Exploring Compatible and Incompatible Transactions in Teams

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ABSTRACT

Introduction: Transactions of information and situation awareness are a critical commodity in team decision making and the development of distributed situation awareness. Schema theory explains production of behaviour and argues that different schemata guide interpretation of external information. Schema theory has been given most attention at an individual level, this paper therefore seeks to consider the manner in which schema influence team interaction, coordination and distributed situation awareness. **Method**: An exploratory study was devised in which the communication of team members were analysed. **Results and discussion:** Compatible and incompatible transactions were explored in light of schema theory. It was found that compatible transactions were associated with a slightly higher efficacy compared to incompatible transactions. The transactions explored were associated with a range of schemata and these early findings indicate that schemata guide not only individual but also team behaviour.

KEYWORDS

Schemata; team decision making; distributed situation awareness; teamwork.

INTRODUCTION

Stanton, Salmon, Walker & Jenkins (2009a) pointed out that situation awareness (SA) transactions are a critical commodity in the development of Distributed SA in teams. As yet, little is known of the nature of compatible and incompatible transactions and the role these may play in Distributed SA. Transactions which take place in a team may not be used by team members in the manner it was intended and, therefore, could play a role in SA breakdown. This paper seeks to shed light on the manner in which compatibility and incompatibility of SA transactions manifests itself in teams and the role of schemata in the establishment of overall team strategies. An exploratory analysis was performed to reveal the manner in which compatible and incompatible SA transactions contribute to the regulation of teams' behaviour and contribute to the development of Distributed SA.

In order for teams' behaviour to be guided in a coordinated manner the individual team members must agree a joint approach for acting. This necessitates that the team members understand what is required of them and is brought about by the spread of information within the team.

Schema theory, based on the work of Bartlett (1932), explains the production of behaviour as an organisation of experience which are drawn when dealing with a current situation (Stanton, Salmon, Walker & Jenkins, 2009b). Stanton et al. (2009b) explained that the schemata held by a person combines with the goals they hold, tools they use and the situations they find themselves in to generate, or blend, new behaviour. Individuals gain different experience and as a result no individual may hold different schemata.

Grasser and Nakamura (1982) argued that schemata are generic knowledge structures which serve to guide interpretation of external information. Marshall (1995) explained that these knowledge structures can be represented as a network of associations. Schemata have been described as "hierarchically organised sets of units describing generalised knowledge about an event or scene sequence" (Mandler, 1984, p.14).

Actions are specified only at the highest, abstract, level and activation of a higher-order schema leads to the activation of lower level schemata to complete a sequence of behaviour (Norman, 1981). Norman and Shallice (1986) defined the higher order schemata 'source schema' and lower-level schema 'component schema'. Component schema, when activated through the source schema, become source schema in their own right as a person runs through the sequence of actions required for performing some task. As an example, "making a stew" may be a source schema which triggers a number of component schemata such as "preparing beef" which in turn become a source schema for "cutting meat", and so on. Schemata are therefore structured in a hierarchical manner (Plant & Stanton, 2012). Graesser and Nakamura (1982) differentiate between mental models and schemata by the example "restaurant eating schema". They state that this schema is generic for any restaurant a

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person might visit, whilst a mental model would have to be related to individual restaurants and the specific time at which the restaurant is visited (Plant & Stanton, in press). An individual's schemata will be combined with the goals they possess and the situation they find themselves in to develop new types of behaviour (Stanton et al., 2009b).

Norman and Shallice explained that "when numerous schemata are activated at the same time, some means must be provided for selection of a particular schema when it is required. At times, however, there will be conflicts among potentially relevant schemata and so some sort of conflict resolution procedure must be provided" (p.4). In many areas of teamwork one course of action must be chosen and agreement within the team must be established if a common goal is to be met in a timely manner. This poses the question of how teams resolve a conflict between opposing ideas or views on what the right course of action may be. Norman and Shallice (1986) described this resolution of conflict as "contention scheduling".

This paper presents an exploratory study which considers the information passed around in the team. In particular, the information is explored to reveal whether the information trigger a number of alternative courses of action from which one must be chosen, explained as contention scheduling (Norman & Shallice, 1986).

