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THE DEVELOPMENT OF REFERENCE SYSTEMS IN CHILDREN

by

Jeanne L. Rivoire

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I hereby recommend that this dissertation prepared under my
direction by Jeanne L. Rivoire
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degree of Doctor of Philosophy

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I. Introduction

A. Modern Theories of the Development of the Concept of Space

1. Einsteinian concept of space. In 1905, young Albert Einstein asserted that the laws of nature are the same for all uniformly moving bodies (Barnett, 1950). He pointed out that nature offers no absolute standards of comparison; and that space is--as Leibnitz had said--"the order or relation of things among themselves." Without things occupying it, it is nothing. According to Einstein the fundamental continuum to be investigated was not one of space but one of space-time, a four dimensional metrical-field governed by the distribution of matter (d'Abro, 1950). For his investigations, Einstein hypothesized that when space-time is substituted for space, and if the assumption is made that free bodies and rays of light follow geodesics, i.e., the geometry of curved surfaces, then the principles of the geometry of extension (Euclidean geometry) are foreign. He went on to find out that empirically this was true (Barnett, 1950). Basically, Einstein's space is curved, filled with things, and made up of what Whittaker called extra-galactic

space¹ as well as molar and molecular space. It is of non-rigid bodies, heterogeneous, and nonisotropic, i.e., not having any properties which are the same in all directions.

D'Abro has said that Euclidean geometry is more consistent with the structure that we tend to attribute to the universe as the basis of ordinary macroscopic experience. He pointed out that if there was a change in our ordering relation we might have obtained a space (that is experienced space) of a greater number of dimensions (d'Abro, 1950). He said "undoubtedly, however, when account is taken of the facts of experience, the three-dimensional co-ordination is by far the simplest; hence, there is no reason to be surprised at its having imposed itself with such force" (d'Abro, p. 83). He went on to say that "we must conceive also of varying intensities of non-Euclidianism, or of departure from Euclidianism" (d'Abro, p. 83). Poincare, as reported by d'Abro (1950), also has pointed out that Euclidean geometry of rigid bodies, homogeneous space, and isotropism, is one of the simplest types of geometry for the same reason that a monosyllable is simpler than a polysyllable. Finally, d'Abro (1950, p. 50) said:

Thus, we see that Euclidean geometry stands at the dividing line of Riemannian and Lobatchewskian

1. Extra-galactic space deals with figures of very great size such as those involved in cosmology (Whittaker, 1949).

geometry. When our surface changes in shape the geometry remains Riemannian so long as there subsists the least trace of sphericity, that is, of positive curvature. Likewise, it remains Lobatchewskian so long as there subsists the least trace of saddle-shapedness, or negative curvature. Finally, it is strictly Euclidean only when the surface has become a plane, that is exhibits zero curvature.

D'Abro (1950) also pointed out that the reason that it is so difficult to determine if the space of the universe is Euclidean or not, is because both Riemannian and Lobatchewskian geometry merge by insensible gradations into Euclidean geometry.

2. Titchener's context theory in relation to spatial concepts. By 1910 Titchener had recognized three types of elements--sensations, images and feelings. He maintained that cognitive processes and perceptions always have images in their earlier stages, although it was recognized that images are but faint copies of sensation aroused by central processes. After the attribute doctrine, i.e., Titchener's theory that sensations have five attributes, was established, attributes not sensations were established as the elements. Thus, we see a straight line, not a series of points. But Titchener even had trouble making attributes the basic elements of perception because it was discovered that a given attribute may be a joint function of several others. Also, Helson (1948) has noted that the afferent fibers involved

in a particular instance of stimulation differ only in rate, frequency, amplitude, and number. These differences are too few for the many perceived characteristics of space. However, the analytical elementarists believed that the attributes are the basic stuff of awareness, although they could not straighten them out in consistent terms. But they felt that these elements are a genuine part of the phenomenology of perception, i.e., the way the world appears to us.

Titchener primarily addressed himself to the meaning of the perceived (Titchener, 1909, 1914, 1915). He said that perception consists of (1) a number of sensations consolidated and incorporated into a group under the laws of attention and the special principles of sensory connection; (2) images from past experiences that supplement the sensations; and (3) meaning. Titchener believed that meaning is something the sensations or images provide for one another--thus meaning is context. He also believed that one set of sensations is usually focal and forms the core of the perception. Titchener is known for his core-context theory of perception. To explain individual differences in space perception he used the notion of context.

In sum, Titchener built up perceptions by cementing together a series of elements or attributes. And although subsequent research has eradicated these concepts per se, nonetheless an advance was made in seeing that perception is

always an integrative process of some kind; it goes beyond mere detached sensations.

3. The Gestalt system of spatial perception. Wertheimer, Koffka, Köhler and their followers showed the supreme importance of factors of relationships and structural groupings even with simple sensory stimuli in the structure and organization of space. Koffka (1935) said that things look as they look because they are what they are. He applied as basic to the organization of space, the field concept which is a system of stresses and strains which will determine real behavior. He believed that organization within this field will always be as good and as simple as the prevailing conditions allow (Law of Prägnanz).

The first and most fundamental characteristic of the organization of the field is its differentiation into two phenomenal parts or categories which Rubin (1921) termed figure and ground. In many respects, the gestaltists believed that perception consists essentially in the emergence of figure from ground. To them figure has form, appears solid and is well articulated, whereas ground has no form, tends toward neutrality, is in the nature of substance and is not well articulated. Ground then is a spatial framework which is the general framework in which every single part of our phenomenal world receives a place (Koffka, 1939). The figures

or the parts within our phenomenal world are organized, according to Wertheimer (1958), by six major laws: the laws of proximity, similarity, closed forms, good contour or common destiny, common movement, and experience. Koffka (1935) listed five fundamental principles of spatial organization: (1) primitive perception is three dimensional and is not articulated; (2) a surface is the product of strong forces of organization; (3) varying stages of homogenization and inhomogenization occur; (4) visual space is a dynamic event rather than a geometrical pattern; (5) the stimulus distribution is as inhomogeneous as possible and thus as articulate as possible. The gestaltists believed that the basis for these laws and principles of organization is the principle of isomorphism according to which characteristic aspects of the physiological processes are also characteristic aspects of the corresponding conscious process.

Köhler (1929) searched for a physiological basis for the gestalt theory of space perception. He feels that an organization, or the experience of a pattern as one thing always implies a corresponding dynamic unit in the physiological process. Accordingly, he developed a thesis to the effect that whatever happened on the conscious side is mirrored by an isomorphic corresponding process in the brain. According to this theory, it is not possible to find certain

receptor cells that will have specific correlates with the conscious pattern of objects. Experience is not put together in a mosaic-like fashion--a percept is a macroscopic phenomenon--therefore its physiological isomorph will be macroscopic and involve an appreciable amount of cortical tissue (Köhler, 1929). Köhler (1929) thus hypothesized macroscopic electrical fields as explaining the facts of perception.

Köhler next set about attempting (1) to prove that the percept was actually field-like in character, (2) to elaborate a hypothetical model by which electrical isomorphic fields in the sensory or adjoining areas of the cortex could be conceived on the physiological data already known, and (3) to show that gestalt-like physiological configurations based on field notions do exist in the cortex of the brain and are intimately associated with percepts (Allport, 1955). Köhler (1938, 1940) envisaged within the ganglionic layers of the cortex stationary chemical states maintained by sensory nerve-impulses as these impulses come into the cortex from the afferent neurons. These states have their intensity regulated by the intensity of the chemical activity which in turn pass circularly from the cortical region of the figure through the ground in the surrounding tissue and back into the figure again. A "halo" of current occurs around the boundary of the figure, with the current more restricted and dense inside the figure

than outside it. Thus, there is in figure or object perception, an electric current of diffusion whose distribution is governed by the shape of the boundaries of the system; the pattern of current flow is determined by the spatial properties of the object perceived. However, it does not correspond, according to Köhler (1938, 1940), to metrical concepts but rather to topological ones, i.e., to relationships of betweenness and adjointedness but not to exact sizes, angles and shapes. Köhler and Held (1949) worked to see whether this physiological theory of the perception of space is actually empirically true. They demonstrated experimentally that potential differences between the occipital visual cortex and the vertex of the brain do occur when a bright object is moved across the visual field. The potential difference in the recorded curve of the subject was found to be greatest as the perceived object crossed the foveal region. Köhler (1951) discussed the possibility that these potential changes are due to random or synchronized distributions of nerve impulses. However, since no attempt was made to correlate the electrical field changes with the cortical boundaries or adjacentness of the percept-figure, the cortical field theory was not differentially established (Allport, 1955). Nonetheless, there was established at least the possibility that electric brain currents do occur in the perception of objects.

4. The probabilistic functionalist concept of space.

Egon Brunswik was interested in dimensional order, the stabilizing factors of which are the constancies of perception. Brunswik (1949) envisaged the formation of the percept of an object as the combining together of the elements of an aggregate, with an emphasis on the molar view as the basis for perception. His research is essentially molar, functionalistic, and environmentalistic and not molecular and physiological. It differs from gestalt psychology by placing emphasis on achievement or distal focusing whereas gestalt psychology emphasizes proximal focusing as basic to the perceptual process. In order to study the organism's achievement, Brunswik contended that situations representative of the natural habitat of the subject must be analyzed. To do this, correlations between the distal value and the attained value of a stimulus, e.g., the correlations between the physical size and the estimated size of objects, must be made (Postman and Tolman, 1959).

5. The concept of space from the transactionalists point of view. The Hanover-Institute group led by Ames, Cantril, Ittelson and Kilpatrick as reported by Kilpatrick (1952) view perception of space as the product of the continual recording of the relatedness of things as defined by action. For these investigators, perception of space is the apprehension

of probable significances (Ittelson, 1951). Accordingly, out of a relatively stable significance, as determined by the relative effectiveness of actions, a pattern of unconscious assumptions is built; these assumptions may be considered as weighted averages of past experiences. For the transactionalists, the sum total of assumptions which the individual makes constitutes his assumptive world which is largely unconscious. It is this assumptive world of the individual which determines his perceptions, i.e., provides him with predictions of probable significances which are based upon the statistical average of a great number of past experiences (Lawrence, 1949). Perception, then, never takes place by itself, it can only be studied as part of the situation in which it occurs (Ittelson and Cantril, 1954). For the transactionalist, it is meaningless to speak of either perception or the situation in which perception occurs as existing apart from the situation in which it is encountered. For these investigators, then, the word transaction is used for this interaction of the organism and environment.

6. Bruner's and Postman's views on space perception.

Bruner (1951) stated that perceiving involves a three step cycle. Perceiving begins with an expectancy or a hypothesis. "We not only see but we look" (Woodworth, 1947, p. 121). Bruner pointed out that "we are always to some extent prepared for seeing.....some particular thing or class of things"

(Bruner, 1951, p. 308). Thus a hypothesis is evoked which results from the arousal of central cognitive and motivational processes by preceding environment states of affairs. The second step in the perceiving process is the input of information from the environment and the last is a check or confirmation procedure. "Input information is confirmatory to or congruent with the operative hypothesis, or it is in varying degree infirming or incongruent" (Bruner, 1951, p. 308).

