Dynamic and spatial variables in data visualization systems

BY: **Johanna Drucker**

ABSTRACT

Jacques Bertin's groundbreaking work, *Sémiologie Graphique*, has remained definitive for the more than half a century since its initial publication (1967). His formal description of graphic variables is fundamental for information design because it offers a way to understand how visual entities can be used to create a semiotic system with clear and distinct categories. According to Bertin, color, texture, value, pattern, shape, position, and orientation can each be assigned a specific role within a signifying system in accord with logical rules of representation. However, given the technology of the time in which Bertin was writing, features of dynamic display were not included in his discussion. These include elements of animation (such as direction, speed, acceleration, transformation, and rate of change) as well as some features of perspectival and spatial systems (including point of view, scale, projection, folding) that did exist but were not much used. The critical question is whether these graphical features can be formalized to the same degree as Bertin's seven graphic variables, and included within the operation of semiotic systems. While these variables are not associated with fixed values any more than Bertin's original ones, their use in information display suggests that they would benefit from the same kind of descriptive analysis he applied to static ones. This paper describes dynamic and spatial variables, offers some preliminary thoughts about their specific contribution to visualization of big data, and addresses the way they produce meaning within a graphical semiotic system.

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The first screen of the May 14th *New York Times* online displays a map made of small black dots that mark the site of Covid-19 related deaths (2022). Within seconds, the dots swarm, rise from their places, and reform into a bar chart. After a brief pause, they swarm again and distribute across the map. I read the two graphics as versions of the same statistical information connected by the movement of the dots. In recent decades, this sort of dynamic feature has become integrated into information graphics and most common platforms have built-in animation capacities. Excel, for instance, readily integrates Visual Basic commands to show various states of data in progress and Tableau has its own Viz Animation with parameters for speed, duration, and control of various actions, such as changing an axis or shifting scale (Koenig and Shay: 2020). Online newsfeeds regularly make use of data journalism with graphic animations of large data sets. These visualization benefit from the ability to show change over time, increase or decrease in values, or simply to animate a presentation for the sake of reinforcing a narrative. The dynamic and spatial features are part of the designer's toolkit, but little systematic critical work has been done on the way they produce meaning. How and what do these features *signify* and what critical reflection might make it possible to understand these dynamic and spatial qualities as part of a semiotic system?

Jacques Bertin's groundbreaking work, *Sémiologie Graphique* (1967), has remained definitive for the more than half a century since its initial publication. His formal description of graphic variables continues to be fundamental for information design through its clear articulation of the ways visual entities can be used effectively as a semiotic system. Bertin described seven distinct graphic variables: color, texture, value, pattern, shape, position, and orientation. He showed that each could be assigned a specific role within a signifying system in accord with logical rules of representation. Given the state of visualization technology at the time, information graphics (maps as well as charts and graphs) were static print images, so features of dynamic display were not included in his system. Now, it seems that the elements of animation (such as movement and rate of change) and their behaviors (interaction, acceleration etc.), as well as features related to perspectival and spatial systems (especially point of view) all deserve the same critical attention Bertin gave to static variables.

The critical question is whether these dynamic features can be formalized to the same degree as Bertin's seven graphic variables and included within the operation of semiotic systems. While these variables are not associated with an inventory of fixed values any more than Bertin's original ones, their use in information display suggests that they would benefit from a descriptive analysis of the way they produce meaning within a graphical semiotic system. This paper describes these dynamic and spatial variables and offers some preliminary thoughts about the ways their capacity to signify makes specific contributions to data visualization.

Dynamic variables always include a rate of change. This fundamental fact introduces some instability into the visualization because at any moment the display will always be only one of many possible states. The variation can occur continuously or in discrete intervals. The generation of these changes depends in part on the kind of data that feeds the visualization. But changes can be generated through a continuous feed or as a series of discrete data files displayed sequentially or blurred to appear as if they are a smooth transformation. As a result, a user may not be aware of how the data are structured, nor what processing is generating the display. So this paper will focus on the graphic properties of the visualizations rather than on the back-end underlying programming.