Norman (1981) described situations in which the wrong schemata were selected as a means of describing different types of human error. He suggested that three basic types of schemata account for most errors: activation of the wrong schemata (as described in contention scheduling similar triggering conditions may lead to the wrong schemata being activated), failure to activate appropriate schemata (e.g. lack of attention to the triggering conditions which could have activated the schema) and a wrong triggering of schemata (e.g. triggering of schema at the inappropriate time).

The Role of Compatible SA

Salmon, Stanton, Walker, Jenkins, Baber &McMaster (2008) explained that each agent may hold different SA for the same situation. The individual is governed by their specific team role, tasks and goals in the manner in which they perceive the situation as it evolves (Stanton et al., 2009b; Salmon et al., 2008). This is closely linked with Schema Theory, as described above, which argues that each individual holds different schemata (as the sum of their experiences) and that no schema will be identical between two individuals (Stanton et al., 2009c; Stanton et al., 2009d). This is also closely linked to the idea that it is not necessary for the whole team to know everything (Salmon et al., 2008; Hutchins, 1995a). Successful team performance depends on knowing who knows what to access information, not knowing everything. Given the difference between individual team member's schemata and interdependent tasks awareness is not shared (Salmon et al., 2008). One team member's SA could therefore be different but remain compatible as their SA will be required to ensure that the team can perform successfully (Salmon et al., 2008). This was argued by Stanton, Salmon, Walker & Jenkins (2006) who asserted that team members have unique but compatible portions of awareness. In other words, that the team requires separate awareness but also compatible awareness whilst working towards a goal (Salmon et al., 2008).

The diverse but related literature described here point to a number of pertinent questions which may shed light on the role of schemata in team decision making and compatible SA in the team's development of Distributed SA. The exploratory research presented here was therefore guided by the following research questions:

1. Do teams exhibit the use of source schemata and component schemata (Norman & Shallice, 1986; Grasser & Nakamura, 1982; Plant & Stanton, 2012)?
2. Are conflicts of schemata, such as that described as contention scheduling, observed in team communications (Norman & Shallice, 1986)?
3. Do the team members exhibit transactions of information which are either compatible or incompatible and associated with a component schema (Stanton et al., 2006a; Stanton et al., 2009b; Salmon et al., 2008)?

METHODS

Research Design

A qualitative approach was chosen to explore the data and shed light on the three research questions detailed above. The research utilised two qualitative approaches; a top-down approach were the game rules were used as a guide to identify schemata and a bottom-up process where content analysis was utilised to explore compatible and incompatible transactions observed in communications.

Experimental Tasks

A strategy game was developed in which a chess board was used with players of four different colours; blue, yellow, green and red. The blue pieces signified friendly players and were controlled by the experimental team. Yellow players were unknown, while green were neutral and red players were enemy or opponents pieces. The rules of the game were as follows:

- The aim of the game is to take as many red players as possible
- Each Blue player has one move per turn, however, each player can give their move to another player on a turn-by-turn basis

- Each player can move in any direction but not through another player
- Moving through another player constitutes taking
- Blue players have to outnumber a red player before they can take it
- Blue must not take blue, green or yellow players
- Red must move away from blue if a blue player gets to within one space of red
- If red players outnumber the blue players they must move towards them and try and take them
- In two games the opponent players move
- In two games the opponent players are disguised as yellow and will only reveal their true colour (e.g. red or green) if a blue is next to it.
- Changing colour is considered a move (the player cannot immediately be moved after colour change). After revealing the colour the player cannot change back to yellow.

A military SME verified the game as reflecting those strategy games used in command training. The four games played were:

- Static game: The opponent players do not move. All opponent players are shown to the experiment team in their true colours (e.g. red is shown, yellow is shown and green is shown)
- Moving game: The opponent player's move after the experiment team has moved. All opponent players are shown to the experiment team in their true colours (e.g. red is shown, yellow is shown and green is shown)
- Static and disguised game: The opponent players do not move. All opponent players are shown as yellow (e.g. red and green are disguised as yellow) so that the experiment team must reveal what the true colour of the opponent players are (i.e. green, red or yellow).
- Moving and disguised game: The opponent player's move after the experiment team has moved. All opponent players are shown as yellow (e.g. red and green are disguised as yellow) so that the experiment team must reveal what the true colour of the opponent players are (i.e. green, red or yellow).

