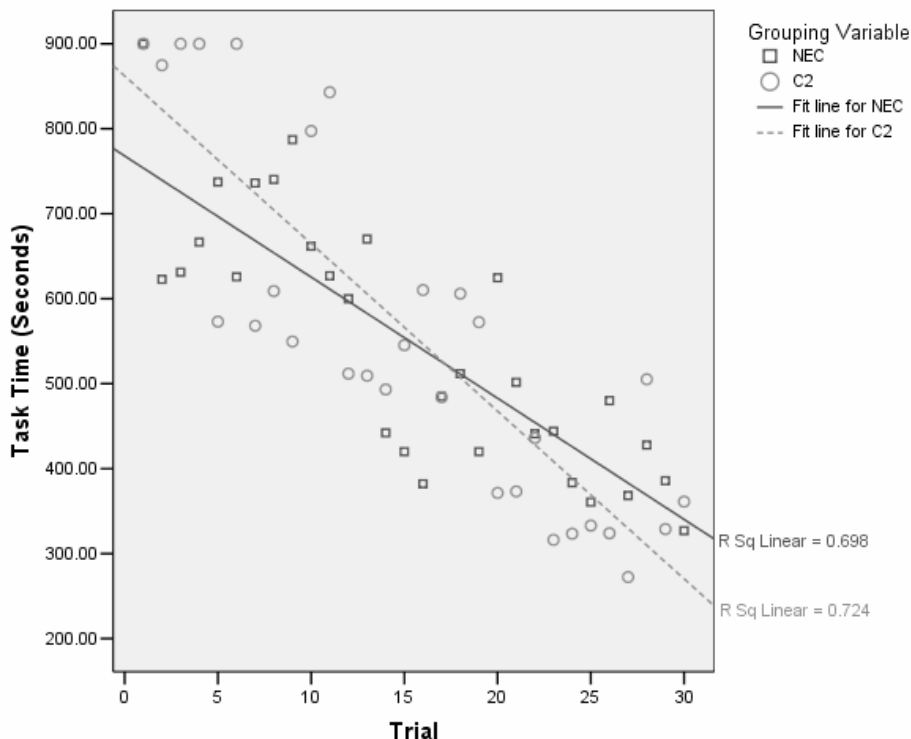
With the participants familiar with the broad paradigm the teams then began to undertake the repeated iterations of the experimental trials in both conditions. Issues and questions were dealt with before the trial started and during it if required. The experimental phase lasted for 7 days (with between four and five iterations occurring per day).

## 4 Results

To briefly recap, participants took part in a simulated MOUT mission over thirty successive iterations. The analysis, therefore, focuses on how the different constraints of NEC and C2 influenced the direction of team adaptation and performance. It is hypothesised that NEC provides better conditions for adaptation, but linear regression is used as a form of time series analysis in order to uncover the underlying theory behind the data and thus to test this supposition.

### 4.1 Task Time

Both teams (C2 and NEC) were measured in terms of how long it took the live fire teams to perform their task. When this first task was complete then both tasks of the dual task paradigm were halted. The maximum amount of time that was allowed to be spent on the task was 15 minutes (900 seconds). As one would expect, over the course of the thirty iterations both teams sped up considerably and continued to do so for every trial. A strong association between task time and trial was obtained for both conditions (NEC  $r = -0.84$  and C2  $r = -0.85$ ), both of which were significant at beyond the 1% level. Furthermore, the regression ANOVA supports the hypotheses that this association is linear in nature for the NEC condition:  $F(1,28) = 64.74$ ;  $p < 0.0005$  and  $F(1,28)=73.53$ ;  $p < 0.0005$  for the C2 condition.