In this theory an intervening mechanism, accentuation, is postulated between perception and behavior. Accentuation is conceived of as a central process (Bruner and Postman, 1949). This variable is, of course, only useful to the extent to which it is anchored to antecedent and consequent conditions, i.e., attribution judgments. For example, the apparent size of a given object to be judged is a function of its distance from the neutral point of the range of such stimuli which the person has judged in the past. The neutral point of the range is the organism's subjective probability about the middle of the range of sizes which belongs in the same class as the object being judged. In regard to this, Helson (1948, p. 299) pointed out "that the neutral level of the range can be closely approximated by assuming that it is the weighted geometric mean of all stimuli being judged."

In sum, it would appear that these constructs on perceptual development are similar to those of the transactionalists,

except perhaps Bruner and Postman have used simpler procedures than those of the transactionalists (Solley and Murphy, 1960). It would seem that the constructs of the assumptive world and the accentuative world are similar except the accentuative world is predicated upon a more limited range of values. However, both sets of investigators believe that the individual is striving toward a so-called neutral point within his assumptive-accentuative world in order to maintain a harmony with past sets of experience.

7. The sensory-tonic theoretical approach to the perception of space. Werner and Wapner (1952) have made a serious attempt to unite the sensory aspects of perception to the motor aspects. The word tonic is used in a broad sense involving not only changes of muscular tensions (tonicity), but also the larger, phasic contractions entering into actual movements. The term sensory apparently means a conscious experience and also the action of the receptors, afferent neurons, and the cortical sensory areas. According to Werner and Wapner (1952), this theory is an attempt to be an organismic theory with the essential tenet being that the organismic states are part and parcel of perception. For example, when the body is erect, a perpendicular rod will be perceived as vertical because its stimuli do not disturb the existing body equilibrium.

8. The texture-gradient concept of space. Whereas the

gestaltists pointed out the necessary differences between the proximal stimulus-pattern and the percept, and attribute the "ways things look" to the organizing forces of the brain-field, Gibson attempted to show that the differences between what the stimulation-pattern contains and what is perceived are not so great after all.

In formulating his theory, Gibson (1950) argued that the abstract space of points, lines, and planes was a poor conception with which to begin the analysis of how we see for "no one has ever seen it." Gibson believed that those investigators who use the geometric space got off to a bad start in studying space perception, rather he considered that the visual world itself should be studied. Gibson (1950) pointed out that because man is a mobile animal, the environmental shapes and dimensions are successively transformed on the retina. Accordingly, he asked the question: "if these locomotion transformations all yield perceptions of the same objects why could no other transformations yield the perception of all possible different visual forms" (Gibson, 1950, p. 192)? He said:

Certain regular transformations (e.g. expansion, contraction, a one-way compression, a certain kind of skew and a simple transposition of the retina) go with a perception of the same shape. They are related to the geometry of perspective and parallax. Certain other

transformations, not experienced as continuous during location, go with the perception of different shapes. They are not confined to the geometry of perspective and parallax.

Conceived thus, visual outline forms are not unique. They could be arranged in a systematic way such that each form would differ only gradually and continually from all others. Such dimensions of similarity among contour forms have never been explored but the fact that modern geometry can specify general modes of transformation suggests that explorations ought to be possible (Gibson, 1950, p. 192).

In connection with this view, Cassirer (1944, p. 8) stated that "the concepts of modern geometry derive their precision and true universality only from the fact that the intuited particular figures are not considered as pre-given and rigid, but rather as a kind of plastic material capable of being moulded into the most varied form."

Gibson went on to point out that reducing the infinite variety of visual forms to order only by classification, beginning with triangles, squares and circles, results in a set of mutually exclusive categories analogous to the classes implied by Aristotelian logic. Therefore, he believes that classification is not the best way of ordering a manifold; he thinks that serializing is more likely to bring out the fundamental relations between things. Thus, he pointed out that the normal or standard shapes are no more than special points of anchorage on a continuous dimension of variation

and all are in the same transformation group; for Gibson entities of shape do not exist.

Viewing the texture gradient theory as a whole, Gibson assumes that the fundamental condition for seeing a visual world is an array of physical surfaces reflecting light projected onto the retina. He pointed out that "this is in contrast with the usual assumption that the problem of perception should start from the geometrical characteristics of abstract space" (Gibson, 1950, p. 132). He stated that in any environment these surfaces are of frontal and longitudinal types, i.e., the frontal surface is transverse to the line of sight whereas the longitudinal one is parallel with the line of sight. Gibson then postulated that the perception of depth, distance, or the so-called third dimension is reducible to the problem of the perception of the longitudinal surfaces. He said "when no surface is present in perception because of homogeneous retinal stimulation, distance is indeterminate" (Gibson, 1950, p. 195). Thus Gibson (1950, p. 196) believes that "the perception of an object in depth is reducible to the problem of the changing slant of a curved surface or the differing slants of a bent surface." The general condition for perception of surface is a kind of ordinal stimulation called a gradient, e.g., the taper of the ground (field below the horizon) or the taper of the sky (field above

the horizon). The general condition for perception of an edge is an abrupt gradient. Hence macrotextures occur in near positions of the field while microtextures are seen of the faraway positions.

Finally, Gibson (1959) extended his theory of textual gradients in the case of a dual array projected from the surface of areal environment to include two additional gradients: (1) the gradient of successive incongruence of the texture (gradient of displacement) and (2) the gradient of simultaneous incongruence of one texture relative to the other (gradient of disparity). There is multiple concomitant stimulation, according to Gibson (1959), primarily perceived according to some type of gradient or the interaction of gradients.

9. Helson's adaptation theory in regard to spatial perception. Helson (1947, p. 5) stated:

Fundamental to the theory is the assumption that effects of stimulation form a spatio-temporal configuration in which order prevails. For every excitation response configuration there is assumed a stimulus which represents the pooled effect of all the stimuli, and to which the organism may be said to be attuned or adapted.....There is an AL^2 for every moment of stimulation, changing in time and

2. AL is the adaptation level and refers to the stimulus in a series which evokes a neutral response. Helson (1947) said it represents the approximate geometric mean of the physical values.

with varying conditions of stimulations. It is a function of all the stimuli acting upon the organism at any given moment as well as in the past.

It would appear that Helson is proposing a theory based primarily on behavior equilibrium or homeostasis. Helson (1943) has also pointed out that color is very important for spatial discriminations. He believes that color compensation by yielding approximate color constancy aids in the production of a stable world not only through perservation of color as such but also just as much through perservations of spatial organization. Helson (1959) concluded that learning, spatial perception, and acquisition of skills can all be handled within this structure of adaptation level theory.

It is of interest to note that Ivo Kohler, as reported by Helson (1959), has formulated a theory of adaptation which is very close to the position taken by Helson. What Helson called the AL, Kohler called the null point. Kohler then went on to say that the null point is the first step in the direction of organization within perception. Perception is changed, according to him, by shifts in the null point when new adaptations to the environment must be made by the subject.

10. Hebb's cell assembly theory and the concept

of space. Hebb believed that complex patternings, regularities, and orderings have basic mirrored structurings in the central nervous system (Solley and Murphy, 1960). These complex structures have innate primitive unity which is a purely sensorily determined wholeness of the figure from its surroundings. With the exception of this primitive unity, however, Hebb constructed a physiological model to explain all other processes of form perception. He started his physiological model with a conditioning postulate similar to Kapper's Law of Neurobiotaxis (1932): "When an axon of cell A is near enough to excite a cell B and repeatedly or persistently takes part in firing it, some growth processes or metabolic changes take place in one or both cells such that A's efficiency, as one of the cells firing B is increased" (Hebb, 1949, p. 62). This postulate evinces a diffuse structure comprised of cells of the cortex, diencephalon, and also perhaps of the basal ganglia of the cerebrum, capable of acting briefly as a closed system, delivering facilitation to other systems and usually having a specific motor facilitation. Hebb called this a cell assembly. He believed that these reverberatory circuits of varying complexity may be set up within area 18 and between cells in this area and cells in 17, 19, and 20 (Osgood, 1953). Repetitive activity theoretically serves

to develop boutons and thus leads to more and more stable organization of the cell assemblies.

However, Hebb (1949) does not believe that perception is a static process. It is his belief that the integrations that result in form perception involve behavior of the organism, especially eye movements. He postulated the next stage in the organization of the process. This phase, the phase sequence, is the basis of the perception of a complex whereby sequential cell assemblies set up by eye movements can be integrated.

Let us consider the system of organization that leads to perception of a triangle, according to Hebb. Postulating that there will be a dominant visual tendency to fixate the corners of figures and that the peripheral retina is most effective in directing eye movements with these eye movements preceding along continuous lines in the field, Hebb (1949) put forth a physiological model for perceiving a triangle.³ He said that movement tendencies would be equal between AB and AC. Letting a represent the cell assembly set up by fixating A, b for fixating B and so on, and assuming that with repeated experiences the corners

3. The reader should imagine an equilateral triangle with its lower left-hand point labelled A, its lower right-hand point B, and its apex C.

of the triangle are successfully fixated, such sequences as ABCCBACBA might occur. Hebb predicted that the already established cell assemblies a, b, and c, would become integrated with systems of eye movements such that looking at any triangle will result in localized activity at some point, t in areas 18 or 20 for example (Osgood, 1953). Activity at t, then, is the perception of a triangle as a whole; it is also the concept of a triangle. This higher level of organization is a perceptual habit (Osgood, 1953).

Basically Hebb's model for form perception consists of primitive unity, the cell assembly, and the phase sequence. However, Hebb (1959) later criticised his own model for vagueness. He said that he doubts if assemblies really work as he had originally proposed. At the present time he is relying more on the phase sequence with some involvement from the brain stem reticular system.

11. Other hypothesis for the physiological basis of spatial perception. Marshall and Talbot (1942), in discussing the projective system of visual images, stated that "the neural image plays continuously over the projection area at every synaptic level, building gradients and peaks of activation at every edge and line.....multiplication of path both increases the reciprocal overlap and refines the

mosaic in proportion to the sharper gradients and peaks produced, as sand forms sharper peaks than bricks.....a fine line oscillating over four or five rows of receptors(produces) a center of gravity of excitation which is further peaked at the center through the action of partially shifted overlapping connections" (Marshall and Talbot, 1942, p. 139). Osgood (1953) pointed out the following interesting implications: "(1) a broken line (peripherally) will tend to be filled in along its own axis by this overlapping action; (2) unconnected figures will tend to be completed in the same fashion; (3) the borders of figures will tend to be given emphasis because of the sharp gradients of activity established in these areas" (Osgood, 1953, p. 197). It should be noted that these mechanisms will operate solely over relatively small areas of the visual field.

Bruner (1957) wrote on the neural basis of perception. He emphasized the integration of complex networks as the basis for perception. These networks were hypothesized to hold up or to alter the characteristics of impulses transmitted to them. Presumably Bruner is making each network a sort of storage house which can be altered or reinforced by the incoming stimuli. In any event, he places great emphasis on the central factors involved in perception.

Penfield (1952) suggested that the centroencephalic

system may be divided into an A-mechanism and a B-mechanism. The function of the A-mechanism is to record conscious perceptions in persisting neuron patterns, and the B mechanism has the function of recollection of past experiences and the integration of the incoming perception with past experience.

