Italian Futurism and "The Fourth Dimension"

Linda Dalrymple Henderson

During the first three decades of the twentieth century, artists in nearly every major modern movement were influenced by a highly popular concept known as "the fourth dimension." In this period, "the fourth dimension" signified a higher, unseen dimension of space which might hold a reality truer than that of visual perception. Linked closely to the philosophical idealism which dominated the era, belief in a fourth dimension encouraged bold, formal experimentation by liberating artists from the domination of three-dimensional visual reality. If some artistic advocates of a fourth dimension, such as the Cubists, did not reject visual perception completely, Kupka, Malevich, Mondrian, and Van Doesburg found support in the idea for their creation of a totally abstract art. The Futurists Boccioni and Severini thus joined a distinguished list of artists attracted to "the fourth dimension," a group ranging from Analytical and Synthetic Cubists as well as Duchamp, Picabia, and Kupka, to Russian Futurists and Suprematists, American modernists in the Stieglitz and Arensberg circles, Dadaists, members of De Stijl, and even certain Surrealists.[1]

The popular, early twentieth-century view that space might indeed have more than three dimensions was an outgrowth of the development, during the first half of the nineteenth century, of geometries of more than three dimensions, known as *n*-dimensional geometry.[2] Although higher dimensions of space were first brought to public attention in the later nineteenth century by debates about the nature of geometrical axioms and the nature of space, "the fourth dimension" quickly acquired numerous non-geometric associations as well. In England, for example, the author Charles Howard Hinton developed a system of "hyperspace philosophy,"[3] based on his belief that the answer to the evils of positivism and materialism was for man to develop his powers of intuition in order to perceive a fourth dimension of space, the true reality. The fourth dimension also took on specifically mystical qualities when adopted by certain Theosophists and spiritualists; it functioned in this way in the writings of the major hyperspace philosophers descended from Hinton—P. D. Ouspensky in Russia and Claude Bragdon in the United States.

Fig. 1 *Pablo Picasso,* Portrait of Ambroise Vollard, *1910, oil on canvas. Moscow, Pushkin Museum.*

The first artistic applications of a spatial fourth dimension were developed in Paris in the years around 1910, and the Cubist literature in which they were set forth had an impact on all subsequent theorizing on the subject. Although Picasso's Cubism evolved from his interest in Cézanne and African art, his step to mature Analytical Cubism was unquestionably encouraged by his era's belief in a reality beyond immediate visual perception. The conceptual nature of African art was the specific factor that encouraged Picasso, as he said, "to paint objects as I think them, not as I see them."[4] For the theorists Metzinger, Gleizes, and Apollinaire, on the other hand, the fourth dimension served as the major rationale for a Cubist painter's freedom to distort or deform objects according to a higher law, as well as for his rejection of perspective.[5] As Apollinaire wrote on the subject of form in 1912, "It is to the fourth dimension alone that we owe a new norm of the perfect."[6]

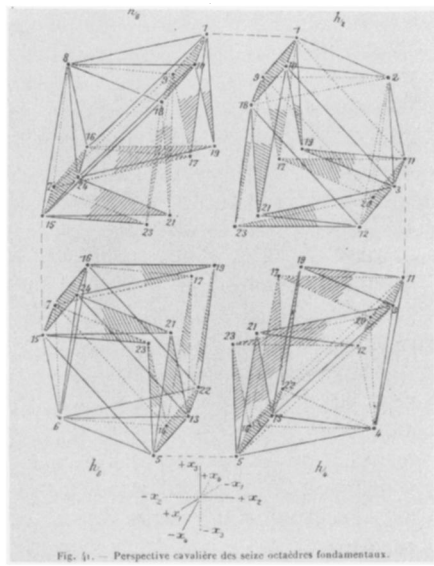

Fig. 2 Perspective cavalière, *from E. Jouffret,* Traité élémentaire de géométrie à quatre dimensions *(Paris, 1903), Fig. 41.*

Apollinaire's reference in *Les Peintres Cubistes* of 1913 to perspective as "that miserable tricky perspective, that fourth dimension in reverse"[7] confirms the specific connection of the fourth dimension with Cubist pictorial space as well as with form. The ambiguous space of a work such as Picasso's *Portrait of Ambroise Vollard* of 1910 offers a striking parallel to a

contemporary illustration in a textbook on four-dimensional geometry by E. Jouffret, published in Paris in 1903 ***(Figs. 1 and 2)***. Although not the source of Picasso's Cubist style, such illustrations would have confirmed the direction in which Cubism was developing. Both images seek to avoid a traditional three-dimensional reading of objects and space. Moreover, multiple viewpoints of the object are juxtaposed, just as Henri Poincaré had suggested in his text *La Science et l'hypothèse*, (1902), in a discussion of a possible means to represent a four-dimensional object. In fact, the explanation by Metzinger and Gleizes in *Du Cubisme* (1912) that the Cubist painter moves around his subject, gathering multiple views of it in order to produce a truer image, is based on Poincaré's connection of tactile and motor sensations with the possible perception of higher spatial dimensions.[8]

The method of the Cubist painter, then, was analogous to that of a geometer striving to achieve a perception of a higher dimensional object. If motion in time was involved in the process, it was only incidental to the artist's pursuit of four-dimensional space. Yet within the tradition of a spatial fourth dimension there had developed, by the end of the nineteenth century, a second approach to higher dimensions, an approach in which time and motion played a positive role. However, authors such as Hinton, who included time in their explanations of the fourth dimension, were not returning to the suggestion made in the eighteenth century that time itself could be defined as a fourth dimension.[9] That idea was to gain widespread acceptance once again only after 1919 with the popularization of Einstein's General Theory of Relativity based on a four-dimensional space-time continuum.[10] During the nineteenth and early twentieth centuries, however, the interpretation of the fourth dimension as time was almost completely overshadowed by enthusiasm about a higher spatial dimension, perpendicular to the three dimensions we know. Thus, Hinton believed firmly in the existence of a fourth dimension of space and argued that time and motion were incompletely understood manifestations of that additional spatial dimension.