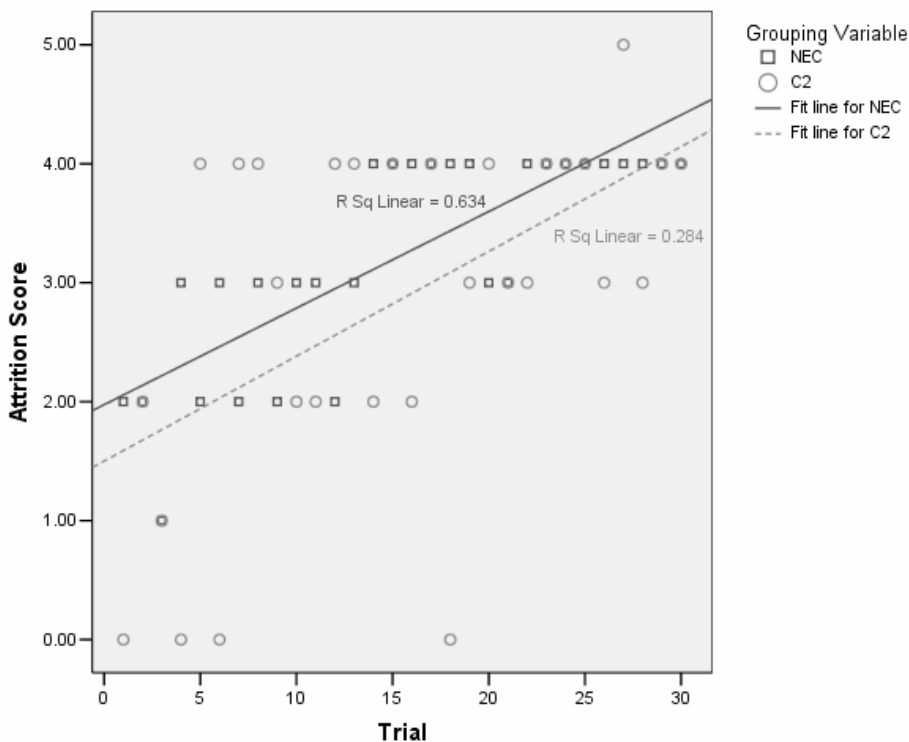
**Figure 2 – Scatterplot showing the regression lines for both NEC and C2 conditions in relation to task time**

The linear regression model fitted to the data accounted for 69% of the variance in the NEC condition (Adjusted  $R^2 = 0.69$ ) and 71% of the variance in the C2 condition (Adjusted  $R^2 = 0.71$ ). Both values represent a large effect size and both regression

models were statistically significant to beyond the 1% level. The regression equation, however, differed between the two conditions. The intercept for the C2 condition was at  $b_0 = 862$  seconds, somewhat nearer the maximum value of 900 seconds permissible for the task than the NEC condition, whose intercept was at  $b_0 = 762$  seconds. However, the regression line for the C2 condition had a slightly more precipitous slope than that for the NEC condition,  $b_1 = -14.26$  compared to  $b_1 = -19.73$ , thus despite the higher intercept the regression lines actually crossed at trial 17 meaning that by trial 30 the regression model predicts the task being completed in 270 seconds for the C2 condition compared to 334 seconds for the NEC condition (approximately a minute faster). Taken in isolation it appears that that the NEC condition favours initial time adaptation with the C2 condition yielding longer term improvements and faster times.

## 4.2 Attrition

In the primary task, the teams were given an attrition score rather similar to the kind of 'lives left' score given in computer games. The attrition score, which begins at five, is diminished through a) time based injects, so the longer that is spent on the task the more chance there is of having the score decremented, and b), if locations of TAIs and markers placed at them are inappropriate and/or inaccurate then the attrition score is also subtracted. A high attrition score connotes better performance.



**Figure 3 - Scatterplot showing the regression lines for both NEC and C2 conditions in relation to attrition score**

In both conditions the attrition score is positively correlated with the number of trials undertaken,  $r = 0.8$ ,  $p < 0.0005$  for the NEC condition and  $r = 0.53$ ,  $p < 0.01$  for the C2 condition. The regression ANOVA supports the hypothesis of linearity in both cases:  $F(1,28)=48.55$ ;  $p < 0.0005$  for NEC and  $F(1,28)=11.09$ ;  $p < 0.002$  for C2. Note, however, that despite the statistical significance of these regression diagnostics the C2 condition

possesses less statistical power in terms of its associative performance ( $r$ ), linearity ( $F$ ) and also in the amount of variance explained by the regression model ( $R^2 = 0.26$  compared to NEC's 0.62).