One of the most recent developments in the search for the neural basis of perception has been the investigations dealing with the brain stem reticular system. Samuals (1959) pointed out, for example, that perception probably needs supportive elaboration from nonspecific sources of the brain stem reticular system. Bishop (1958) said that the neural basis for perception is a diffuse projection from specific sensory projection areas to association areas which converge in the thalamocortex. Lindsley (1958) stated that perception is facilitated by the brain stem reticular system. Gerard (1958) has said that perhaps perceiving occurs when the reverberatory circuits of the brain stem reticular system are cut short.

12. Cybernetics and mathematical models in relation to the concept of space. McCulloch and Pitts (1948) and McCulloch (1951) have investigated how the perception of forms is preserved through differences in the locality of their initial stimulation-patterns on the retina and how constancy of shape in a figure is perceived regardless of variation in the size of the figure.

In the perception of a figure, e.g., a square, they stated that when the square enters the field of vision on one side of the binocular transmitting mechanism and the information is transmitted to the superior colliculus, the colliculus computes by double integration the lateral and vertical coordinates of the "center of gravity of the distribution of brightness" of the object's retinal image with respect to the coordinate system of the square. (It should be remembered that in Wiener's original cybernetic theory the brain acts as a computer.) This information is then transmitted from the colliculus to the oculomotor nuclei from which impulses are sent to the appropriate eye-muscles, serving to move the eyeball in such a way as to reduce these coordinate distances (Allport, 1955). The colliculi supply this information at a rate proportional to the coordinate values as they change from instant to instant. Allport (1955, p. 501) described the rest of the process hypothesized by McCulloch and Pitts as:

Hence, as the eyes turn and the center of brightness of the image with its diminishing coordinates approaches the origin of the coordinate system (fovea), the eyes slow down. They finally stop when the visual axes point at the center of brightness of the object, that is, when the object is centered on the foveas. In this process invariants of translation are maintained.

In the case of the square, mentioned above, the eyes turn until they are centered (foveal centration) and the form of the

square remains always the same. The cybernetists thus answer the question of how the perception of forms is preserved by postulating a model which involves an integration over a range of values, and by computing of invariants as sums or averages for all members of a group of transformations. Pitts and McCulloch (1947) and McCulloch and Pitts (1948) then attempted to answer the question how it is possible to recognize a certain shape regardless of size. They stated that in the case of the square, whose center is at the fovea, there will be an expansion or a contraction of size. It will be seen then with a full sweep of scansion that the same shape of the image will be represented throughout differences of image size. As the sweep goes upward, successively activating the layers in divergent directions, all possible dilations of the figures will be produced on the cortex; but the parameters that represent its shape are preserved (Allport, 1955).

B. Specific Studies on the Ontogenetic Development of Space Perception

1. Studies of pre-kindergarten children. Koffka (1924) maintained that young children tend to ignore detail, and have vague, inaccurate perceptions, which are apprehended

in accordance with their relationship to meaningful and familiar patterns. Gesell and Ilg (1949) found that as soon as a baby begins to creep and crawl, and later to walk and run, he begins to evaluate distance and size. They pointed out that since the baby is exceedingly active, he can build up many associations with his activities which will enable him to develop perception of size, distance, and shape both indoors and outdoors.

Baldwin and Wellman (1928), in their investigations, discovered a gradual improvement in ability to perceive differences in geometric forms from two to six years of age. Ling (1941) found that six months old babies can discriminate between simple geometric forms. In testing this ability, fifty infants ranging in age from six to sixteen months were confronted by pairs of blocks of different shapes: circles, squares, crosses, triangles, and ovals. The correct block was sweetened with saccharin, the other was fastened to the board on which the blocks were presented. Infants as young as six months learned which form to reach for and were unaffected by changes in its size and spatial orientation. Terman and Merrill (1937), in developing the Stanford-Binet Intelligence Scale, found that two year old children with average ability should be able to insert a circle, square and triangle into a three-hole form board.

Welch (1939) found that with increasing age and with practice, infants can improve their size discriminations. His results, however, were limited to the concepts of big and little. When subjects were asked to judge a middle figure, they were unable to do so. Hicks and Stewart (1930), Thrum (1935), and Welch (1938, 1939, 1939a, 1939b, 1940) found that the concept of "middleness" develops later than the concepts of "big" and "little." Vinacke (1951) and Graham, Jackson, and Long (1944) found that the concept of middleness develops at approximately nine years of age. Meyer (1940) found that five year olds can select middle-sized objects. The difference in these findings can probably be explained by the magnitude of the size differences to be discriminated which were demanded by the various experimenters.

Munn and Steining (1931) investigated concepts of triangularity in children between fifteen months and two years. They found that some children by the age of fifteen months had established this concept. Gellerman (1933) and Vinacke (1951, 1954) made similar investigations. Their results confirm those of Munn and Steining. Long (1940) found that by the age of three years concepts of roundness are well enough developed for the child to be able to distinguish cylindrical and two dimensional roundness.

Gellerman (1933) investigated the influence of

spatial orientation upon the perception of young children. He found that two year old children have difficulties in orientating different geometrical forms. For example, if the triangle in one series was turned upside down in the next series, the child could still recognize it. However, this was done only after the child had inclined his head through an angle of about sixty degrees in order to restore the original orientation. It would appear, therefore, that relative position is important.

Meister (1949), investigating figure-ground relationships in the preschool child, concluded that the very young child's ability to discriminate figure from ground is nearer the adult level than is his perception of geometrical forms per se.

2. Studies of kindergarten and school children.

Line (1930-31) investigated growth of visual perception in children. He asked a group of children to compare test cards with specimen cards. He found that his children of four and five years of age were able to differentiate a square from a circle and from a rectangle, but they could not distinguish between the open and closed figures of the same shape. The "whole" figure was perceived at an early age while recognition of parts occurred at a later stage. Segers (1926) reported that few children before nine see complex perceptual patterns.

His three-to-seven year old subjects tended to neglect separate parts and details and to see meaningful wholes when asked to name these complex patterns. They attempted also to make meaningful associations for the patterns.

Vurpillot (1954) studied the development of the concept of a straight line in children from four to seven years of age. She found that for the child of five to six years the term "straight line" has a precise significance, although it is not always the same as the significance which the adult gives to the term "straight line." She stated that the term straight for the seven year old means a relation existing between two different points of a line, a relation which for this age of child is intrinsic and independent of the visual field. When the line is partially interrupted or hidden, the straight line relationship can not be conserved by the seven year olds. She pointed out that it was only later that the child is able to abstract subjective references from himself and rely upon the visual field. Finally, she found that the child attributes to the whole figure a quality which is only true of each part of the figure separately, for example, a broken line may be declared straight. Vurpillot concluded from her studies of five to seven year old children that perceiving a straight line has the characteristics of conservation and independence

of the visual field; there is absence of distinction among the qualities of all of the parts.

Rush (1938-39) investigated individuals between six and twenty-two years of age for the development of the classical gestalt laws of visual organization: proximity, similarity, common fate, et cetera. She presented simple dot patterns which could be organized in one or more ways and determined what method of visual organization was dominant. Her results show that continuity of pattern increases in efficacy up to about fourteen years of age and then drops to a lower level. Similarity and proximity both steadily increase in efficacy with age. There is a shift from seeing equally spaced dot patterns as rows to seeing them as columns --a shift from horizontal to vertical emphasis in visual organization.

Discriminations of size and area have been found to be related to the shape of the particular form which is presented. Peters (1933) found that for his subjects stars, ellipses and triangles were judged larger than squares, rectangles and circles of equal area. He concluded that the sharp angles and greater linear distance between corner points of the stars, ellipses and triangles tended to enhance the apparent size.

Hurlock (1956) pointed out that the ability to distinguish right and left is difficult for a child and is

somewhat late in developing. Swanson and Benton (1955) found that this ability begins at about five years of age and develops rapidly between the ages of six and seven. From then until nine years, they found the development to be at a slower rate. Lord (1941) investigated the notion of cardinal directions in elementary school children. He found that they have a well-generalized notion of these directions, i.e., they can identify south and east. They are likely to fail, however, to identify more specific directions, e.g. northwest. He also found that they have difficulty in using directions correctly in describing location of places. Girls, as a group, were found inferior to boys in space orientation.

Solley and Sommer (1957) and Solley and Engel (1961) investigated the determination of what is figure. They reported that children between five and eight organize the figure as figure significantly better if rewarded than punished, while children between nine and twelve showed little effect from reward or punishment. Jackson (1954) found that young adults on the other hand seemed to organize figure significantly better if punished (reward and punishment consisted of winning or losing money).

Undegraff (1930) found that by the time a child is four years of age his perception of distance is similar to that of an adult. This ability to judge distance appears

to develop more rapidly than the ability to judge depth. Garrison (1952) reported that his six year old subjects had poor ability to see three dimensions in objects.

3. Studies tracing the ontogenetic development of space perception from birth through fourteen years of age.

a. Werner's theory of ontogenetic development. The basic formal principle of Werner's treatise is that every genetic sequence has an intrinsic required order and direction. For Werner (1948) mental growth, including perceptual growth, is definable in terms of reorganization based on inclusion of new data. He included, also, the emotional dimensions in accord with his holistic approach. Although Werner believes in these developmental levels, he makes quite clear that they are not static levels, but dynamic potential ranges of genetic, graded functions. His developmental psychology, therefore, does not deal with actual historic succession but rather with the functional conditions of primitive and advanced forms of cognition.

Werner (1948) believes that developmental directions proceed as a movement from an undifferentiated stage towards an increasing differentiation of parts. For him, development consists of four aspects reflecting lower and higher degrees of differentiation:

(1) Formal-aspects: diffuse-articulate. In diffuseness the individual lacks articulation, e.g., primitive perceptions and thoughts. As articulation increases perceptions and thoughts become more and more complex and involved.

(2) Dynamic-aspects: rigid-flexible; labile-stable. Lack of flexibility which in children may be typified by their sensitivity to change, their tendency to all-or-none reactions, and their dependency on definite order. Lability is expressed in the fluidity of behavior, e.g., the distractibility of young children, their impulsivity, and the transient character of emotions. Stability as well as flexibility stem from an increased central control of behavioral direction.

(3) Cognitive-affective-aspects: syncretic-discrete. Syncretic signifies an indistinctness between the experiences of inner states and of objects; and a lack of separation between self, other and environment. There is a merging of otherwise separable experiences into a global meaning. Syncretism manifests itself by the tendency to respond to objects as "things of action." It recedes with greater individuation and discreteness of mental contents and functions.

(4) Ideational-aspects: concrete and abstract. Relations are first realized through sensori-motor activities; then through perceptual groupings when sameness--difference are concretely apprehended; then through quasi-class concepts in terms of likeness. The next stage is representation through schemata which culminate in genuine concepts. This same sequence is applied to the stages of spatial development. The child goes from the concrete to the abstract. He accomplishes concretely on the lower level what is attained abstractly on the higher level. It is Werner's general thesis that such analogous functions of a lower order must emerge before a function of the next higher order can develop.

b. The development of field independence. Witkin

and his co-workers (1954) have demonstrated several broad developmental trends in perceptual tasks. Using subjects from eight years of age through late adolescence on several perceptual tasks (the rod and frame test, tilting room and tilting chair tests, and the embedded figure test), they found that in part-of-a-field perceptual situations the developmental sequence follows a definite order. In children eight to ten years of age, perception of an item is greatly influenced by the structure of the surrounding field; between the ages of ten and thirteen there is a dramatic decrease in the extent of this influence; from thirteen to seventeen years of age there are slight changes toward independence from the field; but after the age of seventeen there is a reversal of this trend, so that adults show greater average susceptibility to field influence than do seventeen year olds.