Hinton's theoretical writings centered about the four-dimensional hypercube, or tesseract, the higher dimensional analogue of the cube ***(Fig. 3, lower right)***. Just as a cube can be generated by the motion of a two-dimensional plane through a third dimension, a hypercube would be traced by the motion of a three-dimensional cube into a new, fourth perpendicular direction. Given the difficulty of visualizing the four-dimensional appearance of this figure, even in a three-dimensional perspective projection ***(Fig. 3, lower left)***, a reversal of this process was more effective for Hinton's purposes. As a result, he concentrated on the three-dimensional sections which would be produced as a four-dimensional object passed through our three-dimensional space.

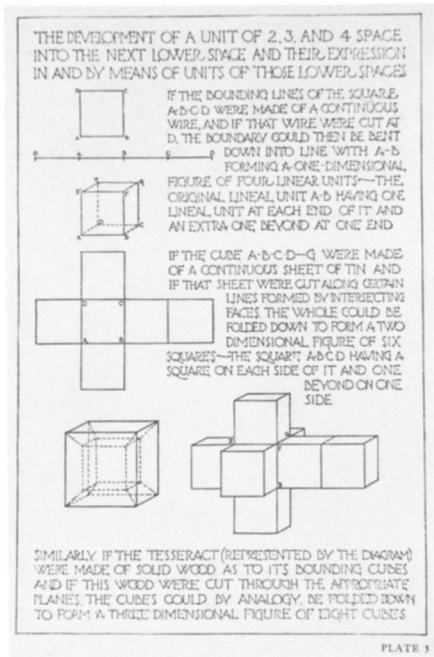

Fig. 3 *Claude Bragdon, Plate 3 from* A Primer of Higher Space (The Fourth Dimension) *(Rochester, N.Y., 1913).*

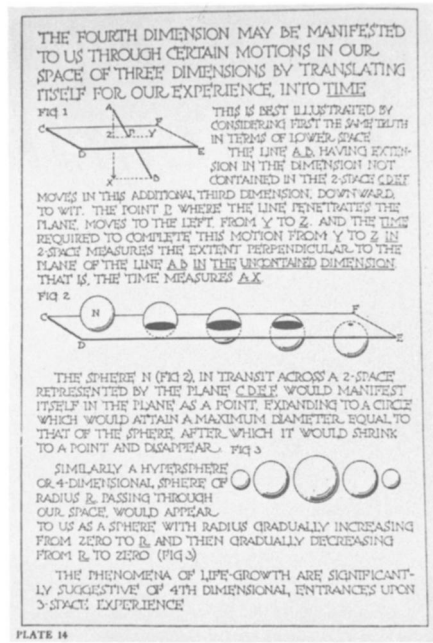

Fig. 4 *Claude Bragdon, Plate 14 from* A Primer of Higher Space *(1913).*

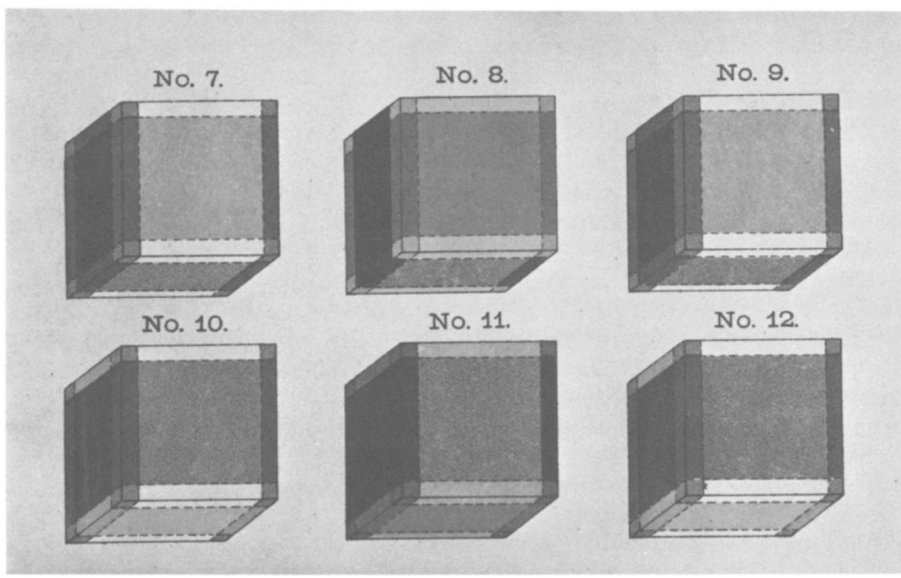

Fig. 5 *Frontispiece from Charles Howard Hinton,* The Fourth Dimension *(London and New York, 1904).*

To explain this process, Hinton and others frequently used the analogy of a planar world of two dimensions and the reactions of its inhabitants to three-dimensional solids passing through the plane ***(Fig. 4)***. Such an event had also formed the basis of the first fictional tale based on higher dimensions, the Englishman E.A. Abbott's delightful book of 1884, *Flatland: A Romance of Many Dimensions by a Square*.[11] As a sphere intersected his plane, Abbott's Flatlander perceived only a succession of concentric circles, first growing and then decreasing in size. These circles, experienced in time and motion, were his only clues to the nature of the three-dimensional sphere.[12] As the four to three-dimensional analogue of this process, Hinton created a series of multicolored cubes standing for the three-dimensional sections of the hypercube, which would be perceived in succession as it passed through our space. The illustration reproduced here ***(Fig. 5)*** includes six of the twelve catalogue cubes for Hinton's system, as it was presented in his book *The Fourth Dimension* (1904).