All teams performed four experimental tasks of a strategy game. The team collaborated to achieve the aim of the game which was to take as many red players as possible whilst at the same time avoiding taking yellow, green or blue (e.g. other team members) players. Collaboration in the teams was ensured through communication.

Data Reduction and Analysis

Communications were explored using content analysis to identify compatible and transactional information elements, using a similar approach to that applied by Stanton et al. (2009a; 2009b) among others (Salmon et al., 2008; 2009a). Using Norman's (1981) and Norman and Shallice's (1986) description of source and component schemata the most prevalent source schemata were identified. Norman and Shallice (1986) defined source schema as a "highest-order control" mechanism which organises a set of learned action sequences. A component schema can therefore be seen as a lower-order schema which achieves some part of the actions which the higher-order, or source, schema initiates.

The communications were further explored for source and component schemata and for schemata which were in conflict with each other as described by contention scheduling. The transactions identified were linked to the component schemata they originated from. The transactions observed were depicted in state-space diagrams. Sanderson, Verhage & Fuld (1989) described the use of state-space diagrams as a means of exploring process control as a dynamic problem solving task. Using state-space diagrams they showed how the operator handled a set of problems and moved from point to point within the state space as they did so. The state-space diagrams were constructed to show how the understanding of team members changed as new information was provided and how it conflicts with existing assumptions, or schemata. These are described as either assimilation or accommodation, where assimilation reflects instances where the incoming information fits with the schema and where accommodation reflects that new schemas had to be developed (Piaget, 1961). In this way compatible and incompatible transactions are shown.

RESULTS

A common source schema, or a 'super-source' schema, observed in all communications was "win the game" from which all other schemata appeared to originate. The component schemata observed from this schema and the manner in which compatible and incompatible transactions between team members developed the schemata are explored here.

Taking a red

Figure 1 illustrates the manner in which teams' compatible transactions were passed around the team with regards to taking red.

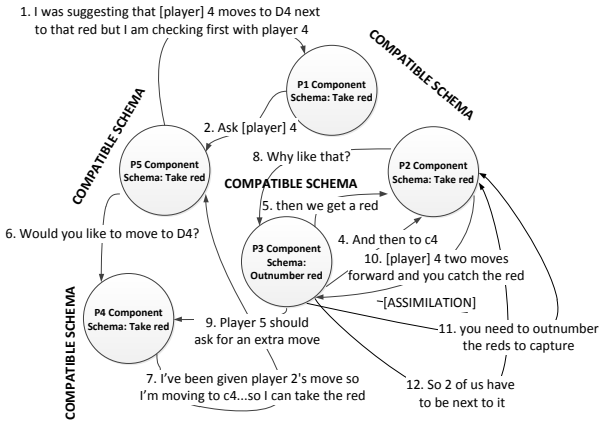

Figure 7. State-space diagram showing compatible transactions associated with the schema "take red"

As seen in Figure 1, Player 5 suggested to Player 1 that Player 4 moves next to a red player (*"I was suggesting that [player] 4 moves to D4 next to that red"*). Player 3 made a suggestion to Player 2 in terms of another move which would take another player next to red (*"And then to c4"*). This was followed by a statement which asserted that doing so would enable the taking of a red (*"then we get a red"*). This prompted Player 2 to ask why this was necessary (*"why like that?"*). Player 3 appeared to have a component schema for taking red which differed slightly from the other team members, namely that in order to take red the red must be outnumbered first, by there being at least two blue players to every red (e.g. the schema "outnumber red"). This was seen in the transaction from Player 3 to Player 2 where this game rule was explained (*"you need to outnumber the reds to capture" and "so 2 of us have to be next to it"*). Player 3's transaction to Player 2 appeared to have triggered the activation of a further component schema, namely "giving away moves" which Player 3 transacted to Player 4 (*"Player 5 should ask for an extra move"*). Whilst this was a different schema to that held by the other team members this was not incompatible and originated from the source schema "take red".

