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SEMANTIC CONTENT OF
TACTICAL PLANNING
ANALYSED THROUGH
MULTIMODAL DIALOGUES



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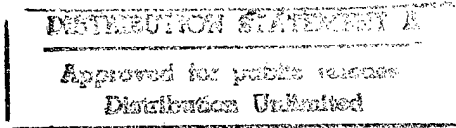
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**SEMANTIC CONTENT OF
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Abstract

This study addresses the semantic content of tactical planning conveyed through human multimodal dialogues over a map. Specifically, the aim of this study is to determine the significant (e.g., spatial objects, tactical concepts) of a tactical planning estimate that commanding officers convey through verbal and graphical (hand) actions.

Seven military officers provided verbal and graphical estimates of a tactical situation portrayed on a topographic map. These estimates were videotaped. The graphical components consisted of graphical actions involving a physical reference to a topographic map. These graphical actions were defined as visual-graphical signifiers in a previous report.

A set of significant was determined from the analysis of the commanders multimodal dialogues in their verbal and visual-graphical components. These multimodal dialogues were analysed using lexical, syntactical, pragmatic (planning phases) and semantic aspects of linguistic analysis.

The significant (N = 382) were categorised, in a representational scheme, along two dimensions: spatial classes and type. The first dimension grouped the significant in four classes: geographical features of the area of operation, tactical features of the area of operation, combat power, and courses of action. The second dimension categorised the significant according to their type, i.e., whether they consisted in objects, concepts, attributes of objects (or concepts), or relations pertaining to objects (or concepts).

The significant identified in this study represent an intrinsic part of the knowledge used during tactical planning. These significant were deduced from all but two of the planning phases. Since commanders used both verbal and visual-graphical signifiers to identify the same set of significant, then both types of signifiers should be paired for the interpretation of other planning estimates. The methodology and representational scheme that we developed in this study should provide a basis for pursuing these tasks. These contributions should also be useful for the design of multimodal interfaces since these are aimed at identifying the semantic content of human multimodal dialogues.

Executive Summary

Computers are now being used to support tactical planning and decision making through intelligent dialogue with humans. Since military planners communicate with each other using both speech and graphical (hand) actions especially while discussing problems that involve spatial data (e.g., spatial objects, spatial relations), then this form of multimodal dialogue should also be possible at the interface between a human and an intelligent computer agent. This is the approach that several military applications have adopted, namely for the command and control of ground forces and air forces.

However, multimodal interfaces are typically limited to the interpretation of noun phrases (e.g., that one) and pointing actions, only two of the multiple components of multimodal dialogue. This limitation is partly related to the lack of studies regarding the symbolic aspects of human multimodal dialogue. These symbolic aspects include the *significants* (i.e., objects, concepts, attributes, and relationships) that constitute the semantic content of a dialogue, and the *signifiers*, i.e., the verbal and graphical actions that are used to convey the significants. This study aims to determine the significants (e.g., spatial objects, tactical concepts) of a tactical planning estimate that commanding officers convey through the concurrent use of verbal and graphical actions. It is part of a broader project aimed at developing digitized land forces.

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A set of significants was determined from the analysis of the commanders' multimodal dialogues in their verbal and visual-graphical components. These multimodal dialogues were analysed using lexical, syntactical, pragmatic (planning phases) and semantic aspects of linguistic analysis.

The significants (N=382) were categorised, in a representational scheme, along two dimensions: spatial classes and type. The first dimension grouped the significants in four classes: geographical features of the area of operation, tactical features of the area of operation, combat power, and courses of action. The second dimension categorised the significants according to their type, i.e., whether they consisted in objects, concepts, attributes of objects (or concepts), or relations pertaining to objects (or concepts).

The significantants represent an intrinsic part of the knowledge used during tactical planning. These significantants were deduced from all but two of the planning phases. Since commanders used both verbal and visual-graphical signifiers to identify these significantants, then both types of signifiers should be used for the analysis and interpretation of other planning estimates. The methodology and representational scheme that we developed in this study should provide a basis for pursuing these tasks. These two contributions should also be useful for the design of multimodal interfaces since these are aimed at identifying the semantic content of human multimodal dialogues. To our knowledge, no study had yet developed a methodology or a representational scheme that would enable this identification.

1. Introduction

This study aims to determine the tactical objects, concepts, and relations that commanding officers discuss during a planning estimate over a map. It is part of a broader project aimed at developing digitized land forces.

An important objective of digitized land forces is to support the commanders planning and decision making activities through multimodal dialogues, i.e., dialogues in which they can use different modes of communication such as speech and graphical (hand) actions to discuss tactical objects or concepts over a map. This view of command and control support has been adopted in previous DCIEM projects like the Interactive Spatial Information System (ISIS) (McCann, Taylor, & Tuori, 1988; Taylor, McCann, & Tuori, 1984). The intent of ISIS was to support tactical planning through intelligent, multimodal interaction with spatial displays. Multimodal interaction allowed the human user to communicate to the computer through different modalities or sense-organs, principally acoustic (e. g., speech), visual (e.g., graphical actions), and haptic. Conversely, the computer could also provide information through various physical media, whether acoustic, visual, haptic, or a combination.

Multimodal human-computer interfaces based on speech and graphical actions offer opportunities for rich dialogue: one mode may help resolve ambiguities in another while allowing efficient dialogue. These kinds of interface recognise and interpret two or more modes of dialogue concurrently. Methods for doing this have been explored in several military applications, including the command and control of air forces (Hewish, Turbé, & Wanstall, 1991; Neal & Shapiro, 1988; Taylor, 1989) and ground forces (McCann, Taylor, & Tuori, 1988; Taylor, McCann, & Tuori, 1984). These methods involve the integration of the linguistic and pragmatic¹ properties of different modes of dialogue. These properties have been partly addressed in the design of multimodal intelligent interfaces resulting in interfaces that are capable of simultaneously interpreting pointing actions and verbal queries (Hewish, Turbé, & Wanstall, 1991; McCann, Taylor, & Tuori, 1988; Taylor, McCann, & Tuori, 1984; Neal & Shapiro, 1988; Taylor, 1989).

¹ The term *linguistic* is used as a general term to include the lexical, semantic, and syntactical properties of a dialogue. The term *pragmatic* refers to the context in which a dialogue occurs.

However, multimodal interfaces have typically been limited to the interpretation of noun phrases (e.g., that one) and pointing actions, only two of the multiple components of human multimodal dialogue (Boudreau & McCann, 1994, 1995). This limitation is partly related to the lack of information concerning the symbolic aspects of human multimodal dialogue with spatial displays. These symbolic aspects pertain to the *significants* (i.e., objects, concepts, attributes, and relationships) that constitute the semantic content of a dialogue, and the *signifiers*, i.e., the verbal and graphical actions that are used to convey the significants over spatial displays. This study aims to determine the significants (spatial objects, tactical concepts, attributes and relations) of a planning task that commanders designate or generate on a map through the concurrent use of verbal and graphical actions. The analysis will use these two types of signifiers to identify the significants of the planning estimates.

The remainder of this section will provide a framework for the analysis, discussing the roles and relationships of signifiers and significants in the theory of the symbolic representation.

1.1 Components of the Symbolic Representation

Dialogue between humans is accomplished through the exchange of *signifiers*, symbolic tokens by which humans refer to *significants*. A significant can be an object, a concept, a property of an object (or concept), or a relationship between objects² (or concepts). Significants form the semantic content of a dialogue. Signifiers and significants are integrated in a cognitive structure called the *symbolic representation* (Piaget, 1983; Piaget & Inhelder, 1963) that includes the *symbolic properties* (lexical, semantic, and figurative) of the signifiers (Boudreau & McCann, 1995).

There are three general *modes* in which signifiers can be expressed, depending on the human sense-organ (or modality) involved: acoustic, haptic, or visual. Acoustic signifiers may be expressed either vocally (e.g., spoken words) or non-vocally (e.g., fire alarm). Haptic signifiers typically take a graphical form involving indentation of a surface. It is possible to perceive and produce these signifiers solely through touch, without recourse to vision (e.g., Braille signs). Visual signifiers may be expressed graphically or nongraphically. Visual-graphical signifiers are those that involve a

² The four types of significants are specialized to the degree necessary for the particular task for which a dialogue occurs. For instance, if the task involves the use of a topographic map, the level of specialization of objects might be rivers, or mountains.

physical reference to a graphical medium such as a map. The physical reference may be made without any visible mark being left on the medium. An example is the tracing of a linear feature on the graphical medium with the forefinger. The physical reference may, on the other hand, result in some visible mark being left on the medium, for example, a shape or a character (letter, number), produced through drawing or writing. Signifiers that have a visual component with no physical reference to a graphical medium are termed visual-nongraphical signifiers. These include mental images and signifiers in sign languages. Visual signifiers which arise from motions of the hand(s) will be termed *manual signifiers*.