Hyperspace philosophy's two complementary approaches to higher dimensional space (motion to generate a higher solid and, in reverse, the sectioning of that solid by a space of one less dimension) are relevant for artists whose theoretical references to the fourth dimension occurred in the context of a motion-

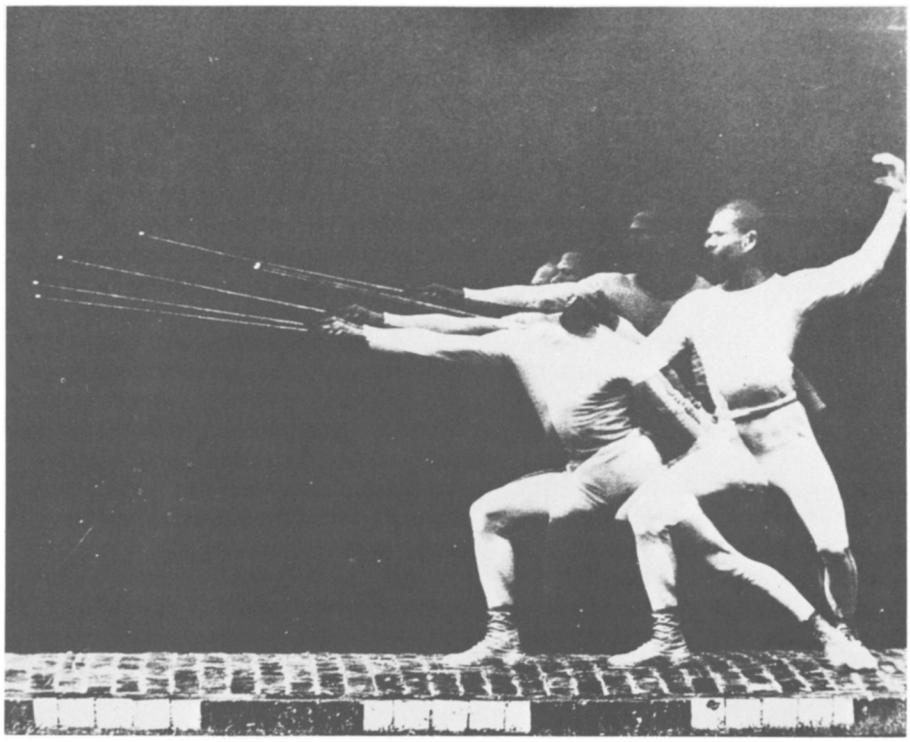

Fig. 6 *Etienne-Jules Marey,* Fencer, *1882. Paris, Cinémathèque française.*

Fig. 7 *Frantisek Kupka, Untitled drawing, ca. 1910, graphite pencil on paper. Paris, Collection Karl Flinker.*

oriented style. Kupka's painterly experiments, inspired by the chronophotography of Etienne-Jules Marey ***(Fig. 6)***, appear to have taken on a four-dimensional association for him once he was aware of Hinton's theories.[13] Most likely introduced to Hinton's ideas through the Parisian Theosophical publications in which they were summarized,[14] Kupka may have come to consider the forms generated in works such as ***Woman Picking Flowers*** (Musée National d'Art Moderne, Paris) and a related drawing of about 1910 ***(Fig. 7)*** as analogous to Hinton's generation of the hypercube by motion in time.

Fig. 8 *Marcel Duchamp,* Nude Descending a Staircase, No. 2, *1912, oil on canvas. Philadelphia Museum of Art, The Louise and Walter Arensberg Collection.*

The notation on the drawing, which Kupka must have added in 1912, confirms his concern with these issues: "Displacement in three dimensions takes place in space, while that in four dimensions by the exchange of atoms. But to fix gesture, a movement in the space of the canvas,—arrest several successive movements." This statement is drawn directly from a segment of Gaston de Pawlowski's tale "Voyage au pays de la quatrième dimension," which appeared on the front page of *Comoedia* on May 20, 1912.[15]

Just as Kupka's motion studies may have acquired a four-dimensional association, his young admirer Marcel Duchamp may have connected his own experiments in the "static representation of movement"[16] with the generation of higher dimensional forms. Duchamp later talked of his ***Sad Young Man on a Train*** (1911) and the ***Nude Descending a Staircase*** (1912) ***(Fig. 8)*** as examples of his early interest in "elemental/elementary parallelism"[17] and the "parallel multiplication of the n-dim'l continuum to form the n+1 dim'l continuum."[18] Yet Duchamp, who knew the geometry of Jouffret as well as Hinton's ideas, must quickly have realized that there is nothing four dimensional about the motion of an object unless it moves off into a new fourth direction (as Hinton's hypercube was to have done). As Duchamp later explained, "The movement of form in time inevitably ushered us into geometry and mathematics."[19] With this realization, Duchamp gave up his motion studies (as well as conventional oil painting) to carry out the most serious study of four-dimensional geometry undertaken by any early twentieth-century artist, a study which culminated in ***The Bride Stripped Bare by Her Bachelors, Even (The Large Glass)*** of 1915–1923.

