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FIGURATIVE PROPERTIES OF VISUAL-GRAPHICAL SIGNIFIERS IN TACTICAL PLANNING OVER A MAP

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TABLE OF CONTENTS

Abstract

This study aims to elucidate the figurative relations between spatial significants, such as geographical objects, and the visual-graphical (hand) signifiers that commanders use to designate or generate these significants on a map during a tactical planning task. Specifically, the objective is to specify whether visual-graphical signifiers have a physical property, such as a geometrical form, that reproduces a corresponding property of their significants. This study is part of a broader project aimed at specifying the symbolic (lexical, semantic, and figurative) properties of graphical actions in multimodal dialogues over a map during tactical planning. Knowledge of these properties will be used in the design of multimodal interfaces aimed at recognising and interpreting such graphical actions. The design of multimodal interfaces is in turn part of the development of digitized land forces.

Seven commanding officers provided verbal and graphical estimates of a tactical scenario portrayed on a topographic map. These sessions were videotaped. The graphical component consisted of graphical (hand) actions which referred to significants on a topographic map. We identified these graphical actions as visual-graphical signifiers in a lexicon. We also determined a set of significants (objects, concepts, attributes, and relations) from the analysis of the commanders' dialogue in their verbal and graphical components. The data for this study were the lexicon of visual-graphical signifiers and the significants related to these signifiers. To elucidate the figurative properties of the visual-graphical signifiers, we classified the significants according to their geometrical properties (one dimension, two dimensions, and nonspecified dimensionality), and then grouped them according to the type of visual-graphical signifier to which they were related. The results indicate that visual-graphical signifiers figuratively relate to their significants' geometrical properties. The figurative properties of the visual-graphical signifiers suggest that commanders use these signifiers to depict significants on a map, and to represent the visual properties of those not easily nor completly conveyed through speech.

Executive Summary

Computers are now being used to support tactical planning and decision making through intelligent dialogue with humans. Military planners communicate with each other using both speech and graphical (hand) actions especially while discussing problems involving spatial data, such as geographical objects or concepts. The multimodal properties of their 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 for the design of multimodal interfaces capable of recognising and interpreting speech and graphical actions concurrently. Multimodal interfaces constitute an intrinsic component of digitized command and control forces.

However, multimodal interfaces have been typically limited to recognising and interpreting pointing actions, only one of the many different types of graphical actions that humans use to denote significants, such as objects or concepts, on graphical media. This limitation is partly related to the lack of information concerning the symbolic properties (lexical, semantic, figurative) of graphical actions in human dialogue, and the extent to which different individuals consistently generate these properties. Both sources of information are required for successful design of graphical interfaces which are a structural part of multimodal interfaces. As Rhyne and Wolf (1986) argue, the real productivity benefits of graphical interfaces depend on users' consistent use of graphical actions as this attribute increases the likelihood of their reliable recognition. There are two kinds of consistency that affects the efficiency of graphical interfaces: inter-subject consistency, the extent to which there is commonality across individuals in the symbolic properties of graphical actions, such as their geometrical form and meaning; and intra-subject consistency, the extent to which each individual reproduces a given action in the same geometrical form and for the same meaning.

Based on a tactical planning task over a map, we have shown in two previous studies that graphical actions have lexical and semantic properties, and thus constitute signifiers. This study aims to specify the figurative properties of the signifiers that commanders produced to designate or generate significants on a map during the tactical planning task. The figurative properties would imply that graphical actions have a geometrical form that reproduces a corresponding geometrical form of their significant.

Seven commanding officers provided verbal and graphical estimates of a tactical scenario portrayed on a topographic map. These sessions were videotaped. The graphical

component consisted of graphical (hand) actions involving a reference to significants on the topographic map. From the analysis of the commanders dialogues, we identified a lexicon of graphical actions, and the set of significants (objects, concepts, attributes, and relations) related to these actions. We used both data sets for this study.

To identify the figurative properties of the graphical actions, we classified the significants according to their geometrical attributes (one dimension, two dimensions, and nonspecified dimensionality), and then grouped them according to the type of graphical action to which they were related. The results indicate that graphical actions figuratively relate to their significants' geometrical attributes. The figurative properties of the actions suggest that planners use such actions to depict significants on a map, and to represent the visual properties of those not easily or completly conveyed through speech.