Signifiers of different modes can be used either singly --- that is, *monomodally* --- or in combination --- that is, *multimodally* --- during human or human-computer interaction. Signifiers can be used monomodally when they can convey a complete meaning on their own. For example, manual signifiers in Sign Languages are capable of conveying a message that is completely equivalent to that of speech. These signifiers are fully lexicalised, that is, they have acquired through social convention, standardised forms³ and specified meanings. Several conventional signifiers (e.g., Braille signs, verbal signs, scientific signs) have these properties.

Nonetheless, fully lexicalised signifiers, such as acoustical-vocal signifiers, are often used concurrently with other modes such as visual-graphical signifiers. For example, a person might speak while gesturing on a graphical medium. One context in which signifiers are used multimodally is when human dialogue involves spatial significant or their portrayal on a graphical medium. In this type of context, references to single significant are *diviplexed* (Taylor & Waugh, 1991), i.e., conveyed through independent signifiers that contribute in a coordinated manner. One of the most important benefits of diviplexing is complementarity: if the contributing signifiers are independent, ambiguities or errors in one can be clarified or corrected by the other (Taylor & Waugh, 1991). For instance, an indefinite phrase such as "that one" can be disambiguated by an action pointing to a specific object on a graphical medium. Reciprocally, an action pointing to overlapping objects can be disambiguated by a concurrent definite noun phrase (e.g., "that route right here") (see Aogáin & Reilly, 1990; Biermann, et al. 1983; Levelt, Richardson & Heij, 1985; Neal & Shapiro, 1988). The visual-graphical and acoustic-vocal signifiers are both used to solve the identity of the significant. We call this process *bimodal referent resolution* (Boudreau & McCann, 1993). This process and that

³ The notion of "form" is equivalent to the mode (acoustic, visual, haptic) in which a signifier is expressed. For example, a spoken word has an acoustic form depicted as a particular word.

of diviplexing occur in multimodal dialogues. We will use both processes as a theoretical basis upon which to justify the use of both speech and graphical actions to determine the semantic content of a tactical planning task over a map.

2. Objective

In a previous study (Boudreau & McCann, 1994), we identified a lexicon of graphical actions that tactical planners use while interacting with a map display during a planning estimate. Graphical actions were defined as hand motions involving either a reference to a significant (e.g., geographical object) depicted on a map display; or the generation of a significant, whether or not the action left any symbolic mark on the display. The lexicon was developed by categorizing all graphical actions on the basis of the physical (geometrical and temporal) properties that visually distinguished the actions. The lexicon consisted of five categories: zero-dimensional pointing actions; one-dimensional actions that are either curvilinear or linear; two-dimensional actions; and drawings. The geometrical properties of the actions suggested their potential use as imitative signifiers that depict the geometrical or spatial properties of the significant. However, graphical actions are only partly lexicalised, and so they must be coupled with acoustical-vocal signifiers (spoken words) to identify the significant.

The aim of this study is to determine and categorize the significant (e.g., spatial objects, tactical concepts) of the same planning task that commanding officers conveyed through the concurrent use of speech and graphical actions. A following report will present the figurative relationships between the graphical actions and the significant related to these actions.

3. Method

3.1 Subjects

Seven commanding officers participated in this study (McCann & Moogk, 1983). Some of the participants had experience in commanding actual combat operations while others had extensive knowledge of Canadian military doctrine. Thus the participants tapped two sources of spatial information relevant for planning: one based on tactical experience, and the other on tactical knowledge.

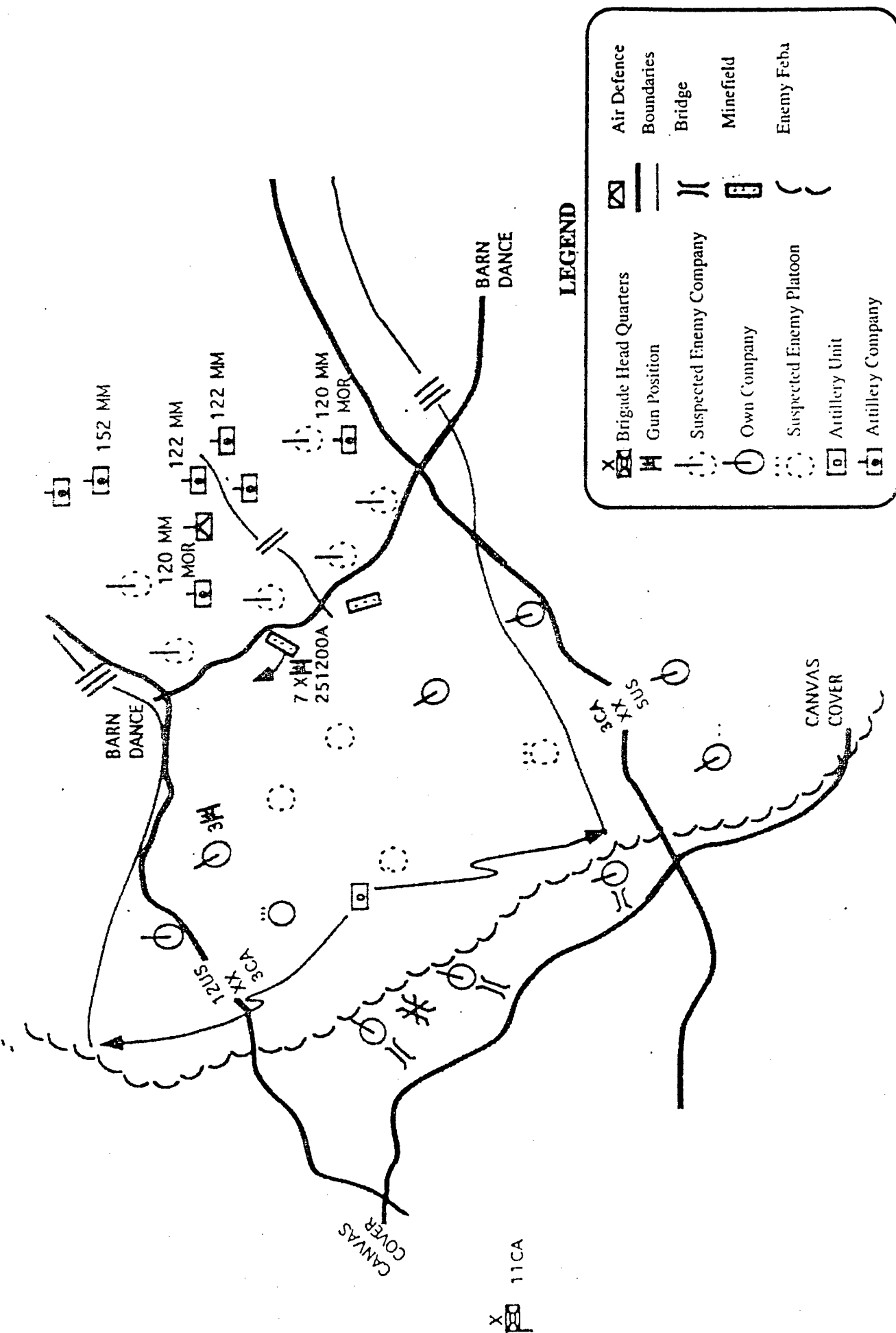


Figure 1. Schematic representation of the topographic map used for the tactical planning estimate.

3.2 Material

A topographic map of 1:50,000 scale (Germany series M745) depicted the geographical and tactical aspects of the scenario for the planning problem (see Figure 1). A plexiglas sheet covering the map allowed subjects to mark and erase graphical annotations. A video camera, mounted to the ceiling directly above the topographic map, recorded all graphical interaction with the map. In addition, all verbal commentary made by the subject was recorded.

3.3 Experimental Procedure

The task of the subjects was to orally develop an estimate of the tactical situation depicted on the spatial display from the perspective of the Brigade commander. The estimate was to be based on their tactical knowledge, the background information⁴ that they had reviewed prior to arriving for the study, and the Division orders and intelligence report that were now available. Subjects were permitted to mark the spatial display in any way using grease pencils provided. The tactical scenario and method are described in more detail in McCann & Moogk (1983).

To facilitate the participants' presentation, the military officer who had written the scenario took the role of the Regiment Artillery Commander, who is often present during the development of the estimate. (The Regiment is tasked by the Division to provide direct artillery support to the Brigade.) Upon completion of the verbal estimate, the experimenters reviewed the recordings with the commanders to clarify the nature of the spatial information (e.g., spatial object, concepts) used. The length of the sessions varied between 1 hour and 2 1/2 hours.