By contrast to *dynamic* features, *spatial* variables are indicators of scale and position that inscribe an enunciative system into graphical formats. Many elements of spatial positioning could be broken out in detail, but the fundamental recognition that all visualizations address and position their viewers is what is crucial for addressing issues of enunciation. Spatial structures (such as a flat plane) may appear to be static. The position of a display on the screen is often fixed. A point of view system may remain stable, it does not have to shift, though in game graphics, immersive displays, and many other dynamic visualizations, it may change dramatically. The scale may also remain unchanged. But the dynamic of the relation of the viewer to their position within a system of enunciation is always active, generating an exchange between display and interpreting subject/viewer.

Though these dynamic and spatial visual effects can be analyzed without any detailed description of the data and its feeds, the basic rules of good (and ethical) data visualization should be observed—such as not representing discrete data with continuous graphs and so on (Schmid: 1983). The goal in this study is not to examine the relation between the structures of data and their visualization, but simply to consider how the semantics of dynamic and spatial variables can be codified in a standard manner and made legible within a signifying system. Again, Bertin did not assign specific values to the seven variables (e.g. texture does not have a specific meaning though it can invoke meaning through association). But he outlined the fundamental principles on which their distinction from each other could be used effectively. Initially Bertin was focused on cartographic systems and by extension his work has been applied to many other information graphics.

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1. Approaches to visual perception

For the foundation of critical work on dynamic graphic images, we turn from Bertin to the work of other scholars engaged in the study of the psychology of perception. In his classic 1954 work on *Art and Visual Perception*, the psychologist and art historian Rudolf Arnheim examined various features of moving images (1974).[1] His insights provide one useful foundation for the extension of Bertin's graphic analyses into the realm of dynamic and animated images. Arnheim stated unequivocally that motion "is the strongest visual appeal to attention." He attempted to isolate "pure motion" by suggesting that something that is at a great distance or small scale becomes a mere dot, trace, point that moves without having any particular identity as anything except movement. His goal in making this separation was to be able to describe the behaviors of moving objects within a classification scheme.

For Arnheim, movement was considered a subset of the larger category of dynamic elements. Arnheim also distinguished between change, which does not depend on a shift of location or place, and movement, which does. He pointed to a boiling lobster turning red as an example of a change that is not related to motion (Arnheim 1974:373). The distinction between movement and change is fundamental to establishing the basic primitives of dynamics in graphical systems. Because his focus was on perception, Arnheim was interested in the meaning that became attached to different kinds of movement and motion, rather than simply in classifying types of movement or change in themselves. In the 1950s, Arnheim was able to draw on a considerable body of experimental studies of human perception in which movement was assigned various attributes according to specific characteristics of the moving objects. As a result, some motion was associated with animate entities, some with mechanical, and so on. While Arnheim's emphasis was on perception, the assignment of qualities to motion allowed these distinct types of movement to function as signs that referenced living and non-living entities (among other categories).

Nearly thirty years after Arnheim's text was published, *Vision*, the 1982 posthumous work of computer vision scholar David Marr, addressed the issue of primitives from the point of view of features that could be parsed individually (1982).[2] Marr's goal was the production of components for an artificial vision system capable of high level analysis of representations as well as of the phenomenal world. His phrase, "processing visual information," made clear the connection to computational capabilities towards which he was working. The step-by-step outline was highly formalized and

[1] Rudolf Arnheim, 1974. *Art and Visual Perception: A Psychology of the Creative Eye*. The New Version. Berkeley and Los Angeles: University of California Press. 1954.

[2] David Marr, Vision: *A Computational Investigation into the Human Representation and Processing of Visual Information*. Cambridge, MA and London, UK. MIT Press: 2010. Originally publication: 1982. W.H. Freeman.

procedural. Nowhere were meaning, semiotic signage, concepts of reference or cultural value present. Marr's approach was fully mechanistic and brought up in this context because, like Arnheim's, it assumed a universal physiological foundation for engagement with the visual world. This mechanistic approach could also be readily translated into computation.

Marr's work became the foundation for formal foundations of machine vision. While we might eschew the adequacy of such an approach for the semiotic understanding of dynamic properties in graphics, the benefits of such a systematic description are worth attention. His formal approach, like that of Bertin, allows us to establish a basic descriptive vocabulary for the various types of dynamic features—movement and change—in animated graphics and in the process consider how their meaning production is structured. The distinction between meaning and effect is important to keep in view, as a movement may be described, tracked, and perceived without its having any referent, while position and location are always situated within parameters with cultural and historical specificity. In other words, we can posit that movement and change may not always be signifiers, and that animated graphics might engage with dynamics that do not constitute signs. At the same time, a formal descriptive system gives rise to the recognition that many of these dynamic features do have explicit and implicit meanings rooted in their formal characteristics.

