How Conceptual Metaphors are Productive of Spatial-Graphical Expressions

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Abstract

The theory of conceptual metaphors is adopted in which conceptual relations are productive of linguistic metaphorical expressions. Conceptual metaphors vary in their degree of productivity according to semantic principles. Spatial-graphical expressions of non-spatial concepts are investigated providing evidence that they are instantiations of metaphors. For three cases of differing productivity it is argued that the same semantic principles which result in metaphor productivity for linguistic expressions also result in spatial-graphical expressions.[1]

Background

Language gives us words, and constructions made of words, to talk about abstract concepts. We find in space, conventional shapes and organizations of shapes which also convey abstract concepts. These representations in space are typically experienced visually, but not exclusive of other experiential modalities. This paper addresses the problem of how spatial-graphical representations convey abstract meanings by means of metaphors, which allow us to understand or express abstract concepts in terms of concrete expressions, particularly ordinary, relatively static, conventional devices (e.g., map legends, key pads, and clocks).

Fourceville's (1996) analysis of abstract concepts conveyed by creative images and language in advertising, aims toward a theory of 'pictorial metaphor'. Tversky (2001) treats depictions, such as maps, graphics, and icons as involving spatial metaphor derived from concrete world experience, across languages and cultures. Zacks, & Tversky (1999) argue that systematic correspondences between graph forms and interpretation are naturally derived, not due to knowledge of explicit conventions. This paper takes a similar treatment of metaphor, adopting cognitive semantic theory (Clausner, 1993, 1994; Clausner & Croft, 1997; Grady; 1997; Lakoff, 1993; Lakoff & Johnson, 1980; Lakoff & Turner, 1987), which treats metaphor as conventional schemas expressive of ordinary conventional language.

In this theory of metaphor, knowledge is organized into experientially based domains; e.g., SPACE, TIME, LIVING THINGS (see Clausner & Croft, 1999, for an overview of the theory of domains in cognitive semantics). A conventional metaphor is a stored relation between two domains. Concepts from an abstract (target) domain are systematically comprehended or expressed in terms of concepts from a different, often concrete, (source) domain. For example, MORE IS UP AND LESS IS DOWN is a conventional metaphor whose source domain UP-DOWN stands in relation to the target domain MORE-LESS. This metaphor is a semantic structure which can be instantiated as linguistic expressions; e.g., *rising prices, fell ill, high esteem, fell unconscious*.

Language expresses abstract concepts metaphorically by means of spatial and other basic perceptual concepts (Grady, 1997). Metaphors that relate spatial source domains to non-spatial target domains can be productive of linguistic expressions about non-spatial abstract meanings by using words having spatial meanings. The metaphor MORE IS UP is strongly implicated by investigations of graphs as expressions in space. Tversky, Kugelmass & Winter (1991) found that subjects assigned interpretations to the axes of graphs, such that increasing quantity was preferentially assigned to the vertical axis, and temporal concepts were preferentially assigned to the horizontal axis. Gatis & Holyoak (1996) investigated subjects' interpretation of graphs, finding a significant advantage when the variable being queried was assigned to the vertical axis. They argue that graphing increasing quantity in terms of vertical spatial increase is based on the metaphor MORE IS UP. Given that there is evidence for conventional metaphor being expressed in the construal of spatial graphs, this paper proposes the following hypothesis: The same cognitive principles which determine metaphor productivity for linguistic expressions also determine metaphor productivity for spatial expressions. This hypothesis will be tested with respect to a specific technical characterization of metaphor productivity.