4. Results

The audiovisual recordings of the tactical estimates were transcribed verbatim. The transcripts included an embedded notation of a graphical action, i.e., the visual-graphical signifier that referred to a graphical object on the map display. As indicated above, the

⁴ This package consisted of a sketch map of the tactical area (scale 1:250,000), and a general concept of the tactical problem; an Intelligence report concerning the organization and equipment of own and enemy forces; and the military doctrine of enemy forces. Although the participants were familiar with this doctrine, this procedure gave them a common basis upon which to base the estimate of the tactical situation.

lexicon of graphical actions was developed separately (Boudreau & McCann, 1994). The data for this study were the verbal signifiers associated with each graphical action (i.e., the visual-graphical signifier) and any graphical object designated or drawn on the map display. The graphical object provided additional information on the identity of a significant.

4.1 Method - Identification of the Significants

The analysis was undertaken in three steps. The first consisted in pairing each visual-graphical signifier with its corresponding verbal signifier(s), and with any graphical object referred to or depicted by the hand action. The second step was to identify the planning phase at the time the visual-graphical signifier was invoked. The third was to determine the significant corresponding to the signifiers, using the planning phase as context.

For each of these phases, we used one or a combination of the following aspects of linguistic analysis: lexical, syntactical, pragmatic, and semantic. In brief, the lexical aspect refers to the signifiers, i.e., the verbal signifier(s) (words or word phrases) and the visual-graphical signifier, used to designate (or generate) a significant. The syntactical aspect pertains to the grammatical structure of a string of verbal signifiers. The pragmatic aspect refers to the context in which the verbal and visual-graphical signifiers occur, in this case, the tactical planning phase. Finally, the semantic aspect considers first the graphical object designated by the visual-graphical signifier, and second the significant related to each pair of signifiers⁵. These aspects of the analysis are elaborated in the following sections.

4.1.1 Step 1: Pairing of signifiers and graphical objects

Each visual-graphical signifier was paired with its corresponding verbal signifier(s). These signifiers were, in turn, linked to the graphical object(s) designated (or generated) by the visual-graphical signifier. To establish these triplets, we used two aspects of linguistic analysis: syntactic, and semantic.

The syntactical aspect of the analysis consisted in delineating the grammatical structure of the verbal reference (e.g., "that one") that co-occurred with a visual-graphical signifier. The verbal references had the grammatical structure of a phrase (e.g., a noun

⁵ A pairing includes one visual-graphical signifier and one or more verbal signifiers depending on whether the former co-occurs with only one word or with a phrase.

phrase such as "that area"). There is empirical evidence that phrases are synchronised with visual signifiers when the speaker is identifying a common referent (Condon & Ogston, 1971; Kendon, 1980; Levelt, Richardson & Heij, 1985; McNeill, 1981). The correspondence seems to hinge on the use of demonstrative pronouns (e.g., "this") and/or locative adverbs (e.g., "there") in the verbal phrase. In particular, Levelt, Richardson & Heij (1985) have shown that pronomial phrases (which include demonstrative pronouns such as "this" or "that") are produced in conjunction with an action pointing to the intended referent. Detailed analysis of the timing of voice onset, movement initiation and apex of the pointing action indicates that voicing of the noun phrases is synchronised with the apex of the gesture. Kendon (1980) has also observed a similar degree of synchronization between spoken phrases and the apex of iconic motions. Our syntactical analysis indicated that phrases, involving demonstrative pronouns and/or locative adverbs, were temporally adjacent to a visual-graphical signifier. Demonstrative pronouns and locative adverbs were thus used to delineate the syntactical boundaries of a phrase, thus delineating the verbal signifier. For example, in the sentence "this unit will take this road here", the phrases are "this unit" and "this road here"; each of these synchronized with a pointing action, the visual-graphical signifier.

The semantic aspect linked each pair of signifiers to the graphical object(s) that the visual-graphical signifier designated or generated on the map. As indicated previously, the graphical object itself was not the significant per se. However, the graphical object provided some of the properties (e.g., linear feature) of the significant, especially visual ones.

The following example illustrates the way in which the commanders' protocols were transcribed to include linkages between the signifiers (verbal and visual-graphical) and graphical object(s) (contained in <>):

"<This unit--- subject points at a brigade unit>⁶ will be deployed onto <this avenue of approach---subject moves his forefinger along the length of a route> whereas <that one---subject points at a squadron> will take <this one---subject draws a linear segment>."

In summary, each subject's dialogue was transcribed and organized so that the parsed multimodal dialogues included the paired signifiers-graphical object(s) as in the above example.

⁶ In the sentence, the angle brackets include the signifiers paired together with a graphical object.

4.1.2 Step 2: Classification of the multimodal dialogues according to tactical planning phases

The second step of the analysis involved classifying the protocols according to tactical planning phases. These planning phases were determined using lexical and syntactical aspects of linguistic analysis. These aspects cued respectively on the key words and key phrases that are typically used in planning phases as defined by the Canadian military doctrine. A description of the process is given in Appendix A.

4.1.3 Step 3: Identification of the significant

In the third step, we identified the significant corresponding to the paired signifiers. This required semantic and pragmatic aspects of linguistic analysis.

The semantic aspect of the analysis helped to specify the identity of each significant by pairing the signifiers with their corresponding graphical object. The analysis is based on the hypotheses that visual-graphical and verbal signifiers designate complementary aspects of the same significant (McNeill, 1985, 1987; Kendon, 1980, 1985) which is thus divplexed through these signifiers (Taylor & Waugh, 1991).

We used the graphical object(s) as an additional source of information on the identity of the significant. For example, the following portion of protocol illustrates the coupling from which the significant were derived:

"<This unit---subject points at a brigade unit> will be deployed onto <this avenue of approach---subject moves his forefinger along the length of a route> whereas <that one---subject points at a squadron> will take <this one---subject draws a linear segment>."

Each visual-graphical signifier co-occurs with a phrase of the sentence, and at the same time designates a particular graphical object, thus permitting the identity of the significant to be deduced. The two linear actions in the above example designate different linear objects: the first action outlines a route already symbolized on the map display; whereas the second one represents, by a drawing, an approach unrelated to any existing route. This second action thus indicates a conceptual significant that the commander has created.

Finally, the pragmatic aspect of the analysis used the context in which the signifiers occurred, i.e., the planning phases (see Appendix B), as a guide for identifying the significant. When possible, we used the exact nouns and verbs employed by the planners

(e.g., "this area of approach": area of approach) to denote the significant. When planners used pronominal phrases (e.g., "this one") or indefinite phrases (e.g., "this area"), we referred to the immediate antecedent phrase (e.g., "this brigade area"), in addition to the graphical object, to determine the proper referent of these phrases.

In summary, we determined the identity of each significant by: (1) coupling the visual-graphical and verbal signifiers together with the graphical object(s); and (2) deducing the significant in the context of the planning phases within which it occurred. The example described above illustrates four of the significant thus identified: "brigade unit", "avenue of approach", "squadron", and "avenue of approach". From a total of 568 signifiers, 382 unique significant were deduced. These are presented in Table 1.

4.2 Results: Defining Classes of Significant

We developed a representational scheme for organizing the significant. A representational scheme (Borgida, Mylopoulos, & Wong, 1984) is an explicit structure for representing classes of knowledge that are instantiated by significant. In this study's representational scheme, the significant were categorized on two dimensions: spatial classes, and type of significant. The spatial classes are defined in section 4.2.1. The types of significant are defined in section 4.2.2.

4.2.1 Spatial Classes

A total of four main spatial classes with various subclasses were determined from the significant's common spatial characteristics. These spatial characteristics were geographical, geographical, and/ or tactical characteristics having a geographical component, such as the deployment of units along routes. The spatial characteristics are fully discussed in section 4.3.

The first spatial class comprises significant which refer to the *geographical features of the area of operation*. The second class groups significant which denote the *tactical features of the area of operation*. This class includes tactical significant such as boundaries, areas of concealment and cover which defend against observation and fire, avenues of approach towards the enemy, and obstacles that counter these approaches. The third class (*combat power*) includes significant which denote the types of military unit that occupy or may occupy the area of operation, and their firepower. The fourth class encompasses the probable *courses of action*, which include tactical operations, disposition, and deployment of combat units.

The geometrical properties of the visual-graphical signifiers elucidated the spatial characteristics of the significant, and thus provided a basis to identify the above spatial classes. As an upcoming study suggests, zero-dimensional (pointing) actions were generally used to designate or locate n-dimensional significant (70%), i.e., significant for which the dimensionality was neither specified verbally or graphically on the map. These significant included combat units, artillery (minefields), and courses of action planned for combat units, such as the disposition of platoons.