The results support the utility of designing graphical interfaces to recognise graphical actions. The graphical interfaces should allow the user to employ any part of his hand(s) to denote spatial significants on a two-dimensional surface as observed in this study, but also to generate significants in a three-dimensional space. The design of a graphical interface constitutes an intrinsic component of a multimodal interface capable of recognising and interpreting both speech and graphical actions concurrently.

1. Introduction

One may contend, as the propositionalist view would hold, that communication takes place essentially through natural language as a system of conventional and arbitrary *signs* (Pylyshyn, 1973; Palmer, 1975). Multimodal views of the symbolic representation (Kendon, 1985; McNeill, 1987b; McNeill & Levy, 1982; Pavio, 1986; Piaget & Inhelder, 1963) argue, however, that communication takes place through the exchange of *signifiers* which include not only *signs* but also *symbols.* Signifiers are symbolic tokens by which humans refer to significants[1], such as objects or concepts, in their presence or represent them in their absence (Piaget, 1983; Piaget & Inhelder, 1963; Saussure, 1959). For example, one can refer to an object by means of a word or an image. In their strict sense, signs are arbitrary because they do not have any similarities with their significant(s). Signs include verbal signs (oral and written words), scientific signs, and braille signs. In contrast, symbols have physical properties (acoustic, visual, and haptic) that reproduce those of their significant(s), and thus have a figurative function. Symbols include, deferred forms of imitation, graphical representations (e.g., map symbols), and mental imagery (Kosslyn et al. 1979; Pavio, 1986; Piaget, 1983; Piaget & Inhelder, 1963). Humans convey signifiers in three general modes depending on the modality or sense-organ used (Boudreau & McCann, 1996): acoustic (vocal, non vocal), visual (graphical, non graphical), and haptic (graphical).

Cognitive theorists (Ellis & Hunt, 1989; Kendon, 1980, 1985; McNeill, 1985, 1987a, b; McNeill & Levy, 1982) recognise a type of signifier that arises from the visual modality, i.e., from hand motions distinct from those involved in writing. These *visual signifiers* are capable of designating significants in their presence, or representing them even when they are not actually perceived at the time they are signified. For example, descriptors from sign languages (Cuxac, 1991) have such a symbolic function.

Visual signifiers would either have arbitrary properties in relation to their significants, as in the case of formless pointing motions, or figurative properties in common with their significants as in the case of drawing motions. Although cognitive theorists (see Ellis & Hunt, 1989; Kendon, 1972, 1980, 1985; McNeill, 1985, 1987b) have proposed arguments in favor of the figurative properties of visual signifiers, few studies (see McNeill & Levy, 1982) have been conducted to support these arguments.

[1] A *significant* refers to the meaning conveyed by a signifier. A significant may consist in an object, a concept, a property of an object (or concept), or a relation between objects (or concepts).

The purpose of this study is to elucidate the figurative properties of the visual-graphical signifiers that tactical planners use to designate or generate significants on a map during a tactical planning task. By virtue of these properties, the visual signifiers would have a physical attribute, such as a geometrical form, that reproduces a corresponding attribute of their significant(s).

This study will be based on a lexicon of visual-graphical signifiers developed from the tactical planning task (Boudreau & McCann, 1994), and the set of significants related to these signifiers (Boudreau & McCann, 1996). In the following section, we will describe the figurative properties of signifiers to provide a theoretical basis upon which to elucidate those of the visual-graphical signifiers.

1.1 Figurative Properties of Signifiers

Signifiers that provide an approximate reproduction of the physical attributes of significants are said to have figurative properties (Pavio, 1986; Piaget, 1983). Such signifiers include: imitation, deferred imitation, mental imagery, and descriptors in sign languages (Cuxac, 1991; Pavio, 1986). Verbal signifiers (oral and written words) also have figurative properties although they range on a continuum from being purely figurative (e.g., onomatopoeia) to purely arbitrary (e.g., mathematical signs). In contrast, mental images[2], deferred imitation, and imitation are essentially figurative (Jeannerod, 1994; Paivio, 1986; Piaget, 1983).

Mental images reproduce significants or their properties when they are no longer perceived. Psycho-physiological studies (e.g., Jeannerod, 1994; Paivio, 1986; Piaget & Inhelder, 1963) suggest that mental images constitute internal forms of imitation generated from previous sensory-motor activity. For example, the mental image of a postural movement involves a motor image sketching the effective production of the movement (Jeannerod, 1994; Piaget & Inhelder, 1963). Reciprocally, mental images also influence imitation.