Productivity in Metaphors

Clausner & Croft (1997) argue that just as phonological schemas vary in their productivity of base-derived relations, so semantic schemas (i.e., meta-

[1] The author thanks the three anonymous reviewers of this paper for their helpful comments. An earlier version of this research was presented at the Seventh International Cognitive Linguistics Conference, 2001, Santa Barbara, California.

phor source-target domains) also vary in their productivity of metaphorical expressions. Schematicity is the range of source (or target) domain concepts consistent with the schema. Productivity is the proportion of a schema's range which can be instantiated as expressions. This translates into strength of stored representations, called degrees of entrenchment. Relative entrenchment between a schema and its instantiations characterizes its productivity. High productivity of a metaphor is a configuration of a strongly entrenched schema relative to a wide range of weakly entrenched instantiations. Whereas, low productivity of a metaphor is a weakly entrenched schema relative to a narrow range of strongly entrenched instantiations.

In the following sections three degrees of metaphor productivity are considered: High productivity, Semi-productivity, and Nonproductivity. The three cases are presented in separate sections. In each case, the section begins with the conceptual principles by which Clausner and Croft (1997) account for how metaphors vary in their degree of productivity for linguistic expressions. Then evidence that spatial-graphic expressions are metaphorical expressions is presented. Measures from human subjects or semantic analysis are used to argue that in each case the pattern of results is attributable to conceptual principles of metaphor productivity.

High Productivity

The case of a metaphor having high productivity of linguistic expressions is characterized by Clausner & Croft (1997) as follows. The source-target domain relation [S → T], is a schema that produces instantiations. Each instantiation [e → c] is a metaphorical expression *e* whose source domain words are about target domain concepts *c* (Figure 1). For example the metaphor schema [UP/DOWN → MORE/LESS] (i.e., MORE IS UP AND LESS IS DOWN) can be instantiated as any number of expressions in which words about verticality (e.g., *rising/falling,…*, *up/down*) express non-spatial concepts. Metaphor productivity is a semantic configuration of a metaphor and its instantiations which includes the relation of schematicity between schema and instantiations (descending arrows). High productivity is high schema entrenchment (bold box) relative to a wide range of *i* weakly entrenched instantiations (lighter boxes).

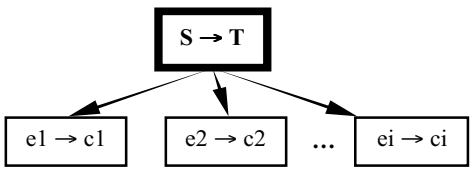

Figure 1: Semantic characterization for high productivity of a metaphor.

A highly productive metaphor expresses a large proportion of concepts consistent with the metaphor schema. Nearly any concept about quantity or quality can be expressed in terms of spatial verticality (e.g., *rising/falling prices,…, feeling up/.down*). This characterization of high metaphor productivity for linguistic expressions will be applied to the investigation of metaphor productivity for spatial-graphic expressions.

High productivity (Spatial-graphical metaphorical expressions)

The vertical spatial axis of graphs can be employed to convey quantities and this can be attributed to the metaphor MORE IS UP (e.g., Gatis & Holyoak, 1996). If this metaphor indeed has high productivity and the theory applies to both linguistic and spatial-graphical expressions, then not only numerical quantities, but also non-spatial qualities (e.g., severity) should be found instantiated in space. Specifically, a wide range of concepts about severity is predicted to be expressed such that great severity is expressed as high vertical space. This was measured using assignments of severity to a vertical map legend. The subjects were 34 graduate and undergraduate student interns at HRL Labs. Each subject was given Figure 2 with the instructions, "This is a legend to be used for a weather map of storm severity. As you can see no colors are yet assigned. Assign colors to the two extremes (two boxes) of the legend. Next, (in the blank lines) label which extreme of storm severity is which."

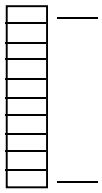

Figure 2: Vertical map legend, uncolored with blanks for labeling the two extreme values.

The aim of color assignment was to first get subjects to commit to a particular orientation of severity (target domain) to verticality (source domain), without having to verbalize target domain concepts. While color names were not expected to be sufficient evidence of any systematic conceptualization of the legend, the labeling of storm severity was expected to evoke words that would demonstrate a preferential orientation consistent with the MORE IS UP metaphor.