Linear actions and linear drawings were mainly used to signify one-dimensional significant (64% and 87% respectively) which included geographical lines such roads; tactical lines such as boundaries; and courses of action to be taken along these lines, such the deployment of a unit along a boundary. In contrast, curvilinear actions and two-dimensional rectilinear actions were rarely used to designate one-dimensional significant (2% and 5% respectively). Two-dimensional rectilinear actions were mainly used to depict two-dimensional significant (60%) including geographical areas such as hills; tactical areas such key terrains; and courses of actions taken within these areas, such as the disposition of a company around a key terrain. Curvilinear actions were used to depict two-dimensional significant as frequently as n-dimensional ones. These results suggest that the geometrical properties of the visual-graphical signifiers helped to identify the spatial characteristics of significant not easily conveyed through speech.

4.2.2 Types

We further categorized and differentiated the significant according to their type, i.e., whether they consisted of objects, concepts, objects (or concepts) including an attribute(s), objects (or concepts) including a relation, or a combination of the latter two. The grammatical structure of the phrase that was paired with the visual-graphical signifier was used as a basis for this classification as now described.

4.2.2.1 Objects / concepts

Objects and concepts were identified from a pairing of a visual-graphical signifier with a noun phrase (e.g., "this river", "an avenue of approach") or a pronomial phrase (e.g., "that one"). Concepts also include actions in the environment such as an attack. These conceptual actions were conveyed through verb phrases (e.g., "attack this one").

4.2.2.2 Attributes

Attributes of objects (or concepts) were deduced mainly from adjectival phrases ("a high ground", "this large area"). A determiner ("a", "an") or a demonstrative pronoun

("this", "that") followed by an adjective ("high") and a noun ("ground") are the essential components of an adjectival phrase.

4.2.2.3 Relations

Relations were deduced from the pairing of a visual-graphical signifier with a phrase that included a locative adverb (e.g., here) or a spatial preposition (e.g., around). Planners conveyed three sorts of relations: the location of an object (or concept), the relative location of an object (or concept), and the direction of an object (or concept).

Relations denoting simple location were deduced from locative adverbial phrases (e.g., "this company here") that consist of a noun phrase (e.g., "this company") followed by a locative adverb (e.g., "here", "there").

Spatial prepositional phrases (e.g., "along this area") indicated the relative location of an object or concept, or the direction of an object (or action). A spatial preposition (e.g., "along", "up", "around", "within", "across") followed by a noun phrase (e.g., "this area") are the basic components of this type of phrase.

Phrases involving two nouns linked by a spatial preposition indicated the relative location of an object (e.g., "bridges across water courses"). Phrases that included a verb (move) followed by a spatial prepositional phrase (e.g., along this avenue) indicated the relative location of an action (e.g., "move along this avenue").

The spatial prepositions "up", "forward" (e.g., an axis going up here, the axis forward) indicate direction. Thus phrases such as "coming up this way", "move forward in this area", are examples of concepts including direction.

The significants were thus classified by spatial classes and by type. In the following section, we will discuss the implications of this classification.

4.3 Results: Significants used in Tactical Planning

4.3.1 Geographical features of the area of operation

Significant referring to the geographical features of the area of operation pertain to general terrain and crossing sites.

Table 1 - Significants of a Tactical Planning task categorised according to Spatial Classes and Type

SPATIAL CLASSES	TYPE							Concept/ Object + Attribute & Relation
	Concept / Object	Concept / Object + Attribute(s)		Concept/ Object + Relation				
		Qualitative attributes	Quantitative attributes	Location	Relative location	Direction		
Geographical features of area of operation	General terrain	crest ¹ ridge (2) areas area (4) water courses (2) streams area of vegetation wooded area	high ground high area ground elevation ground slope alternate flanks steep country hill configuration (2) nature of terrain significant wooded area significant terrain alternate areas area with defiles	distant area extent of area extent of vegetation (3) width of valley	location of crest location of area (5)	river covering road		location of flat ground location of steep area
	Crossing sites	crossing points crossings route(2) gap road	area with defiles	extent of defiles	location of area with defiles	opening in area defiles within an area crossings along BD routes in area including bridges gap within minefields exit along front		extent of opening along a boundary extent of opening near minefields location of open area

¹ The number in parentheses indicates the frequency of occurrence of a particular significant.

(Table 1 continues)

Tactical features of area of operation	Tactical boundaries	area of operation defined by boundaries limit of exploitation boundary check points defining the area of operation boundary dividing area of operation boundary defining the objective area of the mission boundary of killing zone (2) coordinating boundary limits of movement distance designated by boundaries	line to be masked		location of inner boundary(ies) location of division boundaries			location of central axis
Lines of operation		line of attack						

(Table 1 continues)

Tactical features of area of operation (contd)	General tactical areas	part of area of operation (3)	area to circumvent area to avoid (2) main area of operation area for surveillance area of main operation area of operation		location of area of operation location of task area within which to operate	area around BD		
	Objective	battalion's objective BD	part of BD (3) choke point		area of BD			
	Key terrain		high ground(2)		location of key terrain			location and extent of area of ground attack
	Killing ground	killing ground killing zone			location of area of attack			location of dominating area location of dominating feature location and quality of area of observation
	Observation and fire		dominated approach dominated line dominated road dominated river dominating feature dominating line lack of intervisibility area of fire areas of fire area to screen	range of fire	location of fire location of fire support relocation of guns location of smoke screen position of observation location of area to dominate location of intervisibility	intervisibility along a crest intervisibility from a crest		

Tactical features of area of operation	Concealment and cover	area of little cover		location of hide location of hide for tanks(2) location of line of cover masking position in cover			
	General mobility	mobility	accessible area terrain mobility area of motion	distance to travel		motion across an area motion within canyon	tractability in alternate areas

<p>Tactical features of area of operation (contd)</p>	<p>Areas/Avenues of approach</p>	<p>area of approach (2) areas of approach avenue of approach (5) avenues of approach (2) axis</p>	<p>feasibility of area of approach (4) feasibility of approach infantry approach covered approach area of approach delimited by lines feasibility of avenue of approach (4) feasibility of track main axis major axis alternate avenue of approach alternate axes effect of march area on tank movement enemy's sole route quality of tracks restricted avenue of approach (3) selected courses</p>	<p>speed of approach width of axis</p>	<p>location of areas of approach location of avenue of approach (7) location of avenues of approach (3) location of march area location of squadron's avenue of approach location of opening and avenue of approach location of axis</p>	<p>approach within area approach through a defile location of GE to go from location of road leading to an obstacle/accessible obstacle road leading to a high ground road between locations routes outside main approaches (2) roads leading to a high ground</p>	<p>direction along avenue of approach direction of axis (2) circumventing avenue of approach</p>	<p>location of main areas of approach location and feasibility of area of approach location of high speed avenues of approach location and speed of avenue of approach location and direction of avenue of approach location and direction of axes location and feasibility of route location of alternate avenue of approach location of alternate avenues of approach undefendable position on avenue of approach</p>
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Tactical features of area of operation (contd)	Obstacles	choke point	difficult area (2) difficult route difficult terrain enemy obstacle wooded area impeding motion obstacle to deployment obstacles to mobility			difficulties in wooded area obstacle along BD location of obstacles between GEs ² location of difficulties in area location of dangerous crossing along BD ³		location of difficult position
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² GEs: goose eggs i.e., enemy positions

³ BD: BARN DANCE i.e. a line along a major river

Combat power	Own/ enemy forces	battle group (2) platoons troops armor company (4) tank company battalions enemy unit (10)	unseen enemy	size of force size of unit concentration of enemy force (2)	location of armored company location of battalion (4) location of company (2) location of reconnaissance unit location of unit location of units location of enemy unit (2) location of enemy units location of battalion group location of enemy area location of enemy areas location of enemy unit (3) enemy area (3) enemy location enemy position (3) enemy positions (3) position of armor group location of assault force company positions location of mobile unit	location and quality of forces location and size of forces location and size of enemy force location of large enemy unit location of concentration of enemy forces alternate company location
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Combat power (contd)	Artillery	minefield minefields (4) tanks (3)	grouping of tanks group of tanks		location of minefield (2) location of gun positions area of tanks location of enemy tanks location of tanks location of fire location of smoke screen	location of minefields within GEs	number of tanks in areas main gun positions alternate location of tanks
Courses of action	Tactical operations	maintaining a route route to observe minefield to avoid enemy activity use of tanks battle group tasks	maneuverable element offensive movement counter attack enemy retreat	sufficient time to operate		accessible enemy unit ridge across which to operate	direction of operation direction of retreat
	Disposition	disposition of battalion disposition of tanks disposition of armor	disposition of company in columns alternate position alternate disposition		location of disposition regrouping area location of enemy disposition (3)	disposition of battalion on high ground disposition of units along a river	

Courses of action (contd)	Deployment	deployment of unit deployment of battalion deployment of company deployment of enemy unit	excluded areas of deployment	extent of deployment	location of deployment (4) location of unit's deployment location of units deployment location of deployment of infantry location of deployment of forces location of deployment area location of route for deployment area of deployment (3) enemy's area of deployment location and movement of column	deployment along ridge deployment of company along route	directions of unit deployment direction of enemy deployment (3)	alternate direction alternate directions
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4.3.1.1 General Terrain

General terrain includes relief, water courses, and vegetation. Planners analysed relief in terms of physical attributes such as steepness (e.g., steep country)⁷, elevation (e.g., high ground, high area, ground elevation), slope (e.g., ground slope, alternate flanks), and configuration of hills (e.g., hill configuration). They also identified the location of high areas (e.g., location of crest, location of steep area).