All dynamic graphics created in digital platforms are produced through formal specifications based on step-by-step instructions. This is essential for algorithmic operations of feature identification and image parsing as well as for the creation of dynamic graphics. Marr's approach to vision was grounded in representation, not perception (in this he deviates from Arnheim). Thus analysis of the elements of *picturing* were the foundation of his approach to visual *processing* consistent with his goal of creating a model of highly functional machine vision able to parse an image of the world. The categories into which his analysis was divided showed this clearly as he began with techniques such as "zero-crossings" designed to segment an image into constituent parts, identifying light sources, groups, and developing a basic understanding of visual components (2010:54). To reiterate, no meaning was attached to such procedures or the object of their analysis. Marr began his processes by creating a full sketch of objects in a scene and then shifting to analysis of surfaces, shapes, textures, shading, and color (among other features). More properties followed (e.g. image segmentation, discontinuities) and he devoted chapters to the representation of surfaces as well as shapes. While a brief statement on "psychological considerations" appeared at the very end of his study, Marr was chiefly concerned with what could be automated (2010:325).[3]

[3] For a useful conversation about Marr's work, in particular in relation to that of James J. Gibson, see this thread: https://www.researchgate.net/post/In_what_way_exactly_was_David_Marrs_approach_different_from_that_of_James_Gibson_in_the_field_of_Vision_and_Perception

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2. Data visualization

Work on visual perception, machine vision, and interactive design continues to expand. But in addition, a separate literature has emerged in information graphics. In this arena, Colin Ware's publication, *Information Visualization: Perception for Design* provides an excellent example of a systematic approach (2013). Created as an instructional text for producing visualizations, Ware's text exhaustively detailed the many elements of graphic communication. Drawing on considerable empirical user studies, Ware produced a comprehensive handbook. In his opening chapter, "Foundations for an Applied Science of Data Visualization," he rejects both Ferdinand de Saussure's concept of the arbitrary nature of signs and the cultural relativism of Claude Levi-Strauss, Roland Barthes, and others building on that tradition (2013:6). Ware's assertion that "a new semiotics" could be based on "scientific evidence" returned to an empirical orientation towards human perception. Ware's work is included here because it sits between the classical semiotics of Bertin and computational information visualization while making use of some of the same principles of psychology of perception that shaped Arnheim's work and the approach to digital production that was central to Marr's. The mechanistic approach that Ware outlines also has no mention of subject-centered experience, cultural values, interpretative processes, or the inflections of historical circumstances.

Dynamic visualizations present the challenge for producing a useful structural analysis and description of their features and potential for signifying. To reiterate, it is important that Bertin did not assign specific meaning values to his graphic variables, but instead offered a framework in which the distinct and discrete qualities of shape, color, value, orientation, position, size, and texture could be used effectively. Certain shapes and combinations might well have semiotic properties. A star is not a circle, a huge square placed beside a small triangle produces a certain relational value. But meaning production is context and system dependent as well as cultural, historical, and referential. Perception of movement is highly sophisticated and much studied from neuro-biological and psychological perspectives. This work is of essential importance in the design of automated systems for self-driving cars and other marketable technology. But the *significance* of movement is less systematically addressed.

The features of dynamic graphics can be divided, as per above, into change and movement. These features suggest certain binaries, such as animate and inanimate, organic and mechanical, intentional and incidental, and growth and decay (Hoare 2017). Experiments with users' perceptions have demonstrated, for instance, that an object that stretches and shrinks will be perceived as organic and animate, while one that simply moves without morphing is more likely to be understood as mechanical (Arnheim 1974:398).[4] Not surprisingly, these categories of identity correspond to some extent to analogs with the phenomenal world. In addition to these fundamental binaries, attributes of various kinds—speed, acceleration, direction, rate of change, apparent force, efficiency, or efficacy—add qualities of behavior to dynamic elements.