Fig. 9 *Kazimir Malevich,* The Knife Grinder, *1912, oil on canvas. New Haven, Yale University Art Gallery.*

A similar rejection of motion in three-dimensional space was made by Kazimir Malevich after he painted his one example in this mode, ***The Knife Grinder*** of 1912 ***(Fig.9)***.[20] Malevich's exploration of sequential motion in this work was most likely influenced by Léger's ***Essai pour les trois portraits*** of 1911 (Milwaukee Art Center) which was exhibited in the Jack of Diamonds exhibition in Moscow in February 1912. Léger's own subtle exploration of motion in this painting may well have been inspired by the chronophotography fashion, reinforced by the Unanimiste poet Jules Romains's belief in the interpenetration of objects in nature, as well as by Henri Bergson's description of a reality in flux within the flow of duration.[21] Yet, Bergson himself had rejected

the chronophotograph and the cinematograph. For him such "snapshot view[s] of a transition"[22] were antithetical to the continuous, pure time of duration. Thus, the chronophotographically inspired records of the motion of three-dimensional objects painted by Kupka, Duchamp, Malevich, and Léger were not four-dimensional nor, if one were content to pursue Bergsonian duration alone, were they truly Bergsonian.

Enter the Futurist painter and sculptor Umberto Boccioni. In the second technique suggested by hyperspace philosophy (i.e., the visualization of a four-dimensional object by means of its successive three-dimensional sections), Boccioni was to find an alternative approach to the problem of the fourth dimension. This solution, he believed, was far superior to the Cubists' pure geometrical method as well as to the chronophotographic views that even his countryman Giacomo Balla had explored in such works as *Dynamism of a Dog on a Leash* of 1912 (Albright-Knox Art Gallery, Buffalo).

Although Boccioni's earlier writings had regularly included numerous positive references to mathematics and science,[23] and although Italy was one of the most prolific sources of scholarly literature on the fourth dimension,[24] it seems that Boccioni's artistic interest in the topic was aroused only through his connections with the art world of Paris. Marinetti's frequent presence in Paris from the 1890s onward and his acquaintance with Alfred Jarry and Apollinaire[25] might have provided an initial introduction to the idea. More important, however, was the position of the Futurist Severini in the midst of the Cubist avant-garde. When Boccioni and Carrà traveled to Paris in October 1911, as a prelude to their Bernheim-Jeune exhibition of February 1912, the studio visits Severini arranged included the atelier of Metzinger, who particularly impressed Boccioni.[26] If Boccioni did not hear of the fourth dimension at that time, his return trips to Paris in February and November 1912 and in June 1913 for his sculpture exhibition would have afforded ample opportunity to discuss the notion. For example, Boccioni wrote to his friend Nino Barbantini from Paris in February 1912, describing the goal of his new painting in terms of a "spiritualization [which] will be given by pure mathematical values, by pure geometrical dimensions. . . ."[27] In addition, the first major statement of Cubist views on the fourth dimension was soon to be published by Apollinaire in an article of April 1912 in *Les Soirées de Paris*, a text that formed the basis for one chapter of his *Les Peintres Cubistes* of March 1913.

Boccioni's only major discussion of the role of the fourth dimension in Futurist art was written and published initially in December 1913.[28] It was then included, with additions, in his text *Pittura scultura futuriste (dinamismo plastico)*, of 1914. In the final version Boccioni wrote as follows, introducing his ideas with a critique of earlier attempts at expressing dynamism in art:

> It seems clear to me that this *succession* is not to be found in repetition of legs, arms, and faces, as many people have stupidly believed, but is achieved through the intuitive search for the *unique form which gives continuity in space.* It is the form-type which makes an object live in the universal. Therefore, instead of the old-fashioned concept of sharp differentiation of bodies, instead of the modern concept of the Impressionists with their subdivision, their repetition, their rough indications of images, we would substitute a *concept of dynamic continuity* as unique form. And it is not by accident that I say form and not line, since *dynamic form* is a species of fourth dimension in painting and sculpture, which cannot exist perfectly without the complete affirmation of the three dimensions which determine volume: height, width, depth.
>
> I remember having read that Cubism with its breaking up of the object and unfolding of the parts of the object on the flat surface of the picture approached the fourth dimension. . . . However, this procedure is nothing but the transcription onto the surface of the canvas, of the planes of the object which its accidental position prevents us from seeing. It is a rational procedure which exists in relativity, not in an intuitive absolute. The integral notion of the object exists, with this procedure, in the three concepts of height,

Fig. 10 *Umberto Boccioni,* Unique Forms of Continuity in Space, *1913, bronze. New York, The Museum of Modern Art.*

Fig. 11 *Umberto Boccioni,* Muscular Dynamism, *1913, charcoal on paper. New York, The Museum of Modern Art.*

> width, depth, thus I repeat, in the relative, in the finite of mensuration. If with the artistic intuition it is ever possible to approach the concept of a fourth dimension, it is we Futurists who are getting there first. In fact, with the unique form which gives continuity in space we create a form which is the sum of the potential unfolding of the three known dimensions. Therefore, we cannot make a *measured and finite* fourth dimension, but rather a continuous projection of forces and forms intuited in their infinite unfolding. In fact, the unique dynamic form which we proclaim is nothing other than the suggestion of a form in motion which appears for a moment only to be lost in the infinite succession of its variety.
>
> In conclusion, we Futurists give the method for creating a conception more abstract and symbolic of reality, but we do not define the fixed and absolute measure which creates dynamism.[29]