Deferred imitation is a motor action (or a set of such actions) that humans use to reproduce, through the aid of memory, a significant that is no longer physically present. The production of graphical symbols (Lee, 1991) constitutes a particular sort of deferred

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[2] Arguments have been made against the hypothesis that mental imagery constitutes a pictorial representation of significants (for a review see Anderson, 1978). However, Paivio's (1986) Dual-Code theory of mental representation has reinstated this hypothesis, and Jeannerod (1994) has shown that it is compatible with recent neuropsychological models of such mental representation.

imitation in that the hand motion results in some visible mark, such as a shape, being left on a graphical medium. Imitation in its broad sense constitutes a motor reproduction performed in the presence of its significant rather than in its absence. For example, a linear motion might reproduce the linear shape of a route symbolised on a map.

Deferred imitation and imitation include a type of signifier called *visual signifiers* (Boudreau & McCann, 1993, 1996). Humans express visual signifiers either graphically or nongraphically. *Visual-graphical signifiers* are those that involve a manual (hand) reference to a graphical medium. The manual reference can be made without any visible mark being left on the medium. An example is the tracing of a linear feature on a map with the forefinger. The manual reference may, on the other hand, result in some visible mark being left on the medium, for example, a shape or a character (letters, numbers), being the result of drawing or writing. Signifiers that have a visual component with no manual reference to a graphical medium are termed *visual-nongraphical* signifiers. These include iconographic motions (Efron, 1941), physiographic motions (Freedman, 1977) spatial motions (Ekman & Friesen, 1972), iconic motions (see McNeill, 1987b; McNeill & Levy, 1982), and descriptors from sign languages (Cuxac, 1991). According to Freedman (1977) and McNeill (1987a, b), the above visual signifiers would depict, through overt manual activity, the mental imagery that occurs during speech, but that is not easily nor completely conveyed through speech. For example, a linear motion would represent the mental image of an avenue of approach. Visual signifiers would then symbolize the figurative properties of these mental images[3] as well as imitate those of significants that are physically present.

Humans would use the above signifiers, and in particular visual-graphical ones during dialogues over graphical media such as maps. Since military planning involves manual references to significants on such media (McCann & Moogk, 1983), we should expect the use of visual-graphical signifiers in denoting the figurative properties of the significants.

1.2 Objective

This study aims to elucidate the figurative relations between visual-graphical signifiers and the significants related to these signifiers. A figurative relation would imply that the visual-graphical signifiers have, by imitation, a physical property such as a

[3] A mental image may constitute a symbol for a significant, such as an object seen in the past, as well as act as the signified content, i.e., a significant for another signifier.

geometrical form that reproduces a corresponding property of their significants. The answer to this issue will help determine the symbolic properties of visual-graphical signifiers, and their use in communicating spatial significants during tactical planning. Both sources of information will provide a basis upon which to design graphical interfaces for human-computer multimodal dialogues.

2. Method

2.1 Subjects

Seven commanding officers participated in this study (McCann & Moogk, 1983). Some of the participants had experience in commanding actual combat operations (e.g., in the second world war) 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 doctrine.

2.2 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. 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 the subjects' graphical interactions with the map and their verbal commentaries.

2.3 Experimental Procedure

The subjects task was to develop and orally present an estimate of the tactical scenario depicted on the spatial display from the perspective of the Brigade commander. Subjects were to base their estimate on their tactical knowledge, background information[4] 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

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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 perform the estimate of the tactical situation.

using grease pencils provided. The tactical scenario and method are described in more detail in McCann & Moogk (1983).

To facilitate the participants' presentations, 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 oral estimate, the experimenters reviewed the recordings with each commander 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.

3. Results

The analysis of the figurative relations between the visual-graphical signifiers and the spatial significants is based on two sets of results: (a) the lexicon of visual-graphical signifiers (Boudreau & McCann, 1994), and (b) the total set of spatial significants related to these signifiers as they co-occurred with speech (Boudreau & McCann, 1996). These results are summarized in section 3.1. Section 3.2 describes the figurative relations between the signifiers and the significants. The results were obtained from naturally-occurring multimodal dialogues, but for this reason and because they were drawn from a small sample of subjects, they must be considered tentative.