Table 1 summarizes the range of types of responses subjects gave as labels for the top and bottom of the legend. The left column lists response types which assign extreme storm severity to the top of the legend (e.g., *severe* and *calm* written in for the top and bottom

labels, respectively). The right column of response types are those which assign extreme storm severity to the bottom of the legend.

Table 1: Response types and percent consistent with MORE IS UP or LESS IS UP, N=34.

MORE SEVERE IS UP / LESS SEVER IS DOWN	LESS SEVERE IS UP / MORE SEVERE IS DOWN
high / low	low / high
heavy / light	lightest / heaviest
severe / calm	calm / severe
bad / good	
most / least	
severe / less severe	
very severe / not severe	
extreme / clear	
hurricane / balmy	
misery / balmy	
stormy / fair	
91%	9%

Of 34 subject responses, 31 responses assigned greatest severity to the top of the legend and 3 responses assigned the least severity to the bottom. As expected, the assignment of severity to verticality does not occur at a chance rate, but is significantly biased toward the assignment of greater severity to higher verticality, $\chi^2(1, N = 34) = 46.12$, $p < 0.001$. It can be concluded that something in the cognitive process of doing the task biases the responses, and this bias is consistent with the conventional metaphor MORE IS UP.

Color assignment is not the central task and the results were not expected to bear on the investigation; indeed they are varied. Nonetheless, it is noteworthy that of 34 total color assignment responses, the end of the legend that was also labeled as the most severe (regardless of vertical assignment), was most frequently designated "red" for 68% of color assignments. "Blue" was the most frequent color assigned to the least severe end of the legend for 38% of all color assignments, regardless of vertical assignment.

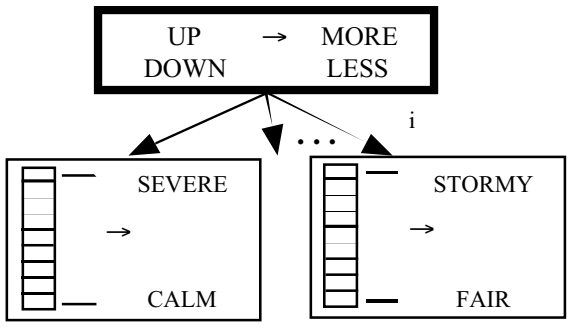

Figure 3: Graphic-spatial expressions of a highly productive metaphor.

These results suggest that understanding the vertical spatial graphic as a legend of storm severity systematically yields interpretations of the top as an expression of greatest severity, contra the bottom. That is, the subjects read the spatial verticality as an expression of concepts about the abstract quality of severity, such that a significantly large proportion of these concepts are consistent with the *up* part of UP/DOWN SPACE expressing the *more* part of the MORE/LESS quality scale. This characterization of the results is depicted in Figure 3 as a case of many concepts about storm severity (e.g., *severe/calm*, *stormy/fair*, ... and others not shown) as the meanings of the extreme ends of the legend. Each instance of the legend having a particular conceptualization is an expression of a metaphor, as depicted by the arrows between the metaphor MORE/LESS IS UP/DOWN (upper bold box) and each of the instantiations (lower lighter boxes) in Figure 3.

This is the same relation between schema and instantiation illustrated in Figure 1 for linguistic expressions of a metaphor. Just as there are many non-spatial concepts *c* expressed as linguistic expressions *e* using words about vertical space, there are also many non-spatial concepts expressed as spatial-graphs. A large range of non-spatial concepts are consistent with the target domain MORE/LESS and these are expressed by means of a vertical graphical legend consistent with the source domain UP/DOWN, respectively.