Boccioni's understanding of the fourth dimension was obviously far more dynamic than that of the Cubists, whose geometric approach he specifically rejected. Dynamism and, by implication, motion in time are essential elements of his interpretation. Yet, Boccioni is careful to separate himself from the analyses of linear sequential motion painted by Kupka, Duchamp, and his fellow Futurist Balla, as well as from the chronophotographic experiments of the Italian photographer Bragaglia, who attempted to embody Futurist tenets in his *fotodinamismo*.[30]

Beyond his criticisms of the mistaken approaches of others to higher dimensions, Boccioni's text provides several indirect clues to his own definition of the fourth dimension. Since "dynamic form is a species of fourth dimension" for Boccioni, his view of the notion must be closely related to "the unique form which gives continuity in space," the title of his most famous sculpture ***(Fig. 10)***.[31] A four-dimensional form for Boccioni is a "form-type" which transcends artificial divisions in space; in other words, it "gives continuity." Boccioni's fourth dimension is an absolute, unmeasurable, infinite concept, as opposed to Cubism's "measured and finite" fourth dimension which is only relative in Boccioni's view. Intuition and not a "rational procedure" is the means by which the Futurist artist can approach this fourth dimension, which is "the sum of the potential unfolding of the three known dimensions." Finally, in creating a "more abstract and symbolic" conception of reality, the Futurist will wisely avoid trying to define or delimit "the fixed and absolute measure which creates dynamism."

To explain Boccioni's very different understanding of the fourth dimension, his prior artistic concerns and his choice of different sources on the fourth dimension must be considered. In the evolution of his artistic theory Boccioni had been particularly influenced by the philosophy of Bergson. Basic to his thinking, then, was a belief in a reality in constant flux, to be intuited by each individual within the flow of duration.[32] When Boccioni began to consider a fourth dimension, he naturally preferred interpretations involving time, the basic element in Bergson's theories. Hyperspace philosophy, with its recognition of time as a means to higher spatial dimensions, was ideally suited to Boccioni's needs. Bergson himself had linked time with space, referring to "homogeneous time" as a fourth dimension of space in his ***Essai sur les données immédiates de la conscience*** of 1889.[33] Significantly, however, Bergson had used the term in a negative sense, criticizing the mind's tendency to contaminate the pure flow of duration by spatializing it.

Yet, for Boccioni the fourth dimension did imply higher spatial dimensions and was not simply time alone (as it would have had to be for a Bergsonian purist). Throughout Boccioni's writings of the period from 1912 to 1914, there are frequent references to "a new inner reality,"[34] "an ideal, superior plane,"[35] and the need of the artist to "render the invisible which stirs and lives beyond intervening obstacles."[36] Boccioni's fellow Futurist Severini, who was later to theorize extensively on the fourth dimension in the context of Synthetic Cubism, wrote in the fall of 1913 that "we must forget exterior reality and our knowledge of it in order to create the new dimensions . . . ."[37] And Boccioni himself revealed a debt to Apollinaire and Cubism's spatial fourth dimension in his assertion that the fourth dimension "cannot exist perfectly without the complete affirmation of the three dimensions which determine volume"—an echo of Apollinaire's statement of 1912 that the fourth dimension "is engendered by the three known dimensions."[38]

What then was the relationship of higher space to time and motion in Boccioni's dynamic interpretation of the fourth dimension? His approach to hyperspace philosophy was not that of Kupka or Duchamp, who sought to generate a higher dimensional form by the motion of a three-dimensional object through space. Instead, if Boccioni was at all influenced by the hyperspace philosophy of Hinton [39] or an Italian parallel, it was the reverse process, the passage of a higher dimensional form through our space, that interested him. The purpose of Hinton's system of cubes had been to educate a reader's "space sense" in order for him to visualize this process. Although the reader would actually perceive only the sections of the hypercube (its eight individual colored cubes in succession), he would hopefully experience some intuition of the greater reality of the whole four-dimensional object.

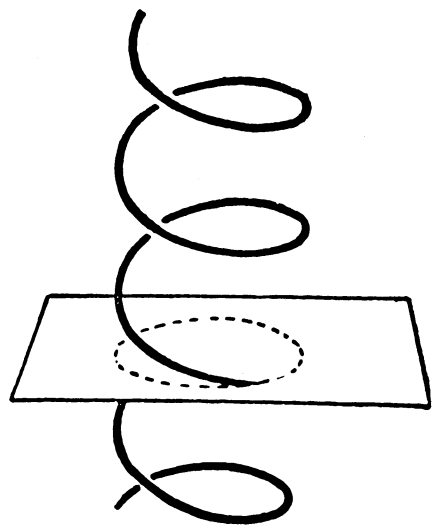

Fig. 12 *Intersection of a Spiral and a Plane, from Hinton,* The Fourth Dimension *(1904), p. 27.*

An analogy Hinton had used as early as 1888, and which was well known in this period, was the notion of a hand with its five fingertips placed on a table.[40] A two-dimensional being in the plane of the table would be unaware of the single "unique form" (the three-dimensional hand) "giving [the five separate fingerprints] continuity in [three-dimensional] space." In other words, the hand would function as a higher dimensional form, transcending the artificial divisions between objects in space, divisions which Boccioni consistently decried. Thus, Boccioni's striding figure, as depicted in sketches ***(Fig. 11)***, preparatory models, and a final sculpture, suggests the passage through our space of a four-dimensional figure (a unique form), whose successive states materialize and dematerialize before our eyes.