The field of cartoon animation also contributes to the basic vocabulary on which dynamic graphics are created and understood. In their classic text, *Disney Animation: The Illusion of life* Frank Thomas and Ollie Johnston outlined twelve principles of animation (1981).[5] Their goal was to create lifelike characters, and so their principles guided production of the illusion of living entities through principles like squash and stretch, staging, timing, anticipation, follow through, overlapping action, secondary action, blocking, arcs, slow in and out motion, exaggeration, and appeal (1981). Their principles addressed attributes of objects as well as of their movement (e.g. the idea that lighter objects move more quickly than heavier ones), and they were keenly aware that a such behavior as the timing of an action could change its meaning. Because of the affective force of these behaviors, they need to be used judiciously when applied to information graphics. Animation tropes can easily carry too much meaning, or unintended values, if misapplied. The problem of unintended semantic values is endemic even in in static visualizations, as many are generated according to display parameters that are not carefully considered (2021).[6]

In addition to movement and change, the features of spatial conventions play a role in structuring the relationship between viewer and scene in implied and explicit ways. Whether orthographic or perspectival, flat or with illusions of space, these graphic conventions inscribe subject positions that are fundamental features of enunciative systems (Drucker: 2017). Often unacknowledged, they are ubiquitous within user interface design, game graphics, and other computationally generated digital displays. Other more complex issues in spatial representation (motion, folding, distortion) could be analysed as well, but for purposes of this piece, only the three fundamental constructions—flat, orthographic, and perspectival—will be discussed.

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4 Arnheim, p. 398, drawing on the work of André Michotte, *La perception de la causalité* (Louvain: 1946).

5 Frank Thomas and Ollie Johnston 1981. *Disney Animation: The Illusion of life*. Westport, CT: Hyperion.

6 For one good study of such issues, see Tim Stobierski, 2021. "Bad Data Visualization: 5 Examples of Misleading Data." Harvard Business School. https://online.hbs.edu/blog/post/bad-data-visualization.

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3. Dynamic features and processes

Each of these dynamic and spatial features will now be examined in turn to understand how they support signification within a visual system.

Animate/inanimate: The distinction between the movement of animate and inanimate entities is fundamental and profound. In the perception of the phenomenal world, it is a primary distinction separating the living world from the non-living.

In accord with this distinction, concepts of agency are assigned differently. An animate entity may have intentional agency, take sentient and considered action. An inanimate entity may have mechanical agency with any number of effects or consequences. The qualities of motion that allow this distinction to be made are based primarily on the difference between the appearance of an uninflected, mechanical motion and the more errant and variable movement of a living entity. These categories are not binary, however, and the continuum of motions allows interpretation to ambiguate between animate and inanimate entities.

Since the discussion here is focused on the movement of entities within animated graphics, the crucial issue is whether the entity appears to be alive—referencing the animate world–or not. If it has the appearance of a living entity, signaled through a higher level of variation and unpredictability in its behavior, then it references the category of animate entities.

Motion capture is sometimes used a base on which to draw animated figures, human or animal, since the complexity of the movement is easier to replicate than to create from scratch. Bird flight, wing motion, ambulatory activity are examples of animate movement, while mathematical models of growth rates, changes over time, or expressions of quantitative change are examples of inanimate movement. The latter are far more frequent in information graphics, which are generally, though not exclusively, expressions of quantitative value while models of animate phenomena are more likely to be simulations of natural and living phenomena used in games, digital art, and simulation for scientific research.

In the animate image, the motion often is the information, while in the inanimate image, the motion represents information. But in both cases, movement is a sign of something. The motion of an animate entity is first and foremost a sign of life, of being alive, of a living-ness of being. With an inanimate entity, movement is a sign of change, and stands for a shift in value measured graphically as a change in position, direction, speed or other attribute. The curiously delicate line between enacted motion and represented motion blurs the line between actual and depicted movement even though both exist as representations.

Organic/mechanical: The animate/inanimate distinction is not exactly the same as that between organic and mechanical entities. Something can be organic, part of the natural world, without being "alive" in the biological sense of being a living entity able to sustain and replicate itself. Organic processes are almost always part of complex systems. Information graphics that model these complex stochastic processes, such as weather, a tsunami, climate damage, or other natural phenomena use non-linear systems to calculate transformation and change.