3.1 Visual-Graphical Signifiers and Spatial Significants

3.1.1 Lexicon of Visual-Graphical Signifiers

Visual-graphical signifiers consisted of any graphical (hand) action involving either a manual reference to a significant (e.g., geographical object) depicted on the map; or the generation of a significant, whether or not the action left any symbolic mark on the display. We identified a lexicon of such signifiers from the total set of graphical actions that commanders used in the tactical planning task. We developed the lexicon by categorizing the graphical actions on the basis of the physical (geometrical and temporal) properties that visually distinguished the actions. The categorization approach differed from that of previous studies (Baraket, 1969; Efron, 1941; Ekman & Friesen, 1972; McNeill, 1985) in that these have not involved graphical media, and have been based on assumptions concerning the symbolic properties of the hand motions. For example, certain hand motions have been classified as *iconic*, assuming visual similarity between the hand motion and the object signified (McNeill, 1985). Our classification was based purely on the visual observation of the physical properties of the graphical actions.

Geometrical form was the primary visual property that we used to categorize the actions. We distinguished small formless "pointing" motions (either with finger or pen) from motions which traced a one-dimensional or a two-dimensional form. One-dimensional actions consisted either in tracing a linear form (categorized as "linear") or a curvilinear form (categorized as "curvilinear"). Two-dimensional actions consisted in covering an area with the hand or length of pen (categorized as "two-dimensional"). If the action resulted in a visible marking of the map, it was separately categorized as a "drawing". Thus all actions were classified into five main categories: pointing, one-dimensional actions that are either curvilinear (closed) or linear (open), two-dimensional (area-covering) actions, and drawings.

We further differentiated one-dimensional and two-dimensional actions according to their *momentum*: continuous or paused. We classified an action as continuous when it involved an uninterrupted change of hand position but a constant shape during the apex of the motion. During this temporal phase, the motion showed a distinct peaking of effort observable from its constant shape (Kendon, 1980). In contrast, paused motions involved holding the hand briefly in position at the apex. Drawings were intrinsically continuous.

Finally, with the exception of drawings, we distinguished the actions according to their *bidirectional* properties. We considered a graphical action as bidirectional when it involved an alternating displacement of the hand (or fingertip) from one position to another. While alternating positions, the form of the motion remained constant. A bidirectional pointing motion consisted of an alternative pointing motion directed at two different objects in a pair.

The lexicon comprises altogether 14 types of visual-graphical signifiers grouped within the five categories identified above. It consists of pointing actions (single, repeated, bidirectional); one-dimensional actions that are either curvilinear (paused, continuous, bidirectional) or linear (paused, continuous, bidirectional); two-dimensional area covering actions (paused, continuous, bidirectional); and drawings (symbols, linear).

3.1.2 Spatial Significants

We determined a set of significants from the analysis of the commanders' dialogues in their verbal and graphical components. These dialogues were analysed using lexical, syntactical, pragmatic (planning phases), and semantic aspects of linguistic analysis. The significants were categorised, in a representational scheme, along two dimensions: spatial classes and type (Boudreau & McCann, 1996).

3.2 Figurative Relations between Visual-Graphical Signifiers and Spatial Significants

To elucidate the figurative properties of the visual-graphical signifiers, we first classified the significants according to their geometrical attributes (one-dimensional, two-dimensional, or nonspecified (N) dimensionalily), and then according to the categories and types of signifiers to which they were related.

One-dimensional significants included:

- geographical lines (e.g., roads, water courses, crest lines, ridges, defiles),
- tactical lines (e.g., boundaries, lines of operation, avenues of approach), and
- courses of actions taken along these lines (e.g., tactical operations along a river, disposition or deployment of units along a boundary).

Two-dimensional significants included:

- geographical areas (e.g., area of vegetation, high grounds, wooded areas),
- tactical areas (e.g., key terrains, killing ground(s), areas of observation and fire, areas of concealment and cover), and
- courses of actions taken within these areas (e.g., tactical operations within key terrains, disposition or deployment of companies along areas of observation).

N-dimensional significants comprised:

- combat units and artillery, and
- courses of actions planned for these combat units (e.g., tactical operations of tank platoons, disposition or deployment of company positions).

N-dimensional significants differed from the other two classes in that their dimensionally was specified neither verbally nor graphically on the map possibly because of the military symbology denoting these significants, or their geometrical complexity. Table 1 relates the significants, so classified, to the different categories and types of visual-graphical signifiers. The percentages are calculated from the total number of significants related to a type of signifier. The table exhausts the whole set of signifiers and significants.