Water courses were particularly important as potential obstacles. The rivers located along Canvas Cover and Barn Dance (see Figure of map) were the main geographical obstacles.

The attributes and location of vegetation were also important in the estimate. Planners identified and located flat ground (e.g., location of flat ground) and contrasted these areas against those which were densely forested (e.g., significant wooded area). In analysing those areas of vegetation, they identified the extent of vegetation (e.g., extent of vegetation), the width of valleys (e.g., width of valley), and the location of defiles (e.g., location of area with defiles).

These general terrain features were subsequently used for deductions pertaining to tactical features such as areas of observation and fire, and areas of concealment and cover.

4.3.1.2 Crossing sites

Crossing sites are passages that permit the movement of units across obstacles or through areas of low mobility. Planners referred to crossing sites as "gaps", "routes", "defiles", "crossings", "open areas", and "exits". They identified the attributes of these crossing sites (e.g., extent of defiles), and/or their relative location (e.g., extent of opening along a boundary, extent of openings near boundaries, defiles within an area), especially in relation to the objective (Barn Dance).

When considering the deployment of units in the direction of Barn Dance, planners analysed the relationships between crossing sites and observation/fire. These relationships depended partly on whether the units were progressing towards BD or had reached it. For units progressing towards Barn Dance, open areas such as valleys and defiles were potential crossing sites, but were also susceptible to enemy observation and fire. To provide protection, planners considered creating temporary crossing sites for their forces.

⁷ The examples given in parenthesis are drawn from Table 1; quotations denote verbatim excerpts from the commanders' protocols.

For instance, they considered screening an area with smoke to reduce enemy surveillance, and thus provide a temporary crossing sites for their units. The location of open areas was also important in determining areas where units could fire and deploy artillery (e.g., "<move your guns up to there---subject encircles an open area>").

For units at Barn Dance, planners located crossing sites on the river obstacle (e.g., crossings along BD) because enemy units had taken main defensive positions along that area. Some of these crossing sites were bridges over the river (e.g., area including bridges), while others were gaps within minefields (e.g., gaps within minefields). For instance, planners considered openings near minefields as crossing points if these allowed sufficient width (e.g., extent of opening near minefields) for the passage of units moving towards the enemy's defensive positions.

4.3.2 Tactical features of the area of operation

Planners considered the tactical area of operation from three views: tactical lines (sections 4.3.2.1 and 4.3.2.2), areas of tactical significance (sections 4.3.2.3 to 4.3.2.7), and mobility (sections 4.3.2.8 to 4.3.2.10).

4.3.2.1 Tactical boundaries

Planners designated three main types of tactical boundaries. One type was used to delineate the geographical area within which the planned operation was to take place. These boundaries had been established prior to the estimate. They were the 12US, and 3CA division boundaries, and the lines Canvas Cover and Barn Dance.

A second type of tactical boundary was used to organize the area of operation into areas of tactical significance (e.g., boundary dividing the area of operation). These tactical boundaries were deduced by the planners. Areas of tactical significance delineated as such included the objective of the mission, which planners defined to be near Barn Dance (e.g., boundary defining the objective area of the mission), and killing zones (e.g., boundary of killing zone).

A third type of tactical boundary, also deduced, assisted in coordinating the movement of units (e.g., coordinating boundary, limits of movement, distance designated by boundary). For instance, one commander drew an inter-battalion boundary, extending along the center of the area of operation, to divide it into two main areas of approach. This boundary provided a central axis dividing the deployment of units between the two areas of approach.

4.3.2.2 Lines of operation

In addition to boundaries, planners deduced lines of operation, namely:

- a) Check lines to ensure coordinated movement of units and equipment;
- b) Lines of resistance which planners define to stop or prevent the enemy from reaching an objective area;
- c) Lines to be masked, i.e., lines that planners intend to conceal from the enemy's view, or by which they intended to hinder an opponent force by standing in its line of fire; and
- d) Lines of attack used for offensive operations.

4.3.2.3 General tactical areas

Planners identified the area of operation (e.g., area of operation, area of main operation) and areas of tactical operation within that area (e.g., part of area of operation, area for surveillance). Because of the river obstacle along Barn Dance and the importance of securing it, they identified areas of tactical operation along it (e.g., area of main operation, area to circumvent).

4.3.2.4 Objective

The main tactical area was the military objective. Planners named the terrain surrounding Barn Dance (BD) (e.g., area of BD) or a portion of it (e.g., part of BD) as their objective. A choke point located near BD was also considered by one of the planners as being his major objective. They used the terms "aim" and "major objective" equivalently during the estimates.

4.3.2.5 Key terrain

A key terrain is a terrain feature whose seizure and/or control provides a marked advantage to enemy or own units. A high ground potentially provides a marked advantage since it can be seized to overlook a significant proportion of a tactical area, and thus permit its control. For example, a high ground located near an enemy's avenue of approach is a key terrain because its seizure and control permits full observation of units advancing along the avenue of approach (example: "This area dominates this avenue of approach"). For these reasons, planners usually select high grounds as key terrains.

4.3.2.6 Killing ground

Planners identified killing ground (e.g., killing zone, killing ground), its attributes and location (e.g., location and extent of area of ground attack). Some of these were in areas of Barn Dance.

4.3.2.7 Observation and fire

During the identification of key terrain, planners also noted additional high ground that would support the acquisition or control of key terrain. They explicitly made reference to ground dominating an area of interest ("this ground dominates this area"; "this hill dominates the northern approach to the objective") because such ground provided good observation over enemy positions.

Intervisibility between own units was also an important factor in planners' identification of dominating ground. They specifically noted crests (or ridges) as providing potential intervisibility (e.g., intervisibility along a crest, intervisibility from a crest) in addition to observation (e.g., position of observation) over approaches.

4.3.2.8 Concealment and cover

Planners identified and located areas which had the potential to provide concealment from enemy observation (e.g., location of hide), and cover from their fire (location of line of cover). Areas which offered these forms of protection were termed "hides" and "lines of cover" respectively (e.g., "This tank company is probably located in a hide, somewhere in this forested area."). For instance, heavily forested areas offered concealment since these areas were difficult to survey even from a position of observation located on high ground. When planners suspected the location of enemy units within hides (e.g., "There is possibly a tank company within this area."), they eliminated those areas as possible areas of approach.

4.3.2.9 General mobility

There were a few general references to mobility or motion within an area, but many significant referred to specific areas of mobility in terms of areas or avenues of approach, and obstacles to these approaches, as described below.

4.3.2.10 Areas of approach and avenues of approach

Areas of approach and avenues of approach are regions within the area of operation that offer the best mobility and accessibility to tactical objectives. Areas of approach are broad spatial areas which include tractable corridors, i.e., potential avenues of approach.

Though areas or avenues of approach may have an obvious geographical analogue, planners must proceed through one or more deductive (or intuitive) steps before selecting areas or avenues of approach. One of the planners in this study divided the area of operation into two areas of approach using a main axis (termed "axis of approach") to outline the central thrust of both areas of approach. Others first partitioned the area of operation into various areas of approach (also termed "approaches"). These areas of approach were then segmented into long linear corridors, potentially suitable as avenues of approach. Planners referred to these corridors as "routes", "tracks", "axes" in addition to "avenues of approach".

After identifying potential avenues of approach (or areas of approach), planners analysed and compared their attributes and relations (location, relative location, and direction). An important attribute was feasibility, evaluated on the basis of the type and size of the force that would use it, the type of equipment allocated to this force, and the speed required for its deployment. An avenue was considered feasible if:

- (1) it afforded enough width (e.g., width of axis, restricted avenue of approach) and speed (e.g., speed of approach) to deploy a unit of a certain type (regiment, battalion, company) and size, and
- (2) it favored the passage of equipment allocated to these units.

For example, defiles which consist of narrow routes will hinder tank mobility. Consequently, planners will not consider them as feasible avenues of approach for tank platoons. However, a defile may be a suitable avenue of approach for soldiers marching in a file.