Making Moves

Figure 2 illustrates the state-space diagram for "making moves".

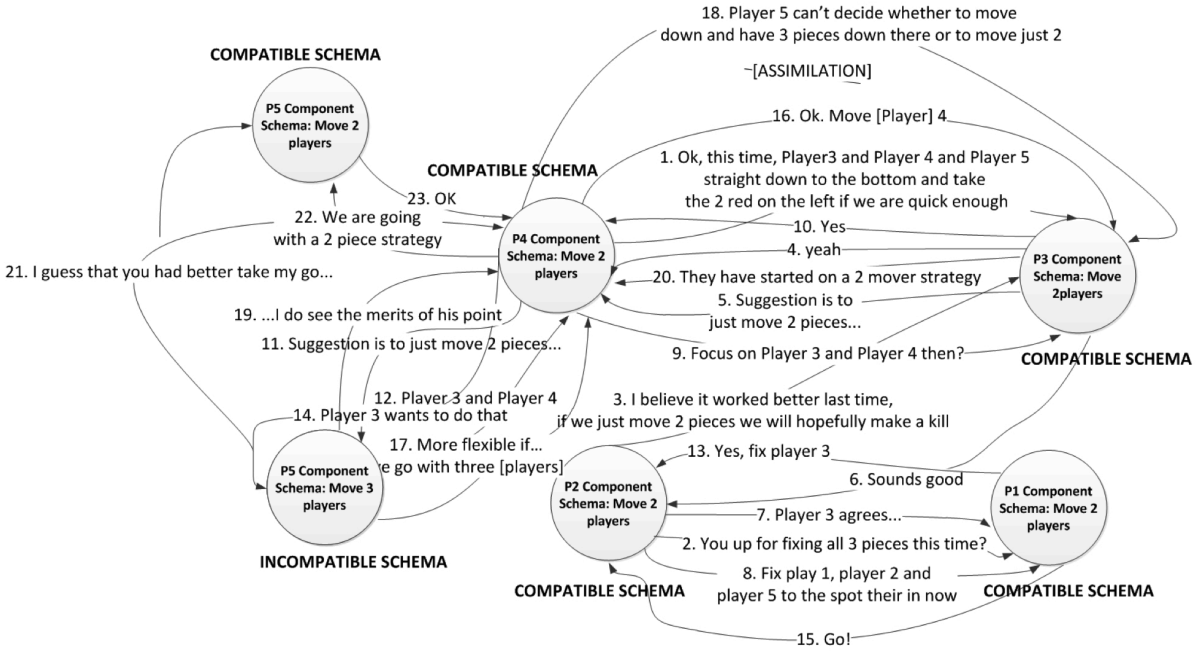

Figure 8. State-space diagram showing adjustment of schemata related to moving players

The component schema of "moves" was observed in the communications, however, contention was observed between the need to move two or more players in order to be effective. Figure 2 shows the state-space diagram developed for the component schema "moves". The schema "moves" has here taken the role of a source schema triggering two different component schema "move two players" and "move three players".

A contention can be seen in the team communications with Player 5 and Player 4 beginning the game with an active schema for "moving 2 players" whilst Player 3, Player 2 and Player 1 have an active schema for "move 2