The dynamics of mechanical entities conform to the laws of classical physics. Their graphical representation can be done using straightforward linear systems. The movement of trains, calculation of effects of load or stress, the estimation of outcomes of investments in relation to interest rates can all be shown using mechanical means. Models of the social and economic conditions in which the interest rates are determined that factor human behavior into their analysis cannot be displayed using mechanical methods. The number of variables and their degree of (un)predictability in these processes also makes them complex stochastic systems. Their graphics need to embody the variation and specificity inherent to these systems to signify their complexity. Almost by default, the depiction of movement will appear mechanical unless it has the variable features of a stochastic, organic, process.

Repetitive movement generally suggests mechanical entities. The higher the degree of precision in a repetitive motion, the more likely it indicates a non-organic entity. The human perceptual apparatus is highly sensitive. Just as the mechanical beat of an automatic drum-machine will always be distinguishable from that of a human musician, so visual motion that is non-variable will be perceived as mechanical. The subtlest variation will shift the perception, and robotic, automated graphics designed to simulate living and sentient entities, play in this liminal space, often very convincingly.

Intentional/incidental: The distinction between intentional and incidental action relies on whether a movement seems to be directed by a decision-making process. Self-initiated movement appears more intentional while reactive movement appears less so. Incidental movement occurs without apparent cause or motivation. The timing of incidental movement, as well as its course, will often be arbitrary and appear disconnected from any surrounding event, though incidental activity often occurs as a byproduct of intentional actions. An intentional movement signals the likely presence of a sentient being capable of self-initiated action. Such actions are associated with agency. Agency takes many forms from mechanical/physical to sentient/intentional, and when it appears to have an effect, becomes associated with causality.

The appearance of causality is not necessarily an indicator of intention. But the closer in time and space that an action and a resulting movement are, the more likely it is that they will be perceived as related, but the implication of causality relies on some

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indication of coordination between one entity and another. Temporal and spatial proximity serve as signs of connection whether the action is intentional or accidental. Synchronicity is never an irrefutable or absolute indicator of causality, when an action and resulting movement occur in a short time window, they are more likely to be read as part of a single action. The notion of follow-through takes the fundamental principles of gestalt perception of continuity into the realm of dynamic variables. The other gestalt principles—figure ground, closeness, similarity, proximity, common region, and closure—also apply to the perception of dynamic graphics in their temporal and spatial dimensions. The basic gestalt principles can be extended so that “common region” becomes “common direction” or “shared speed” and so forth. Each of the standard principles can become dynamic so that features like closeness shift into clustering or scattering, proximity into attraction or repulsion, and so on.

With these features in mind, we can note that perception allows a meaningful, signifying, value to be assigned to movement. The referents for movement include deliberate intention, accidental or circumstantial activity, qualities of animate and inanimate entities, and characteristics of organic and mechanical processes.

Growth/Reduction/Decay: Change over time has its own signifying properties, since the referents for growth, reduction, amplification and decay are associated with larger life-cycles and the perception of the health or well-being of an entity. While increase is not always positive, it signals the productive absorption of energy or resources while reduction indicates a corresponding diminishment.

An entity can grow without any sign of improvement, but decay is always associated with a loss of vitality or well-being. If an element in an information graphic, such as a bar, square, circle, or curve, begins to swell, the implication is that input of resources (money, heat, food, population etc.) can be assessed, even quantified. If the same elements begin to diminish, the opposite is assumed. If an entity begins to sprout, give rise to branching or extension, it seems to signify growth. But if the elements start to crumble, or wither, or show fissures or cracks, the process suggests a breakdown in the sustainability of the systems and structures they support. The affective force of decay is rarely put at the service of information graphics, but no impediment exists for doing so.

Other expressive and affectively connotative actions could also be used to good purpose—such as the rapid jumping up and down of graphic features to signal happiness or agitation, quick shaking or trembling to indicate anxiety or fear, and so on. The semiotic possibilities for these actions has yet to be explored in information graphics, though they are frequently used in animated cartoons and narratives in a fairly-well codified and standard form. Visual methods used in the display of large data sets—charts and graphs—even when interaction or dynamic, tend to be conservative, preserving the authority and seriousness of their effect.

Interaction: As a fundamental category, interaction can be broken down into a considerable number of fine grained subdivisions, and these can carry inflections as well—hostile, friendly, manipulative, beneficial and so on. But as a general category of dynamic signification, interaction signifies through demonstrated connection of an entity to one or more others in a process of exchange. The concept posits the autonomy of each entity as a premise. Interactions are the dynamic processes of exchange among these entities and imply either a physical or social system at work. Interaction signifies these systems and conditions as well as the specific quality of exchange or communication in any particular case.