It can be concluded that since a large proportion of the schema's range can be instantiated as graphical expressions the metaphor schema is highly entrenched relative to a wide range of weakly entrenched instantiations. The metaphor is highly productive, and of more than the legend colorings and labelings investigated here, but of any graphic vertical axis (e.g., mercury thermometers). Having argued for a case of high metaphor productivity expressed in space, we will next consider cases of lesser productivity.

Semi-Productivity

This section presents an analysis of spatial expressions and argues that they systematically instantiate a semi-productive metaphor. First, the characterization of semi-productive metaphors for linguistic expressions given by Clausner & Croft (1997) is summarized. Then, the case of spatial expressions being instantiations of a semi-productive metaphor is made.

Clausner & Croft (1997) argue that semi-productivity of a metaphor is the case of relatively few linguistic expressions of a metaphor, compared with the wide range of concepts potentially consistent with that metaphor. For example, the five idioms, *spill the beans, let the cat out of the bag, loose lips, blow the whistle,* and *blow the lid off* are all about revealing a secret. Lakoff (1987) and Gibbs & O'Brien's (1990) conclude that

these idioms are consistent with the metaphor schema THE MIND IS A CONTAINER and IDEAS ARE ENTITIES. The idiom expressions are transparent idioms, because most people have some awareness of a relationship between specific word meanings and the idiom meaning. They know that the words for physical things (e.g., cat) escaping a container (e.g., bag) are related to an idiomatic meaning of ideas coming out of the mind. Clausner & Croft's (1997) analysis of these transparent idioms argues that the metaphor schema [ENTITIES OUT OF A CONTAINER → IDEAS OUT OF THE MIND] is semi-productive. There are only five instantiations, each a transparent idiom (e.g., cat out of the bag → secret revealed). The metaphor is only partly productive because the transparent idioms express only a limited proportion of possible instantiations that are consistent with the metaphor. For example, **spill the peas* and **let the weasel out of the cage* are expressions which are consistent with the metaphor schema, but nonetheless do not mean, reveal a secret[2]. The five idioms that do have this meaning are highly conventionalized (i.e., highly entrenched) expressions.

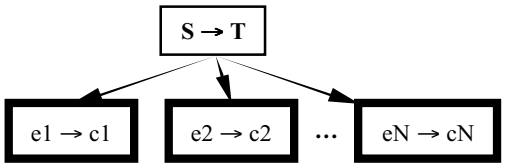

Figure 4: Semantic characterization for semi- productivity of a metaphor.

They conclude that a countable number *N* of highly entrenched instantiations of a relatively less entrenched metaphor schema is characteristic of metaphor semi-productivity. Figure 4 illustrates the cognitive structure of a lightly entrenched metaphor (lighter box) that is consistent with a limited range of highly entrenched instantiations (bold boxes). Given this account of semi-productive metaphors, semi-productivity for graphical spatial expressions is investigated.

Semi-productivity (Spatial-graphical transparent idioms)

The data considered are the spatial-graphic arrangements of digits for entering numerical values, such as those found on telephones, calculators, alphanumeric keyboards, and rotary telephones (left side of Figures 5-8, respectively). Each of these four digit arrangements is highly conventionalized. It is transparent, however, that the digits are arranged in counting order. That is, any specific spatial arrangement of digits is understood to be a meaningful ordering of incrementally successive values. That the spatial arrangements vary widely, but have the same interpretation as ordered values, suggests a systematic relation between their spatial expression and their conceptual meaning.

	*
1 2 3	0
4 5 6	1 2 3
7 8 9	4 5 6
0	7 8 9

Figure 5: Phone, television, and bank ATM digit pad.

	*
7 8 9	0
4 5 6	7 8 9
1 2 3	4 5 6
0	1 2 3

Figure 6: Calculator key digit pad.

1234567890

* 0123456789

Figure 7: Typing keyboard number order.

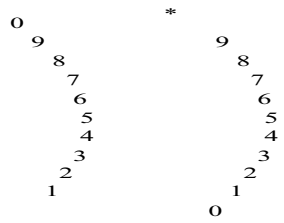

Figure 8: Rotary Telephone digit order.