As shown, pointing actions generally designated or located N-dimensional significants (70%). Linear actions and linear drawings mainly signified one-dimensional significants (64% and 87% respectively). In contrast, curvilinear and two-dimensional actions rarely designated one-dimensional significants (2% and 5% respectively). Two-dimensional actions depicted two-dimensional significants (60%) more frequently than

Table 1

Percentages (%) and frequencies (Fr) of significants of different dimensionality associated with each category and type of visual-graphical signifier. Numbers in the column headed "N" represent significants having nonspecific dimensionality. Numbers in each row should sum to 100.

Visual-graphical signifier		**Dimensionality of Significant**						
Category	**Type**	**One**		**Two**		**N**		Total Fr
		%	Fr	%	Fr	%	Fr	
Pointing	Single	**13**	14	**17**	18	**70**	76	108
	Repeated (tapping)	**4**	1	**32**	8	**64**	16	25
	Bidirectional (two-point)	**0**	0	**20**	2	**80**	8	10
	Combined pointing	**10**	15	**20**	28	**70**	100	143
Curvilinear (closed)	Paused	**0**	0	**45**	5	**55**	6	11
	Continuous	**0**	0	**43**	21	**28**	28	49
	Bidirectional	**22**	2	**67**	6	**11**	1	9
	Combined closed	**2**	2	**48**	32	**50**	35	69
Linear (open)	Paused	**57**	13	**13**	3	**30**	7	23
	Continuous	**77**	55	**9**	6	**14**	10	71
	Bidirectional	**36**	10	**36**	10	**28**	8	28
	Combined open	**64**	78	**15**	19	**21**	25	122
Two-dimensional	Paused	**0**	0	**55**	11	**45**	9	20
(area covering)	Continuous	**9**	3	**60**	19	**31**	10	32
	Bidirectional	**5**	1	**67**	12	**28**	5	18
	Combined area covering	**5**	4	**60**	42	**35**	24	70
Drawings	Symbols	**0**	0	**33**	3	**67**	6	9
	Linear	**87**	34	**7**	3	**6**	2	39
	Combined drawings	**71**	34	**12**	6	**17**	8	48

N-dimensional ones (35%), while curvilinear actions illustrated both types of significants equally (48% and 50% respectively). These results indicate that visual-graphical actions have geometrical attributes that depict those of their corresponding significant(s).

It is interesting to note the similarity that exists between the geometrical attributes of the visual-graphical signifiers, those of graphics (Lee, 1991), and those of descriptors in sign languages (Cuxac, 1991). In all three cases, the hand action specifies geometrical attributes of significants such as size or shape. For instance, Lee observed that the shape of hand actions, called *pointing*, changed with the shape of the significant(s) referred to: two-dimensional motions over extended areas, or linear tracing over linear boundaries. The similarity in use of hand actions, in different contexts, may be related to the fact that geometrical concepts and mental imagery organize and/or influence the geometrical attributes of the hand actions.

4. Discussion

This study aimed at elucidating the figurative properties of the visual-graphical signifiers that commanders use to denote significants on a map during tactical planning. The results are twofold. First, they indicate that pointing signifiers arbitrarily relate to their significants figurative properties. These signifiers act rather as deictic references which co-occur with verbal deictic references, such as *this* or *there*, to identify and locate significants on graphical media (Boudreau & McCann, 1994; Kendon, 1985; Levelt, Richardson, & Heij, 1985).

In contrast, visual-graphical signifiers which reproduce, at least approximately, the geometrical attributes of their significant(s) have *figurative properties.* These signifiers include one-dimensional actions that are either curvilinear or linear, two-dimensional actions, and drawings. A plausible explanation of these results is that the figurative properties of the significants partly determine those of their related signifiers (Kendon, 1985). For example, if the referent of a visual-graphical signifier is linear, the motion imitates the linear form of its referent.

One can further argue that, in real time cognitive processing, the generation of significants precedes and partly determines the production of signifiers in a particular mode (acoustic, visual, haptic) adapted to convey their meaning or figurative properties. Such would be the case in tasks involving graphical media, such as in the present, where humans use visual signifiers to depict significants available on the media. They also use these visual signifiers to represent together with speech: (1) the figurative properties of significants that are already known but not actually perceived at the time they are symbolized; and (2) those of novel significants that have been deduced or imagined during planning. For example, a drawing may symbolize the mental image of a unit's disposition seen in the past, but it may also represent an original disposition of battle units. Because tactical planning involves the above sorts of significants, then one could suggest that visual-graphical signifiers are actively involved with speech, to communicate significants during tactical planning. Visual-graphical signifiers would thus symbolise the concrete or visual properties of significants in a way similar to which verbal signifiers symbolise abstract properties of significants. The complementary role of visual-graphical and verbal signifiers reflects the coordinated and dual nature of the mental representation that occurs during dialogues involving graphical media (Jeannerod, 1994; Paivio, 1986; Piaget, 1983; Piaget & Inhelder, 1963).