With regard to field-as-a-whole perceptual tasks, no such developmental trends were found by these investigators. Children from eight to ten years of age are somewhat less prone to "go along with" the field than are adults. Although young children are on the average more compellingly influenced by the field in perceiving an item within a field, they are at least as able as adults to evaluate the position of the field as a whole (Witkin, et alii, 1954).

Witkin, et alii (1954) found that at each age level there is a wide range of individual differences in performance. Even in the youngest groups, the range of scores and the extremes of the range are fairly similar to those of the adults. Individual differences in perception then appear early in life. Witkin, et alii (1954) reported that for all ages tested, people tend to be self-consistent in their perceptions under different conditions, and that at all ages females tend to be more influenced by the field than males.

In analysing miniature-toy situations, these investigators found that there is a strong tendency for children who can resist the influence of the field in perception to be able to maintain logically organized forms of play expression. Conversely, children whose perceptual performance is marked by dependence upon the field fail in their play to exclude unintegrated irrational material. Among boys, the organization pattern of play appears to be more closely related to perceptual performance than it is among girls. Witkin, et alii (1954) pointed out that they noticed that to a large extent it was the past experience of an individual that made him field dependent or independent. This point of view was not only based on the experimental data but also on clinical evidence from the Rorschach and the Thematic Apperception Test.

c. Lowenfeld's theoretical system of ontogenetic

spatial development. Lowenfeld (1957) traced the development of children's perception of space from four through seventeen years of age. This investigation was carried out by analyzing children's drawings, clay models, linoleum figures, wood models and papier-mache forms. Defining space as everything outside of the body, he found that in the youngest children the inter-relations of things in space are not subject to any law. The child thinks "There I am. There are football players. There is an airplane." At the earliest stages, the child has not yet achieved an experience of space which is of general validity, nor has he experienced himself as part of the environment. Lowenfeld (1957) pointed out that since the experience of the self as part of the environment is one of the most important assumptions for cooperation and visual coordination, the child's inability to correlate things properly in space is a clear indication that he is neither ready to cooperate socially, nor has he the desire to coordinate letters to read. Children of four to seven years fall within this first stage which Lowenfeld calls a pre-schematic stage. This stage is primarily characterized by no orderly space relation except for an emotional type of relationship as "this is my doll."

Lowenfeld (1957) calls the next stage of development which occurs in children from seven to nine years of age the schematic stage. In this stage the most important and basic

experience of the child's spatial development is the discovery of order in space relationships. Accordingly, whenever the child relates himself to others, i.e., sees himself as a part of the environment, the first common experience of space has occurred. This he expresses by drawing everything on one line, the baseline. He uses this line to symbolize at one time the base on which things stand, and at another time to characterize the surface of the landscape. For example, the child will use the baseline elevated over the plain to represent a mountain. How much this "mountain" is still a bent baseline can be seen from the fact that the trees stand perpendicularly to the mountain. Lowenfeld believes that deviations from the baseline express experiences of subjective space by the creators.

From nine to eleven years, Lowenfeld hypothesized the stage of dawning realism. This is a stage characterized by the formation of gangs, lack of cooperation with adults, greater awareness of the self with regard to sex, and drawing more than simple geometric lines or schematic representations. In this stage, the child does not have to draw every thing on the baseline. He understands the concept of a plane, i.e., the space between baselines becomes meaningful. He becomes aware of overlapping, e.g., a tree growing from the ground will partly cover the sky; he has difficulties in spatial

correlations as a result of his egocentric attitude and lack of cooperation. The child of this age has not a fully developed visual percept of depth but certainly the first step is taken toward such a concept.

The pseudo-realistic stage occurs in children from eleven to thirteen years of age. At this stage in the development another psychologically important factor comes into the picture. Lowenfeld (1957, p. 217) stated that "the closer we study adolescence, the more we see a distinction in the sensory reactions of the children toward creative experiences. We see clearly a preference by some children for visual stimuli while others may be more concerned with the interpretation of subjective experiences." Visually minded individuals refer in their pictures to environment whereas nonvisually minded individuals are expressionists. Lowenfeld believes that children who have preference for visual experiences feel as spectators, looking at their work from outside; subjectively minded people feel involved in their work. It is with approaching adolescence that these preferences crystallize. In this stage of development, Lowenfeld (1957) found that three-dimensional space is expressed by diminishing sizes of distant objects--perspective is beginning to develop. For the visually minded, the horizon line becomes meaningful, while often the non-visually

minded will revert to the baseline type of reaction. In this stage, however, the recognition of distance, i.e., space in its three dimensional qualities, moves more and more into the focal point of interest in the visually minded child. The development of the distance concept at this stage Lowenfeld believes to be almost entirely intuitive. For the non-visually minded child the distance concept appears later. It may not occur until the next developmental stage.

Lowenfeld's final stage occurs in individuals from thirteen to seventeen years of age. For the visually oriented individual, it is characterized by perspective space representation with apparent diminuation of size and detail of distant objects. An understanding of the meaning of horizon with emphasis on three dimensional qualities occurs at this time. Children who have had a preference for subjective experiences evolve into children having preference for tactile and kinesthetic experiences of space. These individuals place emphasis on feelings as contrasted to outside appearance. Perspective is of value only in relationship to the self.

d. Topological to projective-Euclidean development of space. In studying representational space⁴, i.e., the

⁴. Perceptual space is studied with the object present. It thus develops faster than representational space but in the same serial sequence (Piaget and Inhelder, 1956).

arising of a visual image of an object without the presence of the object, the work of Piaget and Inhelder (1956) suggests that a child's concept of space develops or evolves from the simple non-metrical concepts to complex metrical ones. In the early years (three to six years) the child is considered by these investigators as having ideas which are primarily topological in regard to space. They include in this category relationships of proximity, separation, order, enclosure, and continuity. These relationships are built up empirically between the various parts of figures or patterns which they organize. They are independent of any contraction or expansion of these figures. Hence Piaget believed that it is impossible for relationships of this type to lead to comprehensive systems linking different figures together by means of perspective or axial co-ordinates, and for this reason these relationships are bound to remain psychologically primitive.

Piaget and Inhelder (1956) pointed out that this primitive, topological space is purely internal to the particular figure whose intrinsic properties it expresses as opposed to spatial relationships of the kind which enable a particular figure to be related to other figures. Topological space furnishes the basis for the type of analysis which operates from the standpoint of each figural object considered

in isolation, rather than from a comprehensive system, i.e., a system capable of co-ordinating all figures within a whole, organized in terms of a common spatial structure.

In this theory, the next stage of development begins at about six years of age and is completed during the fourteenth year. This stage is marked by the development of the ability to locate objects and their configurations relative to one another in accordance with a general perspective system, as well as, the ability to locate objects according to co-ordinate axes. Piaget and Inhelder (1956) called this general perspective system projective space. It begins psychologically at the point when the object or pattern no longer is viewed in isolation but begins to be considered in relation to a point of view. Therefore, the child comes to comprehend the terms above, below, left, right, before, behind. From the outset, projective relationships presume the inter-coordination of objects separated in space, as opposed to the internal analysis of isolated objects by means of topological relations. At the beginning of this stage the child has mastered certain elementary projective operations⁵ such as point to point construction of a projective straight line, and elementary perspective. By eleven he can

5. Operations are defined by Piaget as actions which have become internalized as an image. After the internalization takes place, the actions are completely abstracted being grouped, i.e., by being incorporated in a reversible combination or grouping.

coordinate the various perspectives of the same scene, and by thirteen or fourteen he can coordinate various perspectives of different scenes.

Projective space and the development of co-ordinate systems, i.e., Euclidean spatial concepts, have a transitional stage between them which is shown by affine geometrical relationships (Piaget and Inhelder, 1956). The affine stage is characterized by similarities conserving parallels, similarities conserving angles, or similarities conserving distances. From Piaget's and Inhelder's (1956) research it would appear that this type of development is similar to projective and Euclidean space in evolving. It begins intuitively around seven years of age and is completed metrically around eleven years of age.

In the development of coordinate axes or Euclidean space, according to Piaget and Inhelder (1956) and Piaget, Inhelder, and Szeminska (1960), the child learns to conserve straight lines, angles, curves, distances, volume and area, and length. They distinguished several levels of achievement. At the beginning, the child is capable of carrying on such operations as partitioning and reuniting, placing and displacing, and measuring. Qualitative operations, e.g., length and distance, begin to evolve. The majority of these are elaborated before the age of eleven or twelve. At eleven

the child can perform simple metrical operations, e.g., the measurement of length in one, two, or three dimensions; the construction of a metric co-ordinate system, and the first beginning of the measurement of angles and areas. The final level is reached by the age of thirteen or fourteen when areas, volumes, and proportions are calculated and delayed.

It is beyond the scope of this paper to attempt to review all of the studies on spatial development which Piaget and his co-workers have made in the last decade. Rather an individual representative study of the topological, projective and Euclidean types of space described above will be presented.

One of the studies made by Piaget and Inhelder (1956) concerning topological relationships in representational space involved linear order. Children were presented with two "washing lines," i.e., two strings, one strung out a few centimeters above the other. Small pieces of washing were arranged to hang on the first string. After the child named them, he was asked to place the corresponding objects in the same order on the wash line. He had more objects to choose from than in the model presented to him and he could not look back to check this order. In stage 0 which occurred in children from two to three there was no correspondence,

even by resemblance of items irrespective of order. Stage I involved simple, intuitive correspondence of items irrespective of order. This occurred in children from about three to four years of age. Stage II was that of simple linear order. Here the children from four years of age on could make ordered correspondences. By the age of six or seven the children could arrange the items in reverse order. This Piaget and Inhelder (1956) called the third stage.

A study concerning the co-ordination of perspectives involved pasteboard models of mountains. The child was placed in front of the model. The experimenter had a doll which "travelled" around the mountain. The child had the problem of trying to imagine and to reconstruct, by a process of inference, the changes in perspective that would accompany the doll's movements. Piaget and Inhelder (1956) found that children between three and four did not understand the questions. This they labelled as stage I. In stage II the child (4 to 6 years) could hardly distinguish between his own viewpoint and that of other observers; while children of seven to nine years (stage IIIA) still did not have a comprehensive co-ordination of viewpoints. Beginning from nine to ten years (stage IIIB) a comprehensive co-ordination of viewpoints and mastery of simple perspective was found.

In order to test the development of a child's concept of gravity and the horizontal co-ordinates, Piaget and Inhelder (1956) showed children two narrow-necked bottles, one with straight parallel sides and the other with rounded sides. Each was approximately one-fourth full of colored water. The children were asked to guess the position the water would assume when the bottle was tilted. They found no comprehension in children up to four or five years of age (stage I). In stage II the liquid was imagined as simply expanding or contracting, increasing or decreasing in volume. Between stages II and III the child could predict the level of the liquid only when the rectangular jar was inverted or lying on one side, i.e., when the water level was parallel with the sides. Children around seven or eight years of age (stage III) could correctly predict with hesitation while children at nine years of age gave immediate correct predictions.