The investigation of a common semantic relation that is consistent among these four spatial arrangements can proceed as one would a linguistic case. Analyzing the range of spatial expressions characterizes the schema that might be instantiating them, just as it does for linguistic expressions. Among these four digit arrangements, the "0" numeral occurs in two positions, either near the "9" numeral, or near the "1" numeral. This suggests that the shared meaning of the digit arrangements is the concept of counting, expressed with the "0" numeral representing either the 0th or 10th value. In fact, the first form of the rotary phone had numbered finger holes, except the "0" was marked with the Roman numeral "X" (Hill, 1953).

If the counting order of digits is indeed the common meaning among the four spatial arrangements, then that order is independent of whether the spatial configuration of the digits is rotational, horizontal, vertical, or

[2] An asterisk, "*", which begins a linguistic expression or graphic expression denotes its infelicity as a conventional expression of the particular semantic meaning in discussion.

some combination (e.g., reading "1" to "9" successively left-to-right and top-to-bottom, as on a phone pad). These configurations (or combinations, of them) are expressed, but it is the counting order, not the spatial order, that is common across the expressions. The only variation among digit orderings is the relative position of "0" in the counting order.

In laying out a metaphorical system of how humans understand abstract mathematical concepts Lakoff & Núñez (2000) propose metaphors which fit the above analysis. They first establish that MODULAR ARITHMETIC IS ALGEBRAIC GROUPS and GEOMETRIC ROTATIONS ARE ALGEBRAIC GROUPS. That is, the digits for counting in base 10 modular math are conceptualized as rotations. Successive rotations form the basis for counting, which they argue is the metaphor THE INFINITE CLASS OF NUMERALS FOR THE NATURAL NUMBERS IS AN ITERATIVE PROCESS THAT GOES ON AND ON. For the purpose of this paper, the simpler characterization is [CYCLIC PROCESS → COUNTING WITH DIGITS]. The spatial expression of the CYCLE in this case is the spatial traversal of numerals in one of four conventional arrangements. The traversal is cyclic by means of the "0" indicating modulo 10.

Evidence that the metaphor does not express the full range of spatial expressions consistent with its specifications comes from the absence of specific digit arrangements. The right side of Figures 5-8, depict spatial arrangements of digits that are unexpressed as conventional digit orders (as denoted by "*"). These spatial arrangements are consistent with base 10 counting order, but they are not conventionalized.

Figure 9 depicts the metaphor (upper light box) which is semi-productive of *N* highly conventionalized instantiations (lower bold boxes). The *N*=4 spatial arrangements of numerals are understood as ordered digits. The metaphor is semi-productive, because the four instantiations are consistent with the metaphor, which is not productive of other expressions.

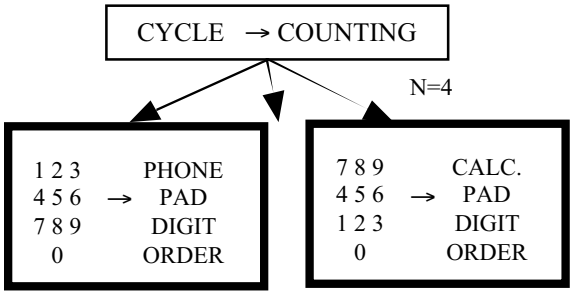

Figure 9: Graphic-spatial expressions of a semi- productive metaphor.

The case of spatial expressions of semi-productive metaphor can be called, "transparent spatial-graphic idioms". Transparent linguistic idioms are highly entrenched expressions of a comparatively lightly entrenched metaphor (Figure 4). This same principle of semi-productivity applies to spatial expressions. Only four of the possible spatial arrangements consistent with the metaphor domain relation are expressed. The expressed spatial arrangements are highly conventional and their meaning is semantically transparent.