5. Conclusions

The results of this study suggest that visual-graphical signifiers provide, when deferred, *symbols* for visual significants, extending some of these, such as mental images, into observable behaviors that are not easily conveyed through speech. The figurative properties of visual-graphical signifiers thus support the utility of designing graphical interfaces to recognise these actions. Rhyne and Wolf (1986) propose two approaches to the design of graphical interfaces: one is *user-independent*, and the other *user-dependent*. In the first approach, one would analyse the figurative properties of hand motions from a large number of subjects, and then create templates against which to compare an individual's production. The efficiency of this approach depends on inter-subject consistency, i.e., the extent to which there is consistency between subjects in the use of the figurative properties of the hand motions. In the second approach, the user would train the interface in advance on a set of hand motions that he (she) will use. For accurate recognition, each user must reproduce the trained set of motions consistently in the same geometrical form. The efficiency of the user-dependent approach thus depends on intra-subject consistency.

The subjects in this study generated a common lexicon of signifiers, plus individual additions or variations (Boudreau & McCann, 1994). They also produced, via imitation or deferred imitation, a consistent set of figurative properties to denote significants. Given these symbolic properties, one could design a graphical interface that combines the above two approaches. With the user-independent approach, a first step, prior to the design of a graphical interface, would be to verify inter-subject consistency in the use of the lexicon from a large sample of subjects. This information would then form a basis to create standardized models of the signifiers in terms of their geometrical form and meaning. With the user-dependent approach, the interface would adapt to individual differences in production of the signifiers. Wolf, Rhyne and Ellozy (1989) adopted the above two approaches to design a Paper-Like interface that can recognize written symbols as well as a user's own style of writing for any symbol set. Similarly, Marukami and Taguchi (1991) trained neural networks to recognise an individual's way of signing in Japanese using datagloves.

Paper-Like interfaces recognise two-dimensional (2D) motions, such as hand-drawn symbols, while datagloves are tailored for three-dimensional (3D) motions. Since visual-graphical signifiers have 2D and 3D components, graphical interfaces should integrate the two technologies. Such graphical interfaces would allow the user to employ any part of his hand(s) to denote spatial significants on a 2D surface as observed in this study, but also to generate significants in a 3D space. The design of such a graphical interface would constitute an integral part of a multimodal interface capable of recognising and interpreting both verbal and visual-graphical signifiers concurrently.

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This study aims to elucidate the figurative relations between spatial significants, such as geographical objects, and the visual-graphical (hand) signifiers that commanders use to designate or generate these significants on a map during a tactical planning task. Specifically, the objective is to specify whether visual-graphical signifiers have a physical property, such as a geometrical form, that reproduces by virtue of imitation a corresponding property of their significants. The study is part of a broader project aimed at specifying the symbolic (lexical, semantic, and figurative) properties of graphical actions in multimodal dialogues over a map during tactical planning. Knowledge of these properties will be used in the design of multimodal interfaces aimed at recognizing and interpreting such graphical actions.

Seven commanding officers provided verbal and graphical estimates of a tactical scenario portrayed on a topographic map. These sessions were videotaped. The graphical component consisted of graphical (hand) actions which referred to significants on a topographic map. These graphical actions were defined as visual-graphical signifiers in a lexicon. We determined a set of significants (objects, concepts, attributes, and relations) from the analysis of the commanders' dialogue in their verbal and graphical components. The data for this study were the lexicon of visual-graphical signifiers and the significants related to these signifiers. To elucidate the figurative properties of the visual-graphical signifiers, the significants were classified according to their geometrical properties (one dimension, two dimensions, and nonspecified dimensionality), and then they were grouped according to the type of visual-graphical signifier to which they were related. The results indicate that visual-graphical signifiers figuratively relate to their significants' geometrical properties. The figurative properties of the visual-graphical signifiers suggest that commanders use these signifiers to depict significants on a map, and to represent the visual properties of those not easily nor completely conveyed through speech. The visual-graphical signifiers would have a complementary role in communicating the semantic content of tactical planning over graphical media such as maps.

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Human-computer interfaces

Figurative properties

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Significants