Lovell (1959) redid a number of experiments concerning topological development originally reported by Piaget and Inhelder (1956). Using 150 subjects he studied identification by touch of simple geometric forms, linear and circular order, knots, and the projective straight line. In studying touch identification of simple objects, he found little evidence to suggest that it is topological properties

as such which enables the child to identify certain shapes more easily than others. Lovell stated that it was the gaps, holes, curves, points, corners, ins and outs of Euclidean space which make identification easier. His data shows that children before four years of age can distinguish a circle, square, ellipse, et cetera. But there was evidence that straight sided Euclidean figures with relatively long sides and few corners are the hardest to identify. Lovell also found that his children were poor verbalizers in regard to their reactions to the different stimuli presented to them.

In regard to linear and circular order, Lovell's subjects were far more advanced than those reported by Piaget and his co-workers even though they were below the average ability level of those subjects reported by Piaget and Inhelder. In his knot investigations, Lovell found in his subjects that children by the age of four could tie knots. In general, this agrees with the Piaget finding.

In the ability to make a straight line, Lovell's findings do not confirm Piaget's and Inhelder's. He found that 53 per cent of his children of 2 years 11 months could make a good straight line parallel to the edge of a table (40 per cent made only slight irregularities) whereas Piaget and Inhelder reported that their children could not do this until at least 4 years 0 months.

Lovell concluded that more investigations must be made before any conclusive knowledge of the ontogenetic development of space is obtained. He pointed out that much greater variability exists among subjects than Piaget allows. He questioned strongly topological concepts as transforming concurrently into concepts of projective and Euclidean space. Finally, he seriously questioned if the concepts which Piaget places in the topological category, i.e., separation, order, continuity, proximity, and similarity--are really topological in nature. He suggested that perhaps these are really only certain types of relationships, and that Piaget's concept of topology is not the concept employed by the mathematicians.

II. STATEMENT OF THE PROBLEM

In accordance with Lovell's (1959) suggestion and the author's opinion that more investigations must be made before any conclusive knowledge is obtained concerning the ontogenetic development of space, this study is an investigation of the sequential development of representational space in children from four years zero months to fourteen years eleven months. Sears (1958) has pointed out that the stages of concept formation in general which Piaget hypothesizes can not be found for all children. With this in mind, this author undertook the present investigation in order to determine whether the development of the concept of space in children evolves in the sequence hypothesized by Piaget.

This study makes an attempt to meet one of the major criticisms of Piaget's work, i.e., lack of rigorous experimental techniques. In his studies, he has not used refined methods to trace the sequence of spatial development which he reports. His lack of rigorous scientific design is shown by his failure to control many parameters. He did not control his sampling; he had no standardized administration procedure; the ability level of the children was not ascertained or controlled; he did not use statistical tools more

elaborate than classificatory ones; sex differences were not systematically investigated; the precise nature of the material used was not reported; the levels of difficulty of his material within a particular type of geometric space were not controlled.

In connection with the nature of the material used for Piaget's and Inhelder's experiments, this author has become concerned with the question raised by Lovell (1959). As was mentioned above, Lovell strongly questioned whether the so-called topological material used by these investigators was actually topological as mathematicians would classify it. Therefore, it would seem that this question can be raised for the materials for each type of space hypothesized by Piaget.

Finally, it appears that Piaget made no attempt to connect his findings with personality factors. Lowenfeld (1957), as well as Witkin, et alii (1954) and Werner (1948) all reported major correlations between spatial development and personality factors. Ajuriaguerra (1954) reported that differences in the perception of form may be attributed to the particular type of biotype, i.e., introversion or extroversion, of the subject's personality. Because of time and energy limitations of one investigator, investigation of personality dimensions is limited in the present study.

However, a study of the introversion-extroversion trait is included in this investigation in order to determine whether a relationship exists between this trait and spatial development.

III. METHODS

A. Subjects

A total of 144 subjects of average ability was used in this study. They ranged in age from 4 years 0 months to 14 years 11 months and were divided into six age groups with each group consisting of 24 children evenly divided between boys and girls. These six age groups were made up of children whose ages were 4 years 0 months to 4 years 11 months; 6 years 0 months to 6 years 11 months; 8 years 0 months to 8 years 11 months; 10 years 0 months to 10 years 11 months; 12 years 0 months to 12 years 11 months; and 14 years 0 months to 14 years 11 months.

The selection of the school age subjects was from the public schools in a restricted area of Tucson, Arizona, while the preschool children, i.e., children from 4 years 0 months to 4 years 11 months, were obtained from private nurseries in the same area. All of the subjects were first screened by the proper school authorities in order to eliminate those children with emotional problems, extreme reading problems, physical handicaps including poor vision, and above or below average ability as shown by group tests which had been administered previously by the school system.

B. Administration of the Tests

1. The Stanford-Binet Intelligence Scale. In order to obtain subjects of average ability, the short form of the 1960 revision of the Stanford-Binet Intelligence Scale was administered privately to each subject by the author. If a child did not fall within the average range of 90 to 110 intelligence quotient points, he was immediately eliminated from the experiment. In this way the ability level of the children was held relatively constant. Standardized procedure established by Terman and Merrill (1960) was employed. Each subject was tested in the school which he attended. This was done for two major reasons: (1) the subject probably would feel more at ease in familiar surroundings, and (2) the transportation problems which would have ensued in bringing the children to one central location were too momentous to overcome.

2. Form Development Test. After the Stanford-Binet Intelligence Scale was administered, all the school age children in this investigation were given a series of 28 items designed to measure development of representational space. However, two separate sessions⁶ were needed for the

6. In the first session the Stanford-Binet Intelligence Scale was administered. During the second session the Form Development Test and Extrovert-Introvert Scales of the Early School Personality Questionnaire (ESPQ) devised by Coan and Cattell (1961) were administered.

children of 4 years 0 months to 4 years 11 months because of their low attention span.

The 28 items administered to the subjects consisted of seven items predominantly topological in nature, seven items predominantly projective, seven items of affine figures, and seven items predominantly made up of Euclidean characteristics. All of the items were checked by a mathematician whose speciality was the geometries. Only items which predominantly represented one type of geometrical space were used. Further, within each category of seven items, an attempt was made to obtain a range from easy to hard items. For example, within the seven predominantly topological items there were very easy items to very hard items.

Most of the items were negative photostats of artists' drawings of the figures. These were mounted on 4 by 5 inch stimulus cards and 14 by 5 inch response cards of white posterboard. Three of the projective items were partially three-dimensional and one was entirely so. One of the Euclidean items was also entirely three dimensional. Items were presented singly to each subject individually by the experimenter. For the two dimensional items, the child was first shown a 4 by 5 inch stimulus card which had a drawing of the figure on it. He was shown this card for

ten seconds (although many of the children would not look at it for that long) after which time the stimulus card was removed, i.e., the child was not allowed to see the stimulus card again, and the response card was shown. On each of the response cards was a series of four figures which had been arranged on each card in random order. One of the four figures was either like the original stimulus card or nearly like it in some meaningful way. It was the subject's task to point to the figure on the response card which was similar or most similar to the stimulus. For the partially three-dimensional items, the child was first shown a three-dimensional stimulus and then given a 14 by 5 inch response card to choose the figure that would look most like a section hypothetically cut through the stimulus three-dimensional figure. On the items which were entirely three dimensional, the child was shown a stimulus three-dimensional figure which was then taken away and he was asked to point to a particular three dimensional response item. In both of the three-dimensional items the child essentially was to envisage a figure like the stimulus figure only turned 180 degrees.

Figure 1 presents the topological items used in this experiment. Items 1, 2, 4, and 6 were similar to ones used by Piaget in his research. Items 3, 5, and 7 were obtained from the mathematical advisor who listed them as predominantly

Fig. 1. Topological items presented to the subjects.

topological figures. They stress relationships of proximity, insideness-outsideness, order, and magnitude.

Figure 2 shows the seven items which are predominantly projective. Items 5 and 6 were suggested by the mathematical expert, while items 1, 2, 3, 4, and 7 were items suggested by but not identical to Piaget's projective materials. Item 1 was designed to measure the concept of a straight line projected across an object. Items 2, 3, and 4 were items constructed to measure a child's concept of a section of a geometrical solid. As can be seen the stimulus material for these items were respectively an ice cream cone, a cube, and a house-like block. Each had small strips pasted on them to show a horizontal section of the ice cream cone and vertical sections of the cube and small house. On the response cards for these three items were representative sections of different objects. It was the child's task to identify the correct section from the response card for each of these items.

Item 5 attempts to ascertain whether a child has developed the perspective concept of a series of telephone poles, while Item 6 is testing the development of the concept of the shape of shadow projections. Item 7 was a set of three-dimensional mountains. A doll was placed in front of the stimulus set. The experimenter then moved the doll

Fig. 2. Projective items used in this experiment.

around the mountains 180 degrees and asked the child to find the set of mountains in the response material which would look like what the doll saw when she looked at the mountain from the new view. The stimulus mountains were then removed and the child was asked to identify, out of the four sets of mountains, the set similar to what the doll had seen when she was moved around the mountains. The response sets of mountains were placed before the child such that the first set was 180 degrees turned from the stimulus set (and thus the answer), the second set was identical to the stimulus set, the third set was turned 90 degrees, and the fourth set was turned 270 degrees.

Figure 3 presents the affine items used in this experiment. Items 1, 2, and 6 were items suggested to the author by the materials used by Piaget, whereas items 3, 4, 5, and 7 were suggested by the geometer consulted. It should be remembered in these items that only parallels, angles, or distances must be conserved. Primarily these items conserve parallels.

Figure 4 presents the Euclidean items used. All of the items representing Euclidean spatial concepts were suggested by the materials originally used by Piaget and Inhelder (1956) and Piaget, Inhelder, and Szeminska (1960).

Fig. 3. Affine items presented to the children.

Fig. 4. Euclidean items used in this experiment.

Item 1 was an attempt to measure the development of the concept of gravitation, while Item 2 ascertained development of the conservation of distance in relation to filled space. Item 3 was constructed to measure the development of the conservation of area, and Item 4 the conservation of length. Both items 6 and 7 measured the development of the conservation of volume. Item 5 was a three-dimensional item. The subject was presented with the stimulus village which originally has a cowboy riding away from the subject, when the cowboy reached the edge of the village, he was turned around by the experimenter as if to come back through the village. At this point the stimulus material was removed, and the subject's task was to look at the four response villages and tell the experimenter which village the cowboy would see when he turned around to come back through the village. As can be seen the first village is set up such that it is made up of horizontals and verticals, the second is identical to the stimulus village only turned 180 degrees (it is the correct answer), the third set is made such that almost everything is parallel, while the last one has left and right dimensions exchanged.

The items discussed above were presented randomly and individually to each subject. Standardized instructions

were given for each item. These instructions appear in Appendix A.

3. Introvert-Extrovert Scales of the Early School Personality Questionnaire, the Children's Personality Questionnaire, and the High School Personality Questionnaire.

Immediately following the Form Development Test, the child was presented with a short questionnaire type of test primarily measuring the extrovert-introvert dimension of personality. Children from 4 years 0 months to 4 years 11 months and from 6 years 0 months to 6 years 11 months were given the scales of the ESPQ making up the extrovert-introvert second order factor as found by Coan and Cattell (1961). These scales are: Factor A: schizothymia-cyclothymia; Factor F: desurgency-surgency (bored-happy go lucky); and Factor H: threctia-parmia (shy-thick skinned). After having arranged these questions by systematic randomization such that all the questions of the same scale did not appear together, the examiner read each question to the child and recorded his or her verbal answer. Although Coan (1961) did not design the scales of the ESPQ for four year olds, it was decided to administer them in order to obtain a rough measure of this dimension that would be similar to the measures obtained for the remaining age groups.