The location of an avenue of approach and its relative location, i.e., the terrain which surround it, also affected its feasibility. For example, one commander identified a road leading to a high ground (e.g., road leading to an obstacle) as an unfeasible avenue approach because enemy units could occupy that high ground, thus exposing friendly units to their observation and fire. Thus, because of their location, certain avenues of approach were considered unfeasible (e.g., an undefendable position on avenue of approach) even though they were tactically favorable. An equally important relation was the direction of an avenue of approach relatively to an objective (or an obstacle).

After evaluating the attributes and relations of alternate avenues of approach (or areas of approach), planners selected the main one (e.g., main axis, major axis) or most likely ones (e.g., location of main areas of approach, selected courses) when more than one was required.

4.3.2.11 Obstacles

Obstacles are any natural or man-made features of the topography that significantly reduce mobility or access, especially to the objective. Since the value of an avenue of approach depends on its potential to reach an objective area (for example, a key terrain, a killing ground), obstacles located along, or across, an avenue of approach will affect its feasibility. Thus, obstacles were important in assessing the feasibility of avenues of approach.

Planners sometimes identified the nature of terrain obstacles more specifically; for example, if avenues of approach traversed build-up areas, they qualified these areas as "choke points", because these areas had the potential to slow down the passage of units along the avenues of approach. Other obstacles were wooded areas, rivers, and steep areas.

The location of obstacles was also a factor in evaluating their relative importance. For instance, enemy-occupied high ground overlooking a defile could be an obstacle to a potential avenue of approach because the resulting exposure of own troops to enemy observation would prevent its use. Incrementally, obstacles which were located near the main objective area (i.e., Barn Dance) were potentially more difficult to breach since enemy units created them as defense barriers.

Planners identified the area of Barn Dance as the main objective area. While analysing avenues of approach towards that objective area, they also emphasised various dangerous crossings located along both of its sides. On the west bank of Barn Dance, minefields hindered crossing points over the river, and enemy units had mined certain bridges. On the east bank of Barn Dance, the position of enemy companies further dominated and restricted the approach of friendly units once over the river. Thus, the two sets of obstacles reinforced each other.

As planners evaluated obstacles, they also considered the possibility of breaching them by finding or creating crossing sites. The availability of crossing sites through obstacles to an avenue of approach increased its feasibility.

4.3.3 Combat power

Planners evaluated combat power in terms of two factors: own/enemy forces and artillery.

4.3.3.1 Own/enemy forces

When evaluating the relative strength of own and enemy forces, planners identified the type of units (e.g., platoons, companies, battalions), attributes such as size (e.g., size of forces) and concentration (e.g., concentration of enemy forces), and their location (e.g., location of enemy forces). Though planners knew the attributes and location of friendly units, this information was uncertain and incomplete for enemy units. As a consequence, they referred to probable enemy attributes and locations ("we suspect four companies over Barn Dance"), or alternate ones (e.g., alternate company location, alternate location of tanks).

4.3.3.2 Artillery

The attributes and location of artillery were also essential in determining relative combat fire power (example: "there are protective minefields in these areas"; "these are the main gun positions"). Fire power depends on intervisibility between friendly units and/or their capacity to cover each other with fire. Positions that provide both forms of support constitute mutually supportive positions. For instance, certain planners made specific references to the relationship between intervisibility and fire support between companies (example: "This company and this one, they can see one another, they can support each other with direct fire.").

Alternatively, enemy fire support help to assess obstacles to own mobility. For instance, enemy units had laid protective minefields around bridges over major crossing sites, namely the rivers located respectively along Canvas Cover and Barn Dance. While they had mined some of these bridges, these demolitions did not entirely influence approaches to the river near Barn Dance. Planners located gaps amongst these minefields, and proposed covering others with smoke screens to provide concealment for crossing units.

4.3.4 Courses of action

Planners defined courses of actions in terms of tactical operations, disposition of units, and their deployment. They specified the location of courses of action, their direction, and analysed alternate dispositions and directions. For example, the disposition of own units along a crest line would provide them intervisibility. Planners contrasted these selections to areas to avoid, or exclude for courses of actions. Courses of action were tactical concepts (i.e., conceptual actions) that planners had generated and represented on the map.

5. Discussion

As we have seen, the above types and spatial classes of significant were instantiated through specific spatial significant (geographical and tactical) discussed during the different planning phases. These significant were deduced from each planning phase, excepting two: one addressing the climatic and weather conditions, and the other the temporal factor⁸. Planners discussed these two planning phases without the use of visual-graphical signifiers perhaps because the significant related to those phases are not easily amenable to physical references to the map. Nonetheless, the general use of visual-graphical and verbal signifiers across the planning estimates suggest that they have together an important role for communicating and analysing the spatial significant of tactical planning.

The particular communicative role of visual-graphical signifiers is to depict or represent the figurative characteristics of significant (e.g., their attributes such as shape, and relations such as location) that are not efficiently described through speech (Boudreau & McCann, 1995; Graham & Argyle, 1975; Graham & Heywood, 1975; Slama-Cazacu, 1976). This *figurative function* of visual-graphical signifiers would be carried out through their imitative properties (Boudreau & McCann, 1995). This function has also been observed for certain visual-nongraphical signifiers such as iconic gestures (McNeill, 1985), illustrators (Ekman & Friesen, 1972), and iconographic gestures (Efron, 1941). It is the figurative function of certain visual signifiers, also called a *modelling*

⁸ A preliminary analysis suggests that commanders used measuring hand actions to estimate certain temporal and spatial factors. Since measuring actions are part of Euclidean operations (Piaget, Inhelder, & Szeminska, 1948) while visual-graphical signifiers are not; these measuring actions were not included in the lexicon of visual-graphical signifiers nor in the present analysis.

function (Lee, 1991), that suggests that they play a significant role in human or human-computer multimodal dialogue.

6. Conclusions

This study aimed to determine the semantic content of tactical planning conveyed through multimodal dialogues. The tactical scenario used for the planning estimates described a highly likely scenario for Canadian Forces Operations. Consequently, the set of significantants that were identified in this study forms an intrinsic part of the knowledge used for tactical planning. However, the set may depend on the particular military scenario (offensive scenario) and its geographic setting (southern Germany). Thus, the results of this study should be generalized to other planning tasks conveyed through multimodal dialogues.

In pursuing these studies, the method and the representational scheme that we developed should provide a basis for analysing and categorising the significantants of the planning estimates. These two contributions should also be useful for the design of multimodal interfaces since these interfaces are intended to identify the significantants that form the semantic content of human multimodal dialogues. To our knowledge, no study had yet developed a methodology that would enable this identification.

There are many other issues that need to be addressed for the design of multimodal interfaces. Four of these emerge from this study. First, multimodal interfaces should be extended to the recognition of continuous visual-graphical signifiers other than written ones (Wolf, Rhyne, & Ellozy, 1989). The recognition techniques, based for example on neural networks, would be similar to those used for continuous speech recognition. Second, experimental studies should clarify the temporal relationships between verbal and visual-graphical signifiers since these relationships are essential to identify their common significant. Third, because the graphical objects that were designated or drawn on the map helped to identify the significantants, interfaces, which are now capable of recognising written symbols (Wolf, Rhyne, & Ellozy, 1989), should be extended to the recognition of those graphical objects. Finally, multimodal interfaces should solve the identity of a significant by integrating the signifiers, the graphical objects, and the context within which they occur. This integration should lead the most plausible identification of a significant.

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8. Appendix A. Key terms and Key Phrases corresponding to each

Tactical Planning Phase

Key terms and key phrases corresponding to each tactical planning phase

In order to maintain consistency across the classifications of the estimates, we identified a list of key terms and phrases that typically represent each planning phase described by the Canadian military doctrine and the commanding officers of this study. For each section, we included excerpts of the commanders' planning estimates so to cover representative examples of the terms (and phrases) that they used. The planning phases "climatic and weather conditions" and "temporal factors" identified in appendix B did not involve the use of visual-graphical signifiers. However, the commanding officers did discuss these two sub-phases during their estimates.

8.1 Planning Phase I: Definition of the Aim

Noun phrases (the aim, the objective)⁹ and adjectival phrases (his major objective, my main objective) referred to the concept of aim or objective. During the estimates, commanders may have used these terms interchangeably.

8.2 Planning Phase II: Definition and Analysis of Factors

8.2.1 Analysis of the area of operation

Noun phrases referred explicitly to: area of operation, area of main operation. Some also used the phrase "area of responsibility" to designate the area of operation.

8.2.1.1 Analysis of the geographical features of the area of operation

Climatic and weather conditions

These factors were not assessed with a visual-graphical signifier.

Terrain conditions

Adjectival phrases described terrain configuration (a high area, high ground, the lower ground, infantry ground, a narrow valley, flat ground, a massive area) and nouns referred to hydrography (rivers, creeks, water courses).