As the Russian mystic Ouspensky would later argue, time and motion in three-dimensional space may be considered illusions that

result only because of our incomplete perception of space.[41] Boccioni, the follower of Bergson, would never have accepted this extreme view, however. Instead, he asserted the positive value of time and motion as the most effective indication of a higher, dynamic reality. A further comparison with Hinton is suggested by Boccioni's interest in the spiral form as an innately dynamic shape possessing "absolute motion," a concern manifested in his writings and in his *Development of a Bottle in Space* of 1912 (The Museum of Modern Art, New York).[42] In *The Fourth Dimension* Hinton had demonstrated the way in which the illusion of circular motion in a plane could result when a spiral passed through a plane ***(Fig. 12)***. In reality the "relative motion" of the point would be subsumed within the "absolute motion" of the spiral (its vertical movement in a third dimension).

For Boccioni, then, the fourth dimension had both spatial and temporal implications, as the "fixed and absolute measure which [at the same time] creates dynamism." Nevertheless, Boccioni's fourth dimension differs radically from that of Cubism, because of its emphasis on time and motion. It is a "continuing projection of the forces and forms intuited in their infinite unfolding." Boccioni's goal in *Unique Forms of Continuity in Space* was a synthetic depiction of motion, a "synthetic continuity" as opposed to the "analytical discontinuity"[43] of Kupka, Duchamp, and the 1912 works of Balla, or the Cubists' simultaneous presentation of multiple views of an object. Undoubtedly, much of Boccioni's stylistic development occurred independently of an interest in higher dimensions. However, when he attempted to bring his own theories into line with the widespread contemporary belief in a fourth dimension of space, Boccioni found a suitable interpretation in one aspect of hyperspace philosophy. His *Unique Forms of Continuity in Space* is a tribute to higher dimensional space as well as to the dynamic reality of Bergson.

In the end, "the fourth dimension" was far less integral to the art and theory of Boccioni than it had been for the French Cubists or would be for artists such as Duchamp and Malevich. Nevertheless, it is a measure of the importance of the idea in this period that Boccioni felt that he must claim "the fourth dimension" for Futurism and even turn it against his Cubist rivals.

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Notes

1 The present essay is drawn from the author's forthcoming study of "the fourth dimension" in early twentieth-century art and theory to be published by Princeton University Press. That text is a revised and considerably expanded version of "The Artist, 'The Fourth Dimension,' and Non-Euclidean Geometry 1900—1930: A Romance of Many Dimensions" (henceforth referred to as "The Artist . . ."), a doctoral dissertation completed at Yale University in 1975.

2 By the later nineteenth century, another type of geometry, known as non-Euclidean geometry, also contributed to public interest in alternative kinds of space. Non-Euclidean geometry, formulated by the mathematicians Lobachevsky, Bolyai, and Riemann, studies spaces of positive, negative, or variable curvature and is thus a totally separate area of study from *n*-dimensional geometry. Although non-Euclidean geometry never enjoyed the widespread popularity of "the fourth dimension," it did have an impact on several artists, including Metzinger and Gleizes, Duchamp, and El Lissitzky.

3 The term "hyperspace philosophy" is not Hinton's but my own. It was invented in order to distinguish the writings of individuals such as Hinton, the Russian P.D. Ouspensky, and the American Claude Bragdon, all of whom explore the philosophical implications of higher dimensions, from more straightforward expositions of a geometric fourth dimension. Hinton's major theoretical texts are *A New Era of Thought* (London: Swan Sonnenschein & Co., 1888) and *The Fourth Dimension* (London: Swan Sonnenschein & Co., 1904; New York: John Lane, 1904); in addition, he published numerous articles and short stories based on the fourth dimension.

4 Picasso, as quoted in Ramón Gómez de la Serna, "Completa y veridica historia de Picasso y el cubismo," in *Revista de Occidente* (Madrid), vol. XXV (July 1929), p. 100.

5 For an initial discussion of Cubist interest in the fourth dimension, see Henderson, "A New Facet of Cubism: 'The Fourth Dimension' and 'Non-Euclidean Geometry' Reinterpreted," *The Art Quarterly,* vol. XXXIV (Winter 1971), pp. 410—33. The significance of higher dimensions for Cubist art and theory is discussed in far greater detail in Henderson, "The Artist . . .," Ch. III.

6 Guillaume Apollinaire, "La Peinture nouvelle: Notes d'art," *Les Soirées de Paris,* no. 3 (April 1912), pp. 90—91.

7 Guillaume Apollinaire, *Méditations esthétiques: Les Peintres Cubistes* (Paris: Eugène Figuière, 1913), p. 68.

8 On the importance of Poincaré's ideas for Gleizes and Metzinger, see Henderson, "A New Facet of Cubism," as well as Henderson, "The Artist . . .," Ch. III.

9 D'Alembert published this idea in his 1754 article on "dimension" in the *Encyclopédie* edited by himself and Diderot. Lagrange presented a similar view in 1797 in his *Théorie des fonctions analytiques.*

10 Einstein began to attract public notice only in November 1919, when the results of experiments during a solar eclipse confirmed his assertion in the General Theory that light waves are bent by the mass of the sun. See, for example, Henderson, "A New Facet of Cubism," pp. 414—19; and Ronald W. Clark, *Einstein: The Life and Times* (New York: World Publishing, 1971), pp. 227—66.