Intra-action: By contrast to interaction, the dynamic principles in intra-action, a term coined by the physicist Karen Barad, are not premised on the autonomy of entities but on their shared and co-dependent condition (2007). The approach eschews hard and fast boundaries between entities, and instead sees them as elements of a constitutive system. The entities involved in the gravitational forces in the solar system, in the relationships in a nuclear family, or in any physical situation (e.g. thermal equilibrium conditions) are thus understood as engaged in intra-action, a set of dynamic exchanges from within a system of which they are the constituting parts and participants. Intra-active dynamics thus signify the existence of the co-constitutive conditions of a complex system.

Metamorphosis/transformation: For an entity to show a metamorphosis in a legible manner, its signifying features must be retained sufficiently for the past or start form to be seen in the later one, at least during the initial process of transformation. Once fully transformed—pupa into butterfly, tadpole into frog, human into vampire, woman into tree—the object that has been metamorphosed might not bear much resemblance to the original entity. But the dynamic process of metamorphosis can reference either a change of shape and form (butterfly) or a change of fundamental identity (e.g. human to non-human). Thus a graphical metamorphosis can be a sign of morphological transformation (just appearance) or of ontological change (actual identity). Retaining the full continuum of states, or, at the very least, the start and end states, is a crucial part of the signifying system. Grasping the full signification of the graphic thus depends on a user's being able to retain an absent image as part of the way the present one is read. This is a highly complicated set of requirements for a sign.

Hybridization: Like metamorphosis, hybridization involves a change of state from one thing to another, either through a merger or a generative act of new production in which features from one entity are grafted onto or integrated into another. When an entity is fully hybridized, the source entities may be completely absorbed, even

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disappear, as is the case with some metamorphoses. To signal hybridization, however, the new entity must retain some recognizable features of the sources. This inscription of more than one state of the entity is what allows the graphic to function as a sign of dynamic hybridization processes, not simply as an image of its outcomes.

Propagation: The act of propagation involves multiplication, possibly also hatching or subdivision of an entity into others. As a dynamic process, it can be single or iterative, involve many generations of new forms emerging from an extant entity, or occur simply once. The process is associated with living entities, but is not limited to them. A mechanical object can also propagate through industrial methods of replication. The process signifies a relationship of derivation—from a mechanical mold or template to a biological genealogy of traits passed through breeding or division of genetic material.

Propagation does not imply animate entities, though of course they often participate in such activity. The dynamic process is one in which an original, a source entity, becomes multiple and therefore it both enacts and stands for this replicative process. As in other dynamic activities, the distinction between depicting and enacting is sometimes blurred since it is difficult, if not impossible, to show propagation without performing it.

In summary, what becomes evident is that the complexity of dynamic processes is manifold. For instance, consider the dynamics of the mechanical world and its efficiencies—do these properties *signify* or do they simply *inhere* in the processes. The assertion that motion can exist without producing any signification seems hard to accept, especially within any framework of cultural semiotics. This consideration raises the question of whether a motion or dynamic action on its own *has* or *produces* meaning and through what means. The categories of dynamic action described above conjure associations and meaning values, and so do the behavioral attributes about to be described. Again, and throughout, the question remains whether or not these dynamic variables function as signs in their own right or merely as inflecting attributes of the signs to which they are attached or associated.

4. Behavioral attributes

Behaviors are attributes that augment the dynamic features, modifying and complicating their capacity to signify through analogy, association, or direct perception of effect.

Speed/acceleration/direction/velocity: The rate of speed is relative to a perceptual frame. Even with the dynamic graphics of quantitative data, not extending to the realms of special and general relativity, the question of the frame is none-the-less crucial. Being able to measure speed relies on having something within which or against which to measure it. The perceptual tendency to see objects in motion is much studied, but the question of gauging speed involves multiple variables, including the stable or unstable position of the viewer.

In standard physics, speed is defined simply as the temporal rate at which something moves along a pathway. By contrast, the category of velocity includes direction as well. In physics the values of these are defined as a scalar vs. a vector value. The question of what the rate means and what the direction signifies are also frame-specific. Speed in a cartoon of racing carrots and other vegetables has a fantasy aspect to it, the sign of an imaginary world, as does the velocity that carries Road Runner or Bugs Bunny off the edge of a precipice for several milliseconds before they realize their mistake in mid-air–and then fall. But the speed at which a data display on a map indicates spikes in the spread of a pandemic has its referent in the world of epidemiology and medical statistics where it may correlate with the actual rate of propagation, though timed displays are almost never structured in real-time.