A copy of this questionnaire as used appears in Appendix B⁷.

The extrovert-introvert scales of the Children's Personality Questionnaire were given to the 8 years 0 months to 8 years 11 months, the 10 years 0 months to 10 years 11 months, and the 12 years 0 months to 12 years 11 months children. These scales are: Factor A: schizothymia-cyclothymia; Factor F: desurgency-surgency (sober-happy go lucky); and Factor H: threctia-parmia (shy-thick skinned). As for the scales of the ESPQ, the items were arranged so that questions from the same scale did not appear together. They were read to each subject and the answers recorded by the examiner. A copy of these questions as used appears in Appendix B⁸.

Three scales of the extrovert-introvert factor from the HSPQ, constructed by Cattell, Beloof, and Coan (1958) were administered to the 14 years 0 months to 14 years 11 months old children. These scales are: Factor A: schizothymia-cyclothymia; Factor F: desurgency-surgency (sober-happy go lucky); and Factor H: threctia-parmia (shy-thick skinned). Again the items were arranged in a systematic randomized order. They were read to each of the subjects and

7. The scales of the ESPQ were used by permission of the senior author, R. W. Coan.

8. The CPQ and HSPQ scales were used by permission of the Institute for Personality and Ability Testing, publisher of these two personality questionnaires.

the subjects' answers were recorded by the examiner.
Appendix B⁹ presents these items of the HSPQ.

9. See footnote number eight.

IV. RESULTS

A. Tabulation Analyses of the Results of the Form Development Test

Table 1 shows the number of children passing each item at each age, and the total number of items passed by each age level for each type of space. Most, but not all items, are passed by progressively more children as age increases. Some items, however, show irregular increases and decreases in performance. In order that the results might be compared with those obtained by Piaget and his co-workers, analyses of responses for particular items will be presented in the discussion chapter.

In general, as can be seen in Table 1 and in Figure 5, there is a rough progression from the four year level through the fourteen year level for each type of space. Beyond eight years of age the total number of items measuring topological space which are correctly answered remains relatively constant from one age to the next. For projective space, the total number of items passed shows an increase through the eight year level, a plateau, and additional development between the ages of twelve and fourteen. With the exception of the four year olds, the affine totals appear not to increase appreciably. Euclidean space totals are low

TABLE 1

Number of Children Passing Each Item According to Age Group

<u>Type of Space</u>	<u>Item</u>	<u>Age Group</u>						<u>Total</u>
		<u>4</u>	<u>6</u>	<u>8</u>	<u>10</u>	<u>12</u>	<u>14</u>	
Topological	1	10	22	22	23	24	23	124
	2	13	18	24	24	23	24	126
	3	18	22	22	24	24	23	133
	4	5	4	7	8	10	13	47
	5	12	17	22	24	23	24	122
	6	8	10	17	14	11	15	75
	7	23	23	24	24	24	24	142
	<u>Total</u>	<u>89</u>	<u>116</u>	<u>138</u>	<u>141</u>	<u>139</u>	<u>146</u>	<u>769</u>
Projective	1	13	17	24	21	24	24	123
	2	4	5	4	9	6	14	42
	3	11	20	22	20	24	21	118
	4	4	5	10	12	14	18	63
	5	7	11	21	21	23	24	107
	6	10	8	8	6	5	13	50
	7	5	5	6	6	17	21	60
	<u>Total</u>	<u>54</u>	<u>71</u>	<u>95</u>	<u>95</u>	<u>113</u>	<u>135</u>	<u>563</u>
Affine	1	18	22	22	21	19	22	124
	2	19	21	22	18	22	20	122
	3	18	20	20	20	23	24	125
	4	22	22	24	24	24	24	140
	5	13	11	19	19	21	18	101
	6	18	22	24	24	23	24	135
	7	8	17	15	17	18	20	95
	<u>Total</u>	<u>116</u>	<u>135</u>	<u>146</u>	<u>143</u>	<u>150</u>	<u>152</u>	<u>842</u>
Euclidean	1	5	2	0	1	2	12	22
	2	2	0	0	11	8	15	36
	3	1	1	6	9	11	19	47
	4	14	10	6	12	12	19	73
	5	3	7	14	15	17	22	78
	6	3	7	9	14	20	20	73
	7	3	0	1	2	1	8	15
	<u>Total</u>	<u>31</u>	<u>27</u>	<u>36</u>	<u>64</u>	<u>71</u>	<u>115</u>	<u>344</u>

FIG. 5. CURVES FOR EACH TYPE OF SPACE SHOWING THE NUMBER OF ITEMS PASSED FOR EACH AGE GROUP

through the eight year olds, increase for the ten and twelve year levels, and increase noticeably at the fourteen year level.

Figure 5 suggests that the development of stages is not so orderly as reported by Piaget. Four year olds do not conceive of space entirely in terms of its topological properties, and affine perceptions begin to develop much earlier relative to other types of space than Piaget would postulate. If Piaget's progressive stages of space development are to be supported, the topological curve should reach its maximum height before the projective curve has risen above a chance value. This condition appears to be satisfied. However, questioning of the younger children revealed that the majority of those who passed the projective items had fairly well formulated concepts which could be verbalized. Projective items are hypothesized as beginning to form at approximately six years of age and as being almost complete by the age of eleven or twelve. The present data reveals the beginning of concepts of this space type by the age of four years and completion at fourteen years or later.

According to Piaget, affine space concepts should begin to develop later than projective space concepts and should reach their peak before full development of the Euclidean concepts. The four year old children passed

considerably more affine items than would be expected on the basis of chance. The maximum height of this curve is reached prior to that of either the Projective or the Euclidean curves.

The Euclidean concepts, according to Piaget, should start to develop at six and be completed by the age of fourteen. The curves and totals in Table 1 and in Figure 5 show values above chance for the first time at the ten year level. It would appear that these concepts were not complete by the end of the fourteenth year.

Table 2 presents the means and percentages of the number of items passed by each age group. As can be seen, there is a range of approximately ten points from the average number passed by the four year group to the average number passed by the fourteen year group. These results are interesting to note for they show a steady progression from 12.08 to 22.83 as age increases, and there is no wide difference from one age group to the next. Similar trends can be seen in the percentages of items passed by each age group.

The means for the four types of space were obtained. Subjects averaged 5.85 items out of the seven items representing the affine group and 5.35 of the topological items. An average of 3.90 was obtained by all subjects for the projective items, and 2.40 for the Euclidean items.

Table 3 presents the means for each age group for

TABLE 2

Mean Number and Percentages of Items
Passed by Each Age Group

	<u>Age Group</u>					
	<u>4</u>	<u>6</u>	<u>8</u>	<u>10</u>	<u>12</u>	<u>14</u>
Mean Number of Items Passed	12.08	14.58	17.25	18.48	19.71	22.83
Percentages of Items Passed	43.14	52.08	61.61	65.92	70.39	81.55

TABLE 3

Mean Number of Items Passed For Each Age Group
For Boys and Girls

<u>Sex</u>	<u>Age Group</u>						Mean For All Age Groups
	4	6	8	10	12	14	
Boys	12.58	14.92	17.33	18.42	19.83	22.58	17.61
Girls	11.58	14.25	17.16	18.50	19.58	23.08	17.36

boys and girls. A steady progression results for both sexes from four through fourteen. The widest mean difference between boys and girls for a particular age group (1.00) occurs at the four year level. The mean for boys, ignoring age, is 17.61 while for girls it is 17.36.

The ranges of correct responses for the different age groups according to the type of space appear in Table 4. As can be seen, there is wider variability between the number of topological items passed by the four year olds than by the fourteen year olds. Some four year olds successfully passed all of the items as did some fourteen year olds. This is also true of the affine items. However, no four year old succeeded in passing all of the projective or Euclidean items, whereas some fourteen year olds succeeded in passing all items of one or the other or both of these types of space.

Table 4 also presents the ranges of total items passed for the different age groups. There is a considerable overlap from the four year olds through the fourteen year olds. Finally, Table 4 presents the ranges for the different types of space ignoring age. With this type of tabulation, very similar ranges appear for all types of space investigated.

TABLE 4
 Ranges of Correct Responses For the Different Age Groups
 According to the Type of Space

<u>Type of Space</u>	<u>Age Group</u>						
	<u>4</u>	<u>6</u>	<u>8</u>	<u>10</u>	<u>12</u>	<u>14</u>	<u>All Ages</u>
Topological	1-7	2-6	3-7	4-7	4-7	5-7	1-7
Projective	0-5	1-5	2-6	1-6	3-7	3-7	0-7
Affine	2-7	3-7	4-7	3-7	4-7	5-7	2-7
Euclidean	0-4	0-2	0-4	0-6	1-6	2-7	0-7
Total Item Range	6-20	11-19	13-21	15-25	16-23	19-26	6-26

B. Statistical Analyses of the Results of the Form Development Test

An analysis of variance was run to determine the relationship of the type of space to the age and sex factors. Table 5 presents these results. As can be seen, the type of space viewed is highly significant. In completely accepting these results as valid it should be remembered, however, that the difficulty of these items was determined hypothetically by the geometer and not by empirical means. Therefore, what may be considered hard to the geometer may not have been hard for the children. This presents the problem of not knowing for each type of space whether the levels of difficulty are equivalent. A significant sex difference does not appear according to this analysis of variance and none of the interactions are significant. A Tukey Gap Test was run for both the space and age variables. No significant gaps were distinguished. It may be assumed that the variability found in these factors is contributed to equally by each of the six age groups.

In order to determine if there were significant differences between items within each space type, chi square analyses were run. Significant differences between items within a particular space type were found for topological, projective, and Euclidean groups. For each of these, the

TABLE 5

Analysis of Variance Table

<u>Source</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Mean Sum of Squares</u>	<u>F Ratio</u>
Space	3	1,045	348.33	15.76****
Age	5	432	86.40	3.91**
Sex	1	0	00	less than 1
Space x Age	15	99	6.60	less than 1
Space x Sex	3	6	2.00	less than 1
Age x Sex	5	3	.60	less than 1
Space x Age x Sex	15	27	1.80	less than 1
Error	528	11,667	22.10	
Total	575	13,279		

****significant beyond the .0001 level.

**significant beyond the .01 level.

level of significance reaches at least the .001 level. No significant differences were determined among the affine group. The level of significance for this group however does reach the .15 level. This finding probably shows a trend toward differences even among the affine group.

C. Statistical Analyses of the Results of the Extrovert-Introvert Scales in Relation to Spatial Development

An analysis of variance was run to determine if a significant difference exists among the different age groups in relationship to the extrovert-introvert factor. Sex differences were also analyzed. In order to make these analyses, all of the raw scores obtained for the extrovert-introvert scales were converted into standardized scores. These scores were obtained from the norm tables which were derived by Cattell and his co-workers for the different sexes and ages involved. As can be seen from Table 6 neither of these factors is significant. Interaction between sex and age likewise is not significant. It may be assumed that all groups are homogeneous for this trait and that no significant differences exist in the standard scores of the two sexes.