11 See Edwin Abbott Abbott, *Flatland: A Romance of Many Dimensions by a Square* (London: Seeley & Co., 1884).

12 In contrast to Bragdon's didactic diagram ***(Fig. 4)***, a sphere passing perpendicularly through a plane would actually produce a succession of increasing and decreasing circles around a single point in the plane. The clearest analysis of the relationship between space and motion in time is to be found in Peter Demianovich Ouspensky's *Tertium Organium: The Third Canon of Thought, A Key to the Enigmas of the World* (1911), trans. from 2nd ed. (1916) by Claude Bragdon and Nicolas Bessaraboff, 2nd Amer. ed. rev. (New York: Alfred A. Knopf), Chs. III—VI. Ouspensky's philosophy and particularly his elaboration of the two-dimensional analogy (Ch. VI) is summarized in Henderson, "The Merging of Time and Space: 'The Fourth Dimension' in Russia from Ouspensky to Malevich," *The Structurist,* no. 15/16 (1975/1976), pp. 97—108.

13 On Kupka and Marey, see Margit Rowell, "A Metaphysics of Abstraction," in *Frantisek Kupka 1871—1975: A Retrospective* (Solomon R. Guggenheim Museum, New York, 1975), pp. 49—67. As Rowell points out, Marey actually experimented with the generation of three-dimensional virtual volumes by photographing a rotating form (p. 56).

14 See, for example, C.W. Leadbeater, *L'Autre Côté de la mort* (Paris: Editions Théosophiques, 1910), which included an account of Hinton's ideas.

15 Rowell ("A Metaphysics of Abstraction," in *Frantisek Kupka,* p. 66) first noted the similarity of Kupka's inscription to the following passage from Pawlowski's "Voyage au pays de la quatrième dimension" (*Comoedia,* 20 May 1912, p. 1):

> Whereas in three-dimensional displacement the atoms constituting a body are pushed aside and replaced by other atoms forming another body . . . displacement in the country of the fourth dimension is enacted by what one used to call a *transmutation.* The world of the fourth dimension being *continuous,* no movement in the ordinary sense of the word can be produced as in the mobile world of three dimensions. Therefore a displacement is made through an exchange of qualities between neighboring atoms. . . . When one enters the country of the fourth dimension, movement such as we know it, no longer exists; there are only qualitative changes and we remain immobile, in the common sense of the word.

16 Duchamp, as quoted in "Eleven Europeans in America" (Interviews by James Johnson Sweeney),

The Museum of Modern Art Bulletin, vol. XIII/4—5 (1946), p. 20. Rowell contrasts the chronophotographically inspired approach of both Kupka and Duchamp to that of the Futurists in "Kupka, Duchamp, and Marey," *Studio International,* vol. CLXXXIX (January—February 1975), pp. 48—51.

17 Duchamp, as quoted in Pierre Cabanne, *Dialogues with Marcel Duchamp,* trans. Ron Padgett (New York: Viking Press, 1971), pp. 29, 34.

18 Marcel Duchamp, *A l'infinitif (The White Box),* in *Salt Seller: The Writings of Marcel Duchamp (Marchand du sel),* ed. Michel Sanouillet (New York: Oxford University Press, 1973), p. 92.

19 Duchamp, as quoted in Cabanne, *Dialogues,* p. 31.

20 Malevich's Suprematist titles such as *Movement of Painterly Masses in the Fourth Dimension* confirm the continued role motion played in his thinking about higher dimensions. However, Suprematism's geometric language and its infinite white space (free from gravity and any identifiable three-dimensionality) were far removed from *The Knife Grinder*'s simplistic sequential motion. See Henderson, "The Merging of Time and Space," pp. 104—5, although a far more developed discussion of the subject occurs in the author's forthcoming book.

21 On the relationship of Léger's *Essai pour les trois portraits* to the intellectual milieu of Paris, see Christopher Green, *Léger and the Avant-Garde* (New Haven: Yale University Press, 1976), pp. 22—27.

22 Henri Bergson, *Creative Evolution* (1907), trans. Arthur Mitchell (New York: H. Holt & Co., 1911), p. 302.

23 The *Technical Manifesto of Futurist Painting* of 11 April 1910 had referred to the "vivifying current of science." See *Futurist Manifestos,* ed. Umbro Apollonio, trans. Robert Brain, R.W. Flint, J.C. Higgitt, Caroline Tisdall (New York: Viking Press, 1973), p. 18. Similarly, the text included in the Bernheim-Jeune catalogue of February 1912, based on a lecture of 29 May 1911 by Boccioni, spoke of "a law of our interior mathematics" (*Futurist Manifestos,* ed. Apollonio, p. 50). Marinetti's later manifesto, *Geometric and Mechanical Splendour and the Numerical Sensibility* (18 March 1914) is a further testament to the Futurist's general predilection for references to mathematics. See *Futurist Manifestos,* ed. Apollonio, pp. 154—60. On the strain of positivism initially evident among the Futurist painters, see Marianne W. Martin, *Futurist Art and Theory 1909—1915* (Oxford: Clarendon Press, 1968), pp. 45, 46.

24 Duncan M.Y. Sommerville's *Bibliography of Non-Euclidean Geometry, Including the Theory of Parallels, the Foundations of Geometry, and Space of n-Dimensions* (London: Harrison & Sons, 1911) lists a total of 322 books and articles on the "new" geometries published in Italy between 1901 and 1910. Italy ranked third behind Germany and France in Sommerville's numerical analysis of publications and counted among her prominent scholars of the "new" geometries Eugenio Beltrami, Giuseppe Veronese, Gino Loria, Roberto Bonola, and Federigo Enriques.

25 Jarry's interest in four-dimensional and non-Euclidean geometries is evident in his writings of the late 1890s, such as *Gestes et opinions du Docteur Faustroll, pataphysicien* (Paris: Eugène Fasquelle, 1911) and "Commentaire pour servir à la construction pratique de la machine à explorer le temps" (*Mercure de France,* vol. XXIX [February 1899], pp. 387—96). See Henderson, "The Artist . . .," pp. 93—100.