players". The first transaction, passing between Player 4 and Player 3 (*"Ok, this time, Player 2 and Player 4 and Player 5 straight down to the bottom…"*), appears to arise from Player 4's schema "move 3 players" and was incompatible with Player 3's schema "move 2 players". This resulted in a transaction from Player 3 to Player 4 (*"Suggestion is to just move 2 pieces"*) where Player 3's active schema for moving only two players is conveyed. Through a process of accommodation Player 4 then adapts the original schema for moving three players to two players. Player 5, like Player 4, held a conflicting schema to that of the other team members (*"move three players"*) which is adjusted to "move two players" through the transactions received from Player 4. Player 4 therefore; after having had their schema changed, goes on to initiate accommodation of Player 5's schema. As can be seen in Player 4's transaction to Player 5 where the same message as that Player 4 received from Player 3 was passed on to Player 5 (*"Suggestion is to just move 2 pieces"*). Player 5 argued against the proposed strategy initially (*"more flexible if we go with three [players]"*) but relents and, seen in the reply, *("I do see the merit of his point"*) adjusted his schema to that held by the majority of the team (e.g. "move two player").
Figure 3 shows the compatible transactions being assimilated into the team member's schemata "move towards red". Here, no conflicts are observed and each team member's transactions aligned with the schemata.

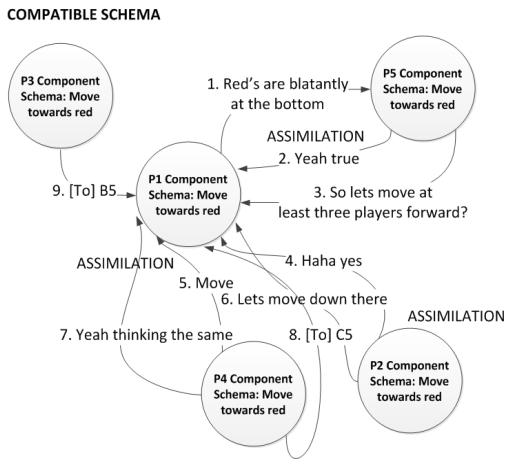

Figure 9. State-space diagram showing assimilation of compatible transactions in relation to moving players

Summary of Results

The transactions explored were associated with a range of schemata, where two were in direct contention with other component schemata, as illustrated in Figure 4 below. In the following section these exploratory findings are discussed.

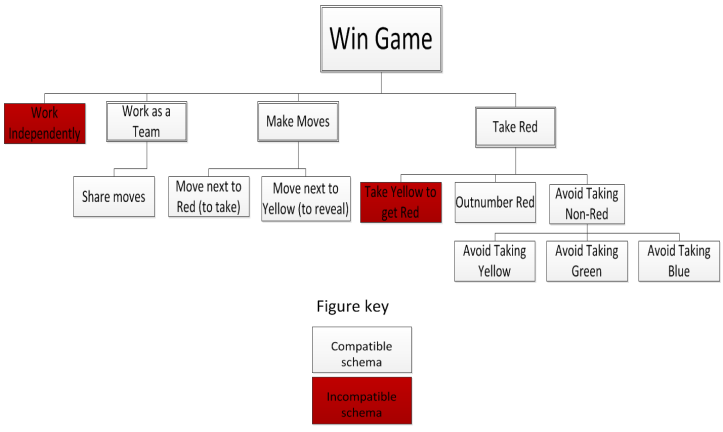

Figure 10. Summary of compatible and incompatible schemata activated from the source schema "win game"

DISCUSSION

Teams are interdependent entities from which Distributed SA emerges through interactions between team members (Stanton et al., 2009a; Stanton et al., 2009b; Salmon et al., 2008). The team's interdependence means that each team member performs separate but related tasks to enable the team to achieve an overall goal. Understanding the role of transactional and compatible SA in holding different parts of a system, or team, together is important to further the theory of Distributed SA. This exploratory research sought to shed light on the manner in which compatible and incompatible transactions support the regulation of team behaviour and the development of Distributed SA.

Three research questions guided the exploratory analyses conducted for this chapter. The first asked whether the teams exhibited use of source and component schema. The findings presented here showed that all teams exhibited the activation of source schemata which in turn triggered the activation of component schemata, as described in the literature (e.g. Norman, 1981; Norman & Shallice, 1986).