But does speed *stand* for anything independently, or only as an attribute of another entity that has either speed or velocity? The contrast between acceleration and deceleration, measured as a factor of relative or comparative speeds, performs a sign value when it is embedded within a sequence of events, whether narrative or merely phenomenal. When an entity speeds up it acquires any one of a number of meanings—of frenzy, desire to escape, exhilaration, exuberance and so on. Similarly, when it slows down it suggests calming, or, exhaustion, even decrease of vitality. But neither acceleration nor deceleration has a sign value in itself that is fixed, determined, and unambiguous. In the semiotic as well as the physical sense, speed registers in relation to a frame of reference.

Direction also carries considerable associative power. Up and down, though fully relative, are marked with cultural associations from the banal to sublime. Our orientation in space as biological creatures makes the *up* direction positive and the *down* direction often negative as in the use of the terms and their association with graphing languages. In information graphics, the conventions of x and y axes reinforce these stereotypes. The values assigned to axes are not natural, merely a convention of Cartesian thinking and grids. Still upward movement carries a very different associative value from moving down, even if the downward motion of an airplane, for example, might signal a return to home, earth, and hearth with only positive connotations.

Force: Force is described in terms of push or pull, attraction or repulsion, an influence that can result in movement or change of the position, speed, direction, or state of an entity. In the sense that any force is attributable to a source, it is an indexical sign,

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connected to the originating object. But force also signifies iconically, as interaction, a property of connection and exchange in which energies interact with various degrees of intensity. And of course force can signify symbolically, when the evidence of power or influence results in motion towards or away or other movement or change.

Play: Play signifies through its specifics and particular modes of behavior, movement, and action. Unlike force, however, play need not be interactive. The concept of play in mechanisms is associated with the idea of mobility, providing room for elements to articulate freely and without friction. Play as an animating quality can inhere in the actions of an individual entity. Interactive play such as seduction or flirtation, avoidance or repulsion, is an inflection of the larger dynamic category of interaction. But play can also be present in an adjectival sense, as an attribute of a playful being, action, expression, or behavior. Play signifies through its specific qualities and characteristics, many of which are read entirely through anthropomorphic codes.

Reaction: As a subset of interaction, reaction is an action that appears to link one entity and another or others through a time sequence of events. Reactions imply a cognizant recognition in the process of exchange, as one entity necessarily acknowledges another for reaction to occur. As in the case of mechanical, or chemical, or physical entities, this activity does not require sentience or consciousness and so reaction cannot be said to signify awareness, only linked action or behavior.

Timing: The semiotics of timing are, like those of speed, reliant on frames of reference for their value. The components of sequence and seriality, of synchrony and apparent simultaneity, of regular intervals and random occurrences are all structured by intervals and segments of timing. Timing has rate/frequency and duration, and as in many of the behavioral features described, it can signify through analogy (as in the imitation of particular beat or rhythm, or the invocation of a calendrical structure, or a clock measure) or through its affective impact (fast or slow pace and/or change of pace). Timing is relational as well as being able to be measured with standard metrics and their encoded anthropological and sociological values. But timing is also profoundly psychological, producing meaning through individual perception and reaction.

5. Spatial conventions and features

The conventions for creating the illusion of space on the flat space of a page or screen have long been codified in the visual arts. Here the classic work by Erwin Panofsky, *Perspective as Symbolic Form* laid the foundation for a critical engagement with the properties of these conventions (1991). Other contributions by such crucial figures as William Ivins and later, Victor Burgin, provide crucial links between the graphical systems and their implications for the creation of subject positions (1946) (1991). Recent work on information as enunciation continued that work into a dialogue with visualization graphics, showing that their graphical organization inscribes a viewer's subject position (Drucker: 2017).