Pearson Product-Moment Correlations were run for the extrovert-introvert scores and the total number of items

TABLE 6

Analysis of Variance Table

<u>Source</u>	<u>Degrees of Freedom</u>	<u>Sum of Squares</u>	<u>Mean Sum of Squares</u>	<u>F Ratio</u>
Age	5	106.2	212.40	less than 1
Sex	1	256.0	256.00	less than 1
Age x Sex	5	1,687.0	337.40	less than 1
Error	132	179,698.8	1,361.35	
Total	143	180,504.0		

each child passed on the Form Development Test. Since there are separate norms for the two sexes, correlational analyses had to be run for each sex. Because a built-in relationship would be found if the age factor were ignored for the Form Development Test, correlations could only be run for the individual age groups. Table 7 presents these results. As can be seen, the correlations are all low and none reach the five per cent level of significance.

A correlation analysis was then made for the scores of the individual factors making up Cattell's extrovert-introvert second order factor and the individual child's results of the Form Development Test. Table 8 presents these results for each age group and for each sex. Only two correlations are significant: the twelve year old boys for Factor A and the fourteen year old boys for Factor F. Both of these correlations are significant at the five per cent level. Since only two isolated cases of significance occur for these correlations, this author feels that these two significant correlations are chance findings.

TABLE 7

Correlations Between Scores of the Extrovert-Introvert
Factor and the Form Development Test

<u>Sex</u>	<u>Age Group</u>					
	<u>4</u>	<u>6</u>	<u>8</u>	<u>10</u>	<u>12</u>	<u>14</u>
Boys	-.22	.43	-.28	.30	.50	.43
Girls	.29	.30	.11	.19	-.48	.05

TABLE 8

Correlations For Factors A, F, and H and the
Form Development Test

<u>Sex</u>	<u>Factor</u>	<u>Age Group</u>					
		<u>4</u>	<u>6</u>	<u>8</u>	<u>10</u>	<u>12</u>	<u>14</u>
Boys	A	.29	.45	.28	.23	.60*	.07
	F	.45	-.02	.11	.04	.07	.62*
	H	-.31	-.13	.31	.30	.26	.12

Girls	A	.29	-.01	.24	.25	-.38	.22
	F	.10	.40	.17	.07	-.18	-.25
	H	.51	.23	.09	-.06	.01	-.01

*Significant beyond the .05 level.

V. DISCUSSION

Before analyzing the responses to each item employed in this study, it should be pointed out that an attempt was made to rule out as far as possible the element of chance. The examiner questioned any child who seemed to be obtaining his answer by guessing. If he was guessing, he was asked to look at the possible choices more closely. Younger children who obtained answers theoretically postulated as being beyond their age level were questioned in detail to determine if a valid concept was being employed. In general, it was found that the younger children who passed questions theoretically beyond their age level had fairly well formulated concepts.

A. Items Measuring Predominantly Topological Characteristics

For this group of children, the concept of insideness-outsideness, which includes the concepts of separation, enclosure and proximity, is not developed in most children until the age of six. This finding does not correspond with Piaget's and Inhelder's (1956). They found that children develop this concept by the

age of four. The concept of contiguous circles also was found by the age of four in the children used by Piaget and Inhelder. However, in the present investigation, only half of the four year olds and two-thirds of the six year olds could identify contiguous circles. Conceivably, the differences in these findings can be explained on the basis of individual differences in rate of development of these concepts and of the average ability level of the subjects employed in this investigation.

Magnitude and similarity concepts appear in almost all the children of all age groups. This confirms the findings of Hicks and Stewart (1930), Thrum (1935), and Welch (1938, 1939, 1939a, 1939b, 1940) who found that simple concepts of magnitude are present in very young children. It is interesting to note that although this item, item 3, could be passed either by judgments of similarity in shape with differences in magnitude or by judgments of order, no subject verbalized the order basis for a selection. These dimensions, i.e., similarity and magnitude, of topological space apparently have been ignored by Piaget and his co-workers for no experiments have been reported by them concerning these concepts.

The broken figure-eight knot with beads, which was designed to determine the development of the concept

of order, was very hard for all age levels. Even at the fourteen year level only one half of the subjects passed this item. It would appear that the concept of this type of order is a growth function occurring from early infancy through young adulthood, and is not well established in the four or six year old groups. Piaget and Inhelder (1956), however, found that their group as a whole could identify this type of knot in an operational manner by six years of age, and most of their children could before this age. Although Piaget's children could successfully identify right and left clover leaf knots by the age of six or seven, the children of this experiment, even the fourteen year olds, had a difficult time doing so. Thus, the concepts of enclosure and order are not completely established by the age of fifteen in the children employed in this investigation. This finding would tend to confirm Rush's (1938-1939) finding that organizational relations of the kind described by the gestaltists develop progressively with age, and those of Lowenfeld (1957) who says that children in their early years do not have an order concept.

Children of this group did pass with ease the complex topological knot. This may have been accomplished because the complex knot did not appear so much as an

isolated simple figure as the preceeding topological items and thus more like objects seen in the environment; or it may have been that the experimenter inadvertently picked three false answers so different from the correct answer that the children passed this item on the basis of contrast effects.

The similarity of a series of points to a straight line was developed in the children in this group by the age of eight. This finding confirms that of Piaget's and Inhelder's (1956). However, the author believes that the younger children probably passed this item, item 5, on the basis of orientation rather than realization that a line is made of a series of points. Many of the younger children who passed this item exclaimed "Oh, it's this one cause it's straight like that other one." If this was the method for obtaining the correct answer, the concept of spatial orientation was more influential for younger children than the concept of contiguity in attaining the correct answer for this item. Piaget interpreted his subjects' answer to an item similar to this one as revealing the development of the concept of contiguity. The present interpretation of the passing of this item would tend to confirm the results obtained by Gellerman (1933) who found that in the younger age groups orientation is

important. It is interesting to note that the author did find a few four and six year old children who declared that the straight line with a piece attached to it was straight. This would tend to confirm Verpillot's (1954) findings that children of this age range attribute to the whole figure a quality which is true only of each part of the figure separately.

The representational topological space concepts found by Piaget in his preschool children are not found fully developed in the preschool children of this experiment. However, the concepts of similarity and magnitude are well developed in these preschool children, and the concept of relative position is fairly well established.

B. Items Measuring Predominantly Projective Characteristics

Half of the four year olds and almost two-thirds of the six year olds were able to visualize a straight line lying at angles to the side of a table. This does not confirm the Piaget finding. His children were unable to project a straight line across an angle of a table until they were at least seven years of age (Piaget and Inhelder, 1956).

In this study, the development of the concept of receding size and detail and the coming together of parallels

in the distance begins in the four and six year olds and is almost completed by eight years of age. This is approximately the same age that Piaget's children only began to have "visual realism", i.e., visual perspective. However, this finding would tend to confirm Lowenfeld's (1957) finding that a child from seven to nine begins to find order in his environment.

Development of the concept of the shapes of sections of geometric solids appears in some children as early as four years in this investigation. The shape of a section of a cube was known by almost half of the four year old children while four children of this age level passed items concerned with sections of a cone and a little house.¹⁰ In all instances but one these children were able to describe what these sections would look like. This finding does not confirm the results reported by Piaget and his co-workers. In the children of their investigation, the concept of geometrical sections did not appear until approximately seven years of age. In no instances did they report a four or five year old child being able to determine what an internal section of an object looks like.

¹⁰. The children who passed the cone item were not the same children who passed the house item.

The concept of the shape of a shadow projection was found in a number of the four and six year old children. Ten of the four year olds passed this item while eight of the six year olds did so. Upon questioning, the examiner found that five of the four year olds had guessed their answers, whereas, the other five were able to explain point to point projection. With the exception of one individual, the six year olds were able to explain the basic concept of this item. This finding does not agree with the results reported by Piaget and Inhelder (1956). They found that children are not able to pass this type of item until around eight years of age.

The three-dimensional item was passed by five children each at the four and six year levels, and it was passed by six children each at the eight and ten year levels. In four out of the five cases at the four year level, and three cases out of five at the six year level, the children had formed concepts of what the doll would see when she looked at the mountains from another viewpoint, i.e., the view turned 180 degrees from the original. All of the eight and ten year old children who passed the item had well developed concepts. Piaget does not report his children as being able to form representational viewpoints other than their own until they were eight years of age, and not usually until eleven.

In sum, the children of this investigation develop concepts of projective space earlier than the children reported by Piaget and Inhelder (1956). They could identify a broken straight line projected across an angle of a table, sections of geometric solids, shape of a shadow projection, and coordinate perspective earlier than the children reported in the Piaget studies. The development of the concept of receding size and distance and the coming together of parallels in the distance was found to be approximately at the same age level as that found by the Swiss investigators. It is interesting to note that the concepts of sections of geometric solids, and the shape of shadow projections are not fully developed in all of the fourteen year old children in this study. This result does not correspond to the Piaget finding that by the age of thirteen or fourteen years these concepts are fully developed. ...

C. Items Measuring Predominantly Affine Characteristics

The concept that oblique or horizontal parallel lines are similar to vertical parallel lines is well established in the four year olds of this experiment. As can be seen in Table 1, page 65, at least two-thirds of the four year olds passed this item as well as almost all the children in the remaining age groups. This finding does

not confirm the finding of Wursten (1954) that thirteen or fourteen year old children have trouble seeing the conservation of parallel lines when turned from their original placement.

Children of all ages had developed the conservation of parallels and angles from one square with its sides vertical to a different size square tilted on one corner. Likewise, children of all ages had developed the concept of the conservation of parallels in the case where a parallelogram is slanted in one direction to the situation where the parallelogram is slanted in the opposite direction. In the case of conservation of parallels from a series of large upright diamonds to a series of small diamonds turned ninety degrees, approximately one-half of the four and six year old children pointed to the correct answer. Most of the children in the remaining age groups passed this item.

Over half of the children at the four year level passed the affine item employing the lazy tongs, and almost all of the children of the remaining age groups passed this item. This finding does not confirm Piaget's finding. His children had difficulty seeing the transformation and hence the conservation of the parallels and angles until seven or eight years of age.

The concept of the conservation of parallels from

within a circle to within an oval was somewhat difficult for the four year old children in this investigation. Out of the eight four year olds passing this item, only two children could not tell the examiner why they had chosen the answer which they did. The remaining six children had formed valid concepts. Most of the children for the remaining age groups passed this item.

The affine items in general were easy for the children. This finding may have been due to the use of easier affine items than items used to measure the other three types of space. However, the level of difficulty for these items was checked by the geometer consulted. It was his opinion that these items had the same range of difficulty as the items in the other types of space. Possibly affine characteristics of spatial objects do not form a transitional stage between projective and Euclidean spatial concepts, as hypothesized by Piaget. On the other hand, the basic concepts of affine geometry may not have been the only concepts employed by the children in passing these items. The concepts of similarity and magnitude may have aided them in their decisions.

D. Items Measuring Predominantly Euclidean Characteristics

The development of the concept of gravitation as measured by the water in the bottle item was difficult for all age groups. Out of the five children passing the item at the four year level, only two children could tell the examiner why their answers were correct. One said "must be smooth like table." The other used his hands to demonstrate the same idea. The two six year olds passing this item both told the examiner that "water must go same way as floor." The ten year old gave a very interesting answer. He said "the pull of gravity will make it look like this" as he pointed to the correct answer. Although more than half of the fourteen year olds passed this item, the entire group had not developed this concept. These findings in general agree with Piaget, however, he does not report any four or five year old children having the concept of gravitational pull. He also reports that by eleven children have completed the development of this concept. This study did not confirm this finding.