In model terms the regression coefficient (the slope of the regression line) was similar for NEC and C2, being 0.08 and 0.09 respectively. The intercept values were, however, different. The C2 model starts with a lower attrition score of 1.5 and maintains a subordinate position to NEC (whose intercept is 1.98) for the duration of the longitudinal testing and data collection intervals. Both of these regression models were statistically significant to beyond the 1% level. So, despite C2's favourable evolution towards faster task completion times it is not all good news, as accuracy seems to suffer (and is punished by slightly poorer attrition performance).

### 4.3 Enemies Neutralised

This factor relates most strongly to the commander's performance in the secondary task (within the wider area of operations). It can be immediately noted that the commander was able to manage these competing tasks satisfactorily, with the secondary task at no time causing the premature cessation of the primary task. That said, it did compete for the commander's attention and thus influenced their performance.

The assumptions underlying a linear approach to time series analysis are not met in the case of friendly versus enemy capture ratio. In other words, trial number or task iteration appeared not to be a good predictor of this factor's performance. In both cases only small ( $r = 0.3/0.24$ ) correlations were detected for NEC and C2 respectively, albeit statistically significant. However, the fact that the resultant regression model only explained around 6 to 9% of the variance in the data ( $R^2 = 0.09/0.06$ ), the hypothesis regarding linearity was not supported:  $F(1,28)=2.75/1.64$ ;  $p = ns$  and, furthermore, both regression models failed to reach significance ( $p = ns$ ) means that this form of analysis is abandoned. Given the lack of a linear relationship between trial and capture ratio a simple cross-sectional approach can be taken. However, even here an independent samples t-test failed to detect a statistically significant difference in capture ratio between NEC and C2 ( $t = 1.48$ ;  $df = 58$ ;  $p = ns$ ). Given that such a test possesses in excess of 80% power to detect medium effect sizes or larger, and that only a very small effect was actually detected ( $r_{bis} = 0.04$ ), this means that there is a high degree of confidence in stating that the constraints imposed by both NEC and C2 conditions are not a particularly meaningful determinant of enemy versus friendly capture ratio. In other words, C2 evolves towards faster task completion times, but with poorer accuracy, but both NEC and C2 are comparable in terms of the numbers of friendlies and enemies captured.

## 5 Conclusions

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The results, in summary, show that the traditional command and control condition is good at optimising task completion times, starting off slower than NEC but catching up and overtaking it. However, optimisation of task time comes at a cost to other factors, in particular, the C2 condition is less accurate. What the NEC condition loses in task time (approximately 1 minute) it 'gains' in accuracy and remains stable in terms of enemies neutralized. These results would have been quite different had the human system interaction been assumed to be stable. Even allowing for not just one but several practice or control trials, the NEC condition would have posted faster task completion times than the traditional command and control condition. In recognising the inherent instability of this interaction, the longitudinal design presents evidence of the following:

- The emergent nature of command and control. Participants did indeed perform adaptations to the way they carried out their task within the confines of the study. This methodological success shows that these open-systems properties can be instantiated (and measured) in a laboratory setting, which...
- ...led to a degree of unpredictability in the NEC condition. This behaviour matched that observed in the case study that motivated the current paper. It was hypothesised that NEC would increase tempo, and had a static view of the human system interaction been taken this view could be upheld. But with NEC representing an initial condition from which adaptations could take place, this hypothesis was not supported, however...
- ...are we comparing like with like? With more than one factor to optimise is the fact that NEC was slower really very meaningful? Perhaps not. Whereas the more traditional hierarchical command and control condition accelerated task completion times this came at a cost to other factors, a cost that the NEC condition was able to trade-off and optimise.

As the case study(s) that have motivated this work have already hinted, NEC-like organisations often exhibit paradoxical behaviour. The NEC condition 'should' have been faster, but actually, the scope of adjustments available (and actually made by the incumbents of the team roles) meant that task time was not elevated to the status of single most important priority. This, surely, is a desirable outcome given the inherent complexity, dynamism and asymmetry present in the context within which these organisations operate. Perhaps this is the hallmark of what NEC is really all about? The greater extent of open systems behaviour is what seems to enable the NEC organisation to undertake a more complex process of optimisation compared to its hierarchically organised counterpart. The take home message seems to be that this situation arises by exploiting the most adaptable, open-systems component of all in NEC: the human.

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