⁹ The examples given in parenthesis are protocol excerpts.

Noun phrases specified the extent of vegetation (lack of vegetation, more vegetation, predominance of foliage, all kinds of defiles), and verb phrases described terrain elevation (the ground is sloping up; it tends to get higher).

Crossing sites

Crossing sites were identified from noun phrases (crossing points, terrain mobility), adjectival phrases (open areas), and nouns (passages, bridges, gaps, roads, routes).

8.2.1.2 Analysis of the tactical features of the area of operation

Tactical lines

Nouns or noun phrases denoted one or several boundaries (Barn Dance, Canvas Cover, the 12 US, the 3CA), and a limit of exploitation (limit of exploitation). Adjectival phrases specified regiment boundaries (regiment boundaries), and inner boundaries (inner boundary, inner battalion boundary, central axis).

Key terrain(s)

Adjectival phrases emphasised high grounds (the high ground; the significant: the higher area), or a key terrain(s) (the key terrain).

Killing ground(s)

Noun phrases referred directly to a killing area (a killing zone, the killing ground, this area of ground attack). If the commander indicated the reason why an area should be considered as a killing ground, without explicitly identifying it as such, the area was considered as a killing ground. Other phrases were much less clear (this spaghetti area, get down to the nitty gritty) even when we considered the clauses (or phrases) preceding them.

Observation and fire

In the case of observation, nouns emphasised the notion of intervisibility (intervisibility), and noun phrases indicated areas of observation (position of observation, areas of observation). Sentences specified the dominating action of a terrain feature (this area dominates this approach), or a dominated feature (this area is dominated by this approach).

In the case of fire, noun phrases and adjectival phrases referred to smoke screens (smoke screens) and areas of fire (open areas for fire, areas of fire, range of fire). Verb

phrases referred to the action of screening an area with smoke (to screen this area with smoke, fire on suspected enemy positions, relocate guns).

Concealment and cover

Nouns and noun phrases referred to hides for concealment (a hide, a hiding), cover (cover), and positions providing cover (line of cover, a masking position in cover, this back door).

Mutually supportive positions

Sentences included verbs which emphasised support or lack of it (this company will receive some support from his board, but the company is isolated; support of crossings). Other sentences indicated a relationship between fire support and intervisibility (this company and this one, they can't see one another, they certainly can't support with any direct sort of fire). Other sentences specified the reinforcing action of a unit (tank company reinforcing a location).

Avenues of approach

Noun phrases (or nouns) referred to areas of approach (area of approach) approaches (approach), and avenues of approaches (avenue of approach, courses of approach). We classified an axis or a route (road, trail, march area, tracks) as an avenue of approach when the commanders identified it as a possible loci for the deployment of forces (e.g., we will go south along this one; go along this axis). We also categorised roads as avenues of approach if they lead to a high ground (a road that leads to a high ground), and if the commanders compared their speed, width, and feasibility.

Obstacles

We identified ground features (e.g., woods, vegetation, defiles, rivers) and enemy assets as obstacles when commanders referred to them using nouns (or adjectives) such as: difficulty, problem, concern, obstacles, dangers. For example: this company can give you a hard time; there are pieces of ground that could cause us some difficulties; it (river) looks like an obstacle, and it looks like a formidable one. Other adjectives which referred to the notion of obstacle were: though (a very tough terrain to go through), hard (that company can give you a hard time).

Verb phrases indicated an area to avoid (minefield to skirt), or an impediment to mobility (river slowing motion). Other phrases were less clear, but did suggest potential problems (how to deal with this; a minefield covering a road).

8.2.2 Relative combat power

8.2.2.1 Own/ enemy forces

Nouns or noun phrases identified units (units) or types of units (battalion, company, maneuver, squadron, brigade troops, group of tanks, forces, the enemy, battle group, platoons); adjectival phrases (suspected positions) and verb phrases (suspect four companies over BD) specified suspected units' locations.

8.2.2.2 Artillery

Adjectival phrases identified types of artillery, such as minefields (protective minefields), tanks (tank platoons), and gun positions (the main gun positions).

8.2.3 Temporal factors

As indicated, visual-graphical signifiers were not used to refer to the temporal factors.

8.3 Planning Phase III: Definition and Analysis of Courses of Action

8.3.1 Tactical operations

Phrases or sentences typically included verbs which indicated an offensive or a defensive action. Verbs that commanders used to describe these operations were: take (take his area), secure, clear (clear this area), capture, get, threaten, brake, swing (swing the mobile element), get (get that position), outflank, neutralize, clean (clean this area), scoop up (scoop up an area), mask (mask a position).

As we indicated, verb phrases which specified a dominating action (e.g., this area dominates this approach) were specific to the planning phase "observation and fire". However, if the subject of the verb "to dominate" was a unit, not an object, then we considered the verb as a tactical operation, for example: "our function is to dominate this area". In few cases, nouns phrases also referred to tactical operations (a handful for the battalion, a true offensive movement).

When verbs did not specify clearly the nature of an action (chances to do something here), we examined the verb phrase which occurred in the antecedent clause, or sentence. If one of the latter indicated a tactical operation, then we classified the subsequent phrase accordingly.

8.3.2 Disposition

Sentences and phrases specified disposition in terms of:

- the positioning of troops (put an infantry here; put a battalion here; this is where I will put my tanks; put a squadron here; take up a position up here; concentrate our two battalions up);
- areas of reorganization or regroupment (my folks are reorganizing here; regroup at this point);
- the relative position of units (put an armor on this position and a company in reserve following up; that [battalion] covers much of the high ground; put his forces around here); and
- the arrangement of units (this would make me a battalion here and a battalion here; consider another disposition).

8.3.3 Deployment

Verb phrases specified the potential organization of units' movement and/ or the direction of their movement (going in this direction; one reserve going up in these directions; follow it up to this area here; go this way; take it along this route; put them on this route; move up your force; move the stronger one through here; move in a very forward approach).

9. Appendix B. Tactical Planning Phases

Tactical Planning Phases for Ground Operations:

Tactical planning is a cognitive process by which commanders analyse the factors influencing a tactical situation, and from which they will take decisions concerning the feasible course(s) of action(s) to pursue relative to their aim. In the Canadian Land Forces, commanders do the estimate themselves, or on their orders, allocate this function to their staff officers. Tactical planning comprises four major phases:

- a) Definition of the aim
- b) Definition and analysis of factors
- c) Definition and analysis of courses of action
- d) Definition of a plan.

These major phases are applicable for ground, sea, and air tactical planning. Tactical planning and the effective execution of the plan itself are part of a broader tactical concept called a *mission*.

9.1 Planning Phase I: Definition of the Aim

Commanding officers first define the *aim*, which is a definite tactical feature, the seizure or control of which is essential to the higher commander's plan. This definite tactical feature has a geographical analog, i.e., a specific physical object (or group of objects) located within a broader geographical area called the *area of operation*.

The definition of the aim includes various substeps leading to a full understanding of the higher commander's aim. These substeps include: a) a review of the commander's analysis of enemy intentions; b) a review of the political, administrative, and operational limitations; and c) an analysis of combat forces involved.

9.2 Planning Phase II: Definition and Analysis of Factors

During the second planning phase, commanders define and analyze each factor that may influence the accomplishment of either opponent's aim. These factors include:

- a) the area of operation within which the tactical scenario will take place (section 9.2.1)
- b) the relative combat power of own/ enemy forces (section 9.2.2), and
- c) the temporal constraints during which it will be possible to exert this combat power (section 9.2.3).

The analysis of these factors enables commanders to deduce the *net combat power* of each opponent, thus preparing them for a definition of courses of actions (planning phase III).

9.2.1 Analysis of the area of operation

An *area of operation* constitutes a defined area of land for which the commander has the responsibility to develop and conduct courses of action involving units under his control. In the tactical scenario presented by McCann and Moogk (1983), the area of operation was defined by the 12US, and 3CA division boundaries, and the lines Canvas Cover and Barn Dance.

The analysis of the area of operation is usually done with an intelligence officer(s). This analysis, which is qualified as "combat intelligence", has three objectives: (1) to produce estimates of the enemy's intentions, (2) to determine the terrain features available to enemy forces, and (3) to determine the effects of those terrain features on feasible courses of action. Commanders analyse the area of operation in terms of its geographical and tactical features.

9.2.1.1 Analysis of the geographical features of the area of operation

Climatic and weather conditions. Commanders analysed the effects of meteorological conditions on terrain, such as the effects of fog on ground observation. These factors were particularly important in assessing visibility and tractability.

Terrain conditions. Analysis of terrain conditions includes that of relief (e.g., elevation, steepness, or slope), hydrography (e.g., water courses), and vegetation (e.g., wooded areas, and cultivated vegetation in non-wooded areas). For instance, commanders took into consideration the relative elevation of enemy positions because elevation provides intervisibility and fire support between these positions.