The second research question asked whether the teams exhibited contention between schemata, as described by Norman (1981). The findings revealed that whilst the triggering of component schemata was mostly appropriate for the context of the game variant played, the triggering of subsequent schemata clearly made the team members vulnerable to activation of inappropriate schemata. The findings highlighted one example of "wrong triggering of schemata" (Normal, 1981) where the team activated a schema which was inappropriate at that time but which could potentially have been appropriate at another time (e.g. in a different type of game). As was seen in the team which held conflicting schemata concerning team working strategies (e.g. work as a team or work independently). Salmon et al. (2008) argued that deficiencies in one agent's SA can be compensated by another. This was exemplified when a team member who displayed the wrong schema adjusted it via accommodation whereby information that conflicted with the original schema was used to develop a new schema. Similarly, in discussing taking a red player the team members supplemented each other's understanding of the manner in which red was to be taken (for instance, by being outnumbered).

Norman and Shallice (1986) explained that individuals may not possess schemata for novel tasks. In such instances no schema will be available for selection and a new schema must be developed. An agent draws on existing experience and knowledge whilst interacting with the world to form a new schema appropriate for the novel task. This may in turn lead to wrong schemata being developed as the interpretation of the new task may not be entirely fitting. This was exemplified in the team communications where a team member had developed a schema for taking yellow as a means by which red players could be got to. The application of previous experience and schemata, which may not be appropriate, may be a rational means by which the teams instigate behaviours. Whilst the schema may be incorrect for a particular game variant expressing it means it becomes possible for the team to adapt it in light of conflicting transactions made by other team members. This is in line with the explanation offered by Bartlett (1936), and early Schema Theory, that the production of behaviour arises from an organisation of experience which are being drawn on in dealing with a situation (Plant & Stanton, 2012; Plant & Stanton, in press). The sequence of activation of a source schema and associated component schemata that were evident in the team's transactions also showed that the team quickly adapted their behaviour to the context, once it was understood, and this led to a triggering of further schemata and acts relating to those. Stanton et al. (2009b) argued that schemata support individuals to proficiently deal with situations in the production of appropriate responses. This was exemplified in the extract of communications where taking a yellow was discussed. Player 1 had an active schema for taking a yellow and expressed this to Player 3. Player 1's schema was therefore transacted to Player 3 who had the same schema triggered. Player 1 then appeared to have checked the game rules whilst Player 3 checked the board and found neither that taking a yellow was allowed by the game rules nor gave any advantage in terms of movement on the board. The "taking of a yellow" schema was then dismissed and a new schema activated. The players went on to discuss making moves around the yellow.

The third research question asked whether contention scheduling was observed in the team communications. The communication extracts presented here did show a degree of conflict between different team members' opposing schemata. Norman and Shallice (1986) explained that when several schemata are activated at the same time selection between these is required. A conflict resolution procedure must then be provided and it would appear that transactions, in conveying what an agent knows, has a 'conflict scheduling' (Norman & Shallice, 1986) function in the teams. Compatible and incompatible transactions, through a process of assimilation and accommodation (Piaget, 1961), appeared to enhance and develop the schemata of other team members, thereby resolving the contention.

CONCLUSION

Given the exploratory nature of this research limited conclusions can be drawn from this study with respect to contention scheduling in teams. It appears that when a conflict existed between team members (as where a yellow player was considered taken and a team member insisted that taking this course of action would be wrong) a resolution was found. It may be that in teams, like the ones studied here, conflict resolution occurs through the schema of member with high status being given higher 'activation threshold' in the team, resulting in this schema being triggered when in conflict with a "lesser" team members' conflicting schema. Such scenarios are commonly found in military C2 and in hierarchical teams where one leader is in charge. The activation threshold value given to team members schemata could, perhaps, be reduced or increased by aspects such as whether their schemata have been appropriate for other situations before (i.e. dependent on team members experience) and therefore build on trust and cohesion. It is also possible that where a more democratic team structure exists, the schema which is held by most team members will be given the highest activation value and thus is selected for team behaviour. This is supported by the finding that compatible transactions were associated with slightly higher efficacy when contrasted to incompatible transactions. As such, more moves were made with fewer transactions than for the incompatible transactions. The absence of contention scheduling between component

schemata held by different team members may explain why fewer transactions were required. In these instances the teams' attention was focused on making the moves rather than establishing the appropriate schema.

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