Nonproductivity

This section investigates productivity less in degree than semi-productive metaphor, specifically the case of nonproductivity. Opaque linguistic idioms are very few. For example, *kick the bucket*, meaning to die, and *by and large*, meaning something in general. They are semantically opaque in that most English speakers know these linguistic expressions and know what they mean, but do not know why they make sense. Clausner & Croft (1997) analyze *save face* and *lose face* as opaque linguistic expressions of an absent metaphor. The expressions were borrowed from Mandarin Chinese. English speakers know their meaning is about avoiding disgrace and incurring disgrace, but they do not know why they mean this. English lacks the relevant metaphor [HAVING FACE → SOCIAL RESPECT] that would be productive of other expressions, such as those not borrowed into English, e.g., **give face*, does not mean, to show due respect for someone's feelings, as it does in Mandarin.

Figure 10 depicts the absence of an entrenched metaphor schema (light dashed box). The expression is extremely conventional, that is, highly entrenched (bold box), and it is opaque since there is no source-target domain relation that would be productive of the expression *e* in relation to concept *c*. Also absent are vertical arrows, indicative of the nonproductivity.

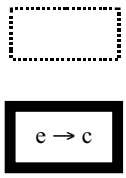

Figure 10: Semantic characterization for metaphor nonproductivity.

Now we turn to graphical-spatial expressions and argue that we find the same semantic structure as for opaque linguistic idioms.

Nonproductivity (Spatial-graphical opaque idioms)

An extremely conventional spatial-graphical expression is the analog clock. There are clockwise clocks, but not counter-clockwise clocks (although they exist for

amusement, but not conventional use). Most people do not know why clocks run in the conventional clockwise direction. It is opaque, in that there is no conventional semantic relation between the source and target which makes the spatial pattern make sense. That is, there is no widespread knowledge that the sidereal rotational direction of shadows cast by sundials in the northern hemisphere is the basis for the rotational direction of clocks. There is no conventional entrenched metaphor schema. If there were a metaphor it might be something like, PASSAGE OF TIME IS SHADOW ROTATION.

Just as there are few opaque linguistic idioms, it should follow that there are few "opaque spatial idioms", precisely because there is no conventional metaphor to produce them. Another example of an opaque spatial idiom would be the QWERTY keyboard[3]. The arrangement of alphanumeric keys is widely known, but why they have this specific arrangement, among all the possible unattested ones, is largely opaque. It is not widely known that early mechanical typewriters arranged keys in order to slow typing speed, thus reducing the likelihood of two keys striking together.

Discussion and Conclusion

These results point to issues of representation and conceptual structure common to linguistic semantics (spoken and signed), psychology, computational modeling and the role of metaphor in human-computer interaction. Further work is required to distinguish the theory of metaphor productivity from alternate interpretations of the results, e.g., treating conventional correlations between the top of a spatial axis and one pole of a semantic scale as due to salience. The top of a legend or vertical mercury thermometer, or keypad digit ordering may be interactions of perception and conventionality; however, conventionalized form-meaning pairs do not obviate a conventional metaphor schema. The theory of productivity is about contemporary conceptual structure (not historical origins of the metaphors) and predicts the above results.

Spatial-graphical expressions are argued to be instantiations of conceptual metaphors which vary in productivity according to the same principles which determine productivity for linguistic expressions. The relative entrenchment of a metaphor to its instantiations is argued to result in varying ranges of expressions. Three degrees of metaphor productivity were investigated. In each case the principles which are held to explain ranges of linguistic expressions are argued to explain evidence about spatial graphical expressions. These are, in decreasing order: High productivity is the case of spatial-graphical metaphorical expressions. Semi-productivity is the case of spatial-graphical transparent idioms. Nonproductivity is the case of spatial-graphical opaque idioms. These cases are concluded to represent three points on a continuum of metaphor productivity for spatial-graphical expressions.

[3] The author thanks Sarah Taub for suggesting this example.

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