On Marinetti in Paris and his connections with Apollinaire and Jarry, see Martin, *Futurist Art and Theory,* pp. 28—37, 43. See also Gino Severini, *Tutta la vita di un pittore* (Milan: Garzanti, 1946), pp. 96—98. On Marinetti and the poets of the Abbaye de Créteil, see Marianne Martin, "Futurism, Unanism and Apollinaire," *Art Journal,* vol. XXVIII (Spring 1969), pp. 258—68.

26 See Martin, *Futurist Art and Theory,* p. 110.

27 Letter from Boccioni to Nino Barbantini, 12 February 1912, in *Archivi del Futurismo,* ed. Maria Drudi Gambillo and Teresa Fiori (Rome: De Luca Editore, [1958]), p. 40. Other letters reproduced by Gambillo and Fiori document Boccioni's presence in Paris on 12 November 1912 and 21 June 1913.

28 For the initial, shorter version of this text, see Boccioni, "Plastic Dynamism" (*Lacerba,* 15 December 1913), in *Futurist Manifestos,* ed. Apollonio, pp. 92—95.

29 Boccioni, "Pittura scultura futuriste (dinamismo plastico)," *Poesia* (Milan), 1914, pp. 196—99.

30 On Bragaglia, see Martin, *Futurist Art and Theory,* p. 179, as well as the text by Giovanni Lista elsewhere in this issue.

31 That Boccioni identified the phrase and title with the fourth dimension is confirmed by Gino Severini in his article "La Peinture d'avant-garde," *Mercure de France,* vol. CXXI (1 June 1917), pp. 451—68. Severini wrote that "Boccioni, when defining what he calls 'dynamism,' in connection with our earlier researches in movement, alluded to a kind of fourth dimension which would be 'the unique form giving continuity in space'" (p. 459).

32 In his discussion of the fourth dimension, Boccioni also reflects the influence of Bergson in his preference for the "intuitive absolute" over Cubism's "rational procedure which exists in relativity." In *Creative Evolution* Bergson, the advocate of intuition versus intellect, had asserted that "in the absolute we live and move and have our being. The knowledge we possess of it is incomplete, no doubt, but not external or relative" (p. 199).

For further evidence of Boccioni's careful study of Bergson, see Brian Petrie, "Boccioni and Bergson," *The Burlington Magazine,* vol. CXVI (March 1974), pp. 140—47. In addition to Bergson's general philosophical influence, Petrie establishes specific sources in Bergson's writings for Boccioni's ideas on the interpenetration of forms, on absolute and relative motion, and on force-lines.

33 Henri Bergson, *Essai sur les données immédiates de la conscience* (Paris: Félix Alcan, 1889), pp. 82—83.

34 Boccioni, "The Plastic Foundations of Futurist Sculpture and Painting" (*Lacerba,* 15 March 1913), in *Futurist Manifestos,* ed. Apollonio, p. 88.

35 Boccioni, "Plastic Dynamism," in *Futurist Manifestos,* ed. Apollonio, p. 94; also, *Pittura scultura futuriste,* p. 201.

36 "The Exhibitors to the Public," in *Les Peintures futuristes italiens,* exh. cat. (Galerie Bernheim-Jeune & Cie, Paris, 5—24 February 1912), p. 6; text based on a lecture of 29 May 1911 by Boccioni.

37 Severini, "The Plastic Analogies of Dynamism —Futurist Manifesto" (unpub.), September—October 1913, in *Futurist Manifestos,* ed. Apollonio, p. 118.

38 Apollinaire, "La Peinture nouvelle," p. 90.

39 In his article of 1917, "La Peinture d'avant-garde" (pp. 461, 464), Severini mentions both Maurice Boucher's *Essai sur l'hyperespace* (Paris: Félix Alcan, 1903), which had discussed the work of Hinton, and the theories of A. de Noircarme whose book *Quatrième Dimension* (Paris: Editions Théosophiques, 1912) had linked a time-oriented hyperspace philosophy to Theosophy. If Severini knew these works before the war, he may well have directed Boccioni to them and even beyond them to Hinton.

40 Hinton, *A New Era of Thought,* p. 65.

41 Had he known of it, Boccioni would also have rejected the interpretation, voiced most clearly by Ouspensky (*Tertium Organum,* p. 102), which suggests that beyond the illusions of time and motion four-dimensional reality is static. Pawlowski shared Ouspensky's views on this subject, as the quotation in n. 15 above demonstrates.

42 Boccioni first described Futurist sculpture as "spiral architecture" in his preface for the catalogue *I^re Exposition de sculpture futuriste du peintre et sculpteur futuriste Boccioni* (Galerie la Boëtie, Paris, 20 June—16 July 1913). See *Modern Artists in Art,* ed. Robert L. Herbert (Englewood Cliffs, N.J.: Prentice-Hall, 1964), p. 48. The spiral is also discussed in "Plastic Dynamism," in *Futurist Manifestos,* ed. Apollonio, p. 94.

Although Boccioni presented his dual definitions of motion in the catalogue preface of 1913, his distinctions between "absolute motion" and "relative motion" are clearest in his text "Absolute Motion + Relative Motion = Dynamism" (*Lacerba,* 15 March 1914), in *Futurist Manifestos,* ed. Apollonio, pp. 150—51.

43 Rowell, "Kupka, Duchamp, and Marey," p. 48.