Planar: The flat plane of the page, wall, or canvas lends itself to rationalization in accord with the tenets of Cartesian grids. The intellectual and ideological force of Descartes's coordinate system makes its integration into information graphics nearly invisible by virtue of its familiarity and apparently "natural" format. But the x and y (and z) axes on which metrics are assigned and then used to construct graphical expressions of value for the purpose of calculation and comparison have no corollary in nature. Their structuring effect relies, however, not only on the ways they are used in producing legible and persuasive graphic arguments, but also, on the extent to which the flat presentation positions a viewer. The plane meets the viewer frontally with such a habitual orientation that that fact of its being a mode of direct address disappears. In effect, the flat plane is hailing its viewer, silently perhaps, but nonetheless irrevocably in its presentational mode. The screen space allows the viewer to be positions in such a way as to not see the presentation as an artifice. The enunciative system that positions the viewer simply disappears through the appearance of the image. But the flat plane positions the viewer within the I/you activity of a graphical system of enunciation. The question of who speaks in the graphic and who is spoken by it—the ideal subject of the image—is further complicated by the presence of an actual user whose subject position is never that of the ideal, but always inflected with the specifics of their own identity and circumstances.

Orthographic: Orthographic projections make use of conventions of architectural and technical drawing in which the scale of measure remains constant. The lack of distortion in these drawings is also accompanied by a bird's eye view, a ubiquitous position that provides the illusion of complete control over the surveilled field. While eschewing the point of view of either the flat plane with its direct address or perspectival systems inscribed from a single position, the orthographic view constructs its own omniscient-seeming subject. The cultural conventions within which these views are several. In Western antiquity they were used to render tactile and sequential encounters with space (e.g. Pompeiian wall paintings). But they are also present within Chinese, Japanese, Mayan representations of structures and spaces, as well as many cartographic and other visualization modes. They perform the curious function of appearing to be without an articulating subject since the metrics are

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not inflected by the viewing position. But at the same time, they inscribe an omniscient subject who views all elements from a seemingly objective position.

Perspectival: The invention of perspective in Europe in the Renaissance transformed spatial renderings into inscriptions of subject positionality. The conceit of the flat plane (of glass gridded for convenience) into the cone of vision to create a scrim on which to depict the complexity of the visual world and its vanishing points remains a feature of graphical construction today. Game graphics for "first-person shooters" are a paradigmatic instantiation of these techniques in dynamic formats, in which the world is continually re-drawn from the point of view of a single subject. The evident effect of this approach in structuring an enunciative system is both obvious and frequently invisible, again, by virtue of its familiarity. But the speaker and spoken of these images are locked into an enunciative relation through the positioning activity of the graphical structure.

Each of these spatial systems (other examples could expand this discussion) offers a distinct mode of structuring the relation between viewer and viewed, inscribing subject positions differently in ways that articulate power through graphical form. They carry potent signifying value by virtue of combining their formal properties with their invisibility and familiarity.

6. Conclusion

In outlining these various dynamic processes, behavioral features, and spatial conventions, the goal of this paper has been to articulate the components of graphical expressions that make use of these in animated images for data display. The dynamic features treated here—movement and change—as well as the spatial structures are common elements of information graphics. Just as Bertin's seven graphic variables were not assigned inherent value as signs, but identified as elements that could be strategically and deliberately deployed to communicate effectively, so the dynamic variables described are not assigned or considered to have inherent sign value. They can be used for signification, and in accord with their particular properties. This outline lists distinct and discrete dynamic graphic variables as a start for the discussion of how they signify.

Because dynamic images have movement, behavioral activity, and change over time, they often exist in an analogy to the living world. But most information visualizations are quantitative abstractions—representations of data or structured information that is already far from the phenomenal world, already cooked, as it were, through the structuring process that parameterizes various features of whatever is under examination. The outcome of this process is referred to as *capta* rather than *data*, a term that calls attention to constructed-ness rather than any "natural" condition (Drucker: 2011).

Many possibilities exist for further work in outlining the structural formality of dynamic systems and developing the description of the relations of their parts and behaviors to signifying practices. In looking at dynamic systems, a constant tension exists between what Gilles Deleuze identified as the distinction between representation and becoming, depiction and enactment (Roberts, 2019:6). Movement is not represented, it is real, but it is also constructed—through the techniques of animation—and semiotic. The dynamic variables on which it operates have signifying properties, but as in all semiotic systems, these are culturally and historically situated as well as inflected by individual psychological interpretation.

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AUTHOR
Johanna Drucker Distinguished Professor and Breslauer Professor in the Department of Information Studies at UCLA.