Crossing sites. In analysing geographical features, commanders also considered human changes to the topography (e.g., roads, bridges, towns) which could provide crossing sites or obstruct those leading to major routes. For instance, commanders identified build-up areas as choke points for units that would pass through those areas to reach major routes.

9.2.1.2. Analysis of the tactical features of the area of operation

Commanders analysed the area of operation in terms of eight tactical features:

- tactical lines
- key terrain
- killing grounds
- observation and fire
- concealment and cover
- mutually supportive positions
- avenues of approach
- obstacles

Tactical lines. Tactical lines delineate the area of operation and divide it into tactical areas. In the scenario presented by McCann and Moogk (1983), the tactical lines provided to the brigade level commander were the inter-unit boundaries used to delineate the area of operation: the 12US, and 3CA division boundaries, and the lines Canvas Cover and Barn Dance. These tactical lines were well defined on the map display from the beginning of the scenario. In contrast, others were generated during the planning activity to divide the area of operation into tactical areas.

Key terrain(s). A key terrain is a terrain feature, within the area of operation, which *seizure* and/ or *control* offers a *marked advantage* to either opponent. The term *seizure* implies physical occupation of an area, but it does not insure control. However, *control* can be exercised without physically occupying an area, but it requires the use of fire and/or air surveillance. An area offers a *marked advantage* if it can lead to the accomplishment of a force's aim.

Commanders identify a terrain feature as a key terrain if it meets one or a combination of the following conditions:

- if it is an objective for either opponent;
- if it affords an effective attack site which dominates an avenue of approach and/ or overlooks enemy-concentrated areas;
- if it impedes enemy communication and transportation.

Selected key terrains include, for instance: a) bridges over unfordable rivers, and b) high grounds overlooking a significant proportion of the area of operation.

During offensive courses of action, commanders often assign key terrains as objectives. For example, a city may act as a key terrain if it favors the seizure and/ or control of the enemy's lines of communication and transportation.

Killing ground(s). A killing ground constitutes an offensive area well covered by defensive fire, and in which the enemy is brought in, by the use of obstacles, to provoke his destruction.

Observation and fire. Observation refers to the ability of a force to exercise surveillance over an area, and to locate the enemy. When provided from ground, observation depends chiefly on high grounds since these usually provide the best observation points over enemy approaches or positions. In contrast, terrain features which restrict observation include for instance dense vegetation.

The term "fire", in relation to observation, pertains to the effects of terrain features on the efficiency of direct and indirect fire weapons.

Concealment and cover. Concealment consists in protection from observation, and cover refers to protection from fire. Most terrain features which provide cover also offer concealment, though the converse is not necessarily true. Commanders consider terrain features which give both types of protection for their mobile units because these features reduce their units' vulnerability against detection and/or destruction. From a defensive view, units deployed under concealment and cover have greater advantages of countering enemy units. For example, dense forests located on high grounds can provide both forms of protection.

Mutually supportive positions. Positions are mutually supportive when they provide intervisibility and tactical reinforcement for units which occupy such positions. Units separated from these positions constitute good targets for counter offensive measures.

Avenues of approach. Because the tactical significance of the above areas depends on the possibilities of reaching them, commanders further analyze the terrain into avenues of approach. An avenue of approach is a passage in an area of operation which is mainly impassable. Commanders consider various factors in estimating a passage as a potential avenue of approach. One factor is that it must provide sufficient width for the type and size of forces that they aim to deploy for a particular course of action. Another factor is its direction relatively to a course of action. For an offensive course of action, commanders analyze avenues of approach which lead from his own units' line of departure to the enemy's key terrain. Conversely, for a defensive course of action they analyse avenues of approach which lead from the enemy's line of departure to own units' key terrain.

Obstacles. Obstacles pertain to any terrain features that hinder mobility of own or enemy units in pursuing their aim. Obstacles include hydrography (e.g., swamps), relief

(e. g., cliffs), vegetation (e.g., defiles) and certain human changes to the topography such as minefields and roadblocks.

Commanders evaluate the effects of obstacles on both own/enemy courses of action. The effects of obstacles depend partly on their spatial orientation relatively to a course of action. Perpendicular obstacles to a line of attack favor defensive actions because they divert, or slow down the opponent. Likewise, parallel obstacles to a line of attack provide flank protection for the opponent's offensive actions, but they may interfere with his units' coordination. Hence, units engaging in offensive actions are to avoid obstacles that are perpendicular to their line of attack, but take advantage of those which are parallel to it.

9.2.2 Relative combat power

The definition of relative combat power involves a systematic analysis of the capabilities and limitations of both enemy and own units. Key factors for estimating combat power includes knowledge of: (a) combat units' organization and operational procedures; and (b) artillery which is characterised through order of battle. Order of battle includes an estimate of security units (e.g., reconnaissance, surveillance), maneuver units (e.g., infantry units, aviation units), fire support units, logistical units (e.g., refueling helicopters), and command and control units.

9.2.3 Temporal factors

In addition to analysing geographical and tactical features, commanders estimate the temporal limitations during which it is required and possible to attain the aim.

9.3 Planning Phase III. Definition and Analysis of Courses of Action

During the third planning phase, commanders outline and compare own/enemy courses of action. Courses of action have three major components: tactical operations (e.g., offensive actions, defensive actions), disposition of combat units, and deployment of such units. Courses of action are outlined in three general steps: analysis of enemy and own courses of action, comparison of opponent courses of action, and selection of optimal course(s) of action. Commanders can go through these steps sequentially or in parallel.

9.3.1 Analysis of enemy and own courses of action

By wargaming, commanders identify own/enemy feasible courses of action. These courses of action are essentially identified in terms of the four following aspects: (1) own/enemy intentions and level of threat; (2) the combat power available to both forces; (3) the spatial-temporal constraints during which the course(s) of action(s) will be effective and completed; and (4) their consistency with principles of war operations.

9.3.2 Comparison of opponent courses of action

Commanders compare opponent courses of action, and deduce potential outcomes for each comparison. These deductions lead them to infer: (a) the courses of action that the enemy is most likely to adopt, and (b) the capacity of own courses of action to adapt to the enemy's.

9.3.3 Selection of the optimal course(s) of action

Having anticipated the potential outcomes of opponent courses of action, commanders select the one(s) which offers the highest probability of success. The optimal course(s) of action must meet at least three criteria:

- it must enable the commander to reach his aim within imposed limitations;
- to adapt to predictable enemy reactions; and
- to imply a minimum, or accepted degree of human risk.

9.4 Planning Phase IV: Definition of a Plan

Commanders complete the tactical estimate by transposing the selected course(s) of action into a plan outline. This plan outline states the tactical plan in the elements of why (the mission), what (the aim), where (the area of operation), by whom (combat units), when (spatial and temporal constraints), and how (the courses of action). The commander and his staff officers will use this plan outline to develop the remainder of the tactical plan.

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This study addresses the semantic content of tactical planning conveyed through human multimodal dialogues over a map. Specifically, the aim of this study is to determine the significant (e.g., spatial objects, tactical concepts) of a tactical planning task that commanding officers convey through the concurrent use of verbal and graphical (hand) actions.

Seven military officers provided verbal and graphical estimates of a tactical situation portrayed on a topographic map. These sessions were videotaped. The graphical components consisted of graphical actions involving a physical reference to a topographic map. These graphical actions were defined as visual-graphical signifiers in a previous report.

A set of significant was determined from the analysis of the commanders multimodal dialogues in their verbal and visual-graphical components. These multimodal dialogues were analysed using lexical, syntactical, pragmatic (planning phases) and semantic levels of linguistic analysis. The significant (N=382) were categorised, in a representational scheme, along two dimensions: spatial classes and type. The first dimension grouped the significant in four classes: geographical features of the area of operation, tactical features of the area of operation, combat power, and courses of action. The second dimension categorised the significant according to their type, i.e., whether they consisted in objects, concepts, attributes of objects (or concepts), or relations pertaining to objects (or concepts).

The significant identified in this study represent an intrinsic part of the knowledge used during tactical planning. These significant were deduced from all but two of the planning phases. Since commanders used both verbal and visual-graphical signifiers to identify the same set of significant, then both types of signifiers should be paired for the interpretation of other planning estimates. The methodology and representational scheme that we developed in this study should provide a basis for pursuing these tasks. These contributions should also be useful for the design of multimodal interfaces since these are aimed at identifying the significant that make up the semantic content of human multimodal dialogues.

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Human-Computer Multimodal Interfaces

Multimodal Dialogue

Ground Tactical Planning

Speech

Graphical Actions (Hand Gestures)

Semantic Aspects of Multimodal Dialogues