Piaget, Inhelder, and Szeminska (1960) report that the conservation of distance from unfilled space to filled space appears about the age of seven. In general, in this investigation this concept did not appear until the

ten year level. However, one of the two correct answers at the four year level revealed a genuine understanding of the concept. This subject said "it is same, suckers just put in."

Conservation of area was a fairly hard item for all children in this experiment. The single six year old passing this item told the examiner "put the chopped off piece back, and it would be the same." The four year old who passed this item traced out the answer with his finger. He then pointed to the correct answer. There was gradual development of this concept by the eight, ten, and twelve year age levels. However, a number of fourteen year olds did not pass this item although it was passed by the majority. In general, Piaget's finding is confirmed. He found that conservation of area does not begin to develop until about seven to nine years of age and is completed by fifteen. This does not confirm Vernon's (1937) finding that children conserve area better than adults.

The conservation of length appears in general to be well established in children from four through fourteen. Children at the four and six year levels who passed this item usually told the examiner that the longest one of the four possible answers was right because the "humps flattened out." With the exception of the finding that fourteen of

the four year olds passed this item, this finding roughly confirms the finding of Piaget, Inhelder, and Szeminska (1960).

More children passed the three-dimensional item than any other Euclidean item. The conservation of this entire scene shows a progressive development from four through fourteen years of age and is established in the majority of individuals by eight years of age. Three of the four year olds passed this item. In all three instances these children (two boys and one girl) described the way the railroad tracks and the road would look to the cowboy when he turned around to come back through the village. The examiner considers these as genuine passes with conservation of the entire scene fairly well developed. All of the six year olds who passed this item could give valid reasons for their answers. Because more children passed this Euclidean item than any other Euclidean item, the question is raised whether a total scene is easier and earlier conserved than isolated objects as in the case of the two dimensional items.

The conservation of volume using marked objects is well established by the ten year old level for the children in this study. Below the age level of ten, however, the children had great difficulty with this concept. Out of

the three four year olds who passed this item, two showed the examiner that the correct response was just twice as large as the stimulus object by counting off the blocks. The other child guessed the answer. Four of the six year olds who passed this item could verbalize a valid concept. In general, these findings agree with those of Piaget, Inhelder, and Szeminska (1960). However, they did not report that any of their children from four through seven passed this type of item.

The conservation of volume from one unmarked box to another unmarked box of different shape appears exceedingly difficult at all age levels. Only seven children passed this item through the twelve year level, and it was passed by only eight of the fourteen year old group. None of the three children passing at the four year level could tell the examiner why he chose the correct answer. The eight and ten year old children likewise could not find valid reasons for their answers. The one twelve year old girl who passed this item marked off squares on the box which was the correct answer to show the examiner that it would hold "the same amount of candy."

In sum, the development of Euclidean space found in this investigation appears to occur later than reported by Piaget and his co-workers. The range of ages at which these

concepts develop is wider than that reported by Piaget, Inhelder, and Szeminska (1960).

VI. CONCLUSIONS

It can be seen from the results of this investigation that the development of the concept of space in the children studied has not been a simple clear-cut sequential process or action. In this investigation, it was found from the tabulation results that: (1) in general, representational topological space concepts are not fully developed as early as reported by Piaget; (2) projective spatial concepts start developing earlier than reported by Piaget and his co-workers, and affine concepts are found in this group of children to develop much earlier than in Piaget's children; (3) on the whole, the development of Euclidean space concepts occurs later than reported by Piaget. The range of ages at which the Euclidean concepts develop is wider than that reported by Piaget.

The statistical analyses made regarding the importance of the type of space in the development of spatial concepts suggest that the particular type of space is important. But they do not show that any one type of space contributes more than any other type of space toward the development. The age factor for over-all development of spatial concepts is important but the statistical analyses do not show that any

one of the types of space develops at any particular age. Since the space and age interaction is not significant, it can be assumed that the characteristics of particular items relating to different spatial concepts are important but a sequence of stages based on space types as a model for the development of spatial concepts is not completely supported. Therefore, from both the tabulation results and the statistical analyses, it can be concluded that the stages hypothesized by Piaget do not occur in a precise manner in the children employed in this investigation.

It should be remembered that item difficulty has been hypothetically rather than empirically determined. There is evidence, however, that a range of difficulties has been studied for all types of space with the exception of the affine group. This can be seen from the results of the chi square analysis. There is, then, evidence that the goal of measuring more than a single level of difficulty within each type of space has been attained. Thus, the experimental weakness of using all simple items to study one type of space and all complex items to measure another type of space has probably been avoided.

The results of this investigation show a steady increase in the number of individuals passing the items from the four year level through the fourteen year level.

Approximately twice as many fourteen year olds passed the items as four year olds.

With the exception of the affine items, more children were able to pass items which dealt with entire objects or entire scenes than items employing only isolated figures. This confirms Gibson's (1950) belief. He thought that very little of the basis for a subject's response being like the original pattern can be determined when only simple points, lines, and planes are investigated, for no one has ever seen them. Leibnitz said that objects exist simultaneously and coexistently not in isolation. This was confirmed by extensive research by Einstein. However, Euclid's entire system is basically a set of definitions, postulates and axioms all of which view characteristics of objects in isolation. It is a system based on tactile congruencies rather than binocular visual space (Schelling, 1956). By utilizing Euclidean characteristics as those latest in the development of spatial concepts, it would appear that Piaget's research is attempting to formulate his operational model on objects in isolation. The passing of more entire scene items than isolated items in this experiment would suggest a basic differences between perception of parts and of the whole. Thus, it would appear that the study of isolated figures probably does not

determine how perception develops in the organized world.

From this study, it may be concluded that most children do not complete the growth of the concept of space by fifteen years of age. This can be seen by the fact that even children from fourteen years zero months to fourteen years eleven months had difficulty with some topological, projective, and Euclidean items.

It may also be concluded that four year old children do not individually nor as a group conceive of space entirely by topological characteristics. Some of these individuals make use of most of the concepts of all types of space. This conclusion does not agree with the Piaget results. It does confirm Rush's (1938-1939) conclusion that relations which are primarily topological in nature increase in efficacy with age. Significant differences were not found between boys and girls. It may therefore be concluded that in the subjects of this investigation sex differences are not influential upon the development of the concept of space.

Undoubtedly, personality factors enter into the development of spatial concepts. However, this investigation did not find a significant relationship between the extrovert-introvert dimension of personality and spatial development. This author believes that to determine the relationship between these variables, other methods than a personality

questionnaire must be employed, e.g., clinical interviews and projective techniques. It is not felt by this author that the personalities of the children in the present investigation were adequately investigated to establish what type of relationship actually exists. This author feels, however, that there is a relationship. This was shown by the work of Lowenfeld (1957). He found that such things as the cooperation of children, negativism, and ego development are substantially related to spatial development. Witkin (1954) likewise showed a relation between personality of the child and the perception of the visual world. Apparently, however, Piaget does not believe that investigations of these factors in relation to the development of space are important for no studies have been reported by him in this area. However, the present investigator considers this a very important area and agrees with Werner and Wapner (1952) that unless the whole individual is studied a true picture of the developmental processes can not be obtained.

On the bases of the conclusions discussed above, this investigator believes that the development of the concept of space in children occurs as a function of experience of all types of space, and that development is from the elementary concepts of each type of space to the more complex concepts of each type of space. The spatial experiences of the child constitute a dynamic process which

is an action and which is an integrative process of the new data which the child receives from day to day. This would account for the individual differences found in this experiment and explain why some children have fully developed concepts at four or six years while other children tend as late as fourteen or fifteen to have not formulated these concepts. This belief is in accordance with Koffka's (1935) views that visual space is a dynamic event rather than a geometric pattern. The theory follows the general construct of the transactionalists, Brunswik, Bruner and Postman, Helson, and Ivo Kohler. Witkin and his co-workers (1954) also concluded that past experience is influential in perceiving the visual world. That the development of space is a function of experience agrees with Werner's (1948) basic tenet that perceptual growth is primarily reorganization based on inclusion of new data. Essentially this is what Piaget and Inhelder (1956) are hypothesizing. But they apparently believe that a child is not aware of projective, affine, and Euclidean figures until certain ages.

VII. SUMMARY

This is a study of the ontogenetic development of spatial concepts in children from four through fourteen years of age. It is an attempt to determine whether or not the development of the concept of space in children evolves in the sequence hypothesized by Piaget. He has reported that children of four or five years of age view objects primarily by topological relations. From the age of six on Euclidean and projective spatial relations develop until at the age of fifteen the development of the perception of objects is complete.

A total of 144 subjects of average ability as determined by the short form of the Stanford-Binet Intelligence Scale was used in this study. They represented the even year age groups from four years zero months to fourteen years eleven months. Each group consisted of twenty-four children evenly divided between boys and girls. The children all came from approximately the same middle class, socioeconomic background. They did not have severe emotional problems, physical handicaps, nor extreme reading problems.

A Form Development Test consisting of twenty-eight items devised by the author and designed to measure representational space was administered individually to each of

the subjects employed. This test consists of seven items measuring predominantly topological space; seven items which measure predominantly projective space; seven items with affine characteristics; and seven items representing predominantly Euclidean characteristics. All items were checked by an expert in geometry in order to be relatively certain that each item would measure the desired space type. The geometer also checked to make sure that in each type of space there were easy and hard items so that children would not see all hard items measuring one type of space and all easy items for another type of space. Most of the items were two dimensional figures, three had three dimensional stimuli with responses in two dimensions. Two items were entirely three-dimensional. A standardized procedure was used to administer the test to the children.

Immediately following the administration of the Form Development Test, the children were presented with the extrovert-introvert scales of the ESPQ, CPQ, and HSPQ personality questionnaires as devised by Cattell and his co-workers. This was done in order to determine if a relation exists between the extrovert-introvert dimension of personality and spatial development in the child.

The tabulation results of this investigation show that most of the children in this investigation did not

develop concepts of topological space before six years of age. Piaget reports that his four year old children had almost completed the development of these concepts. The children employed in this study developed projective spatial concepts earlier than the children reported by Piaget. The concepts involved in affine relations were well established by the six year olds in the present investigation. This is much earlier than for the children reported by Piaget. The development of Euclidean concepts occurred later and with greater variability than reported by Piaget.

The statistical results show a significant difference between types of space, between items within each type of space, and between age levels. There is no significant differences between boys and girls. Pearson Product-Moment Correlations obtained from the Extrovert-Introvert Scales of the ESPQ, CPQ, and HSPQ and the Form Development Test are not significant.

On the basis of the findings of this experiment, the following conclusions were drawn: (1) in general, the occurrence of the specific stages in the development of the concept of space hypothesized by Piaget is not completely supported by the results of this study; (2) the type of space being viewed is important; (3) age is a significantly contributing factor in the development of the concept of

space; (4) the individual item within the particular type of space being viewed is important in this development; (5) the development of perceptual processes utilized in seeing the visual world can not actually be studied by utilization of isolated geometric figures; (6) most children do not complete their space development by fifteen years of age; and (7) four year old children do not, as a group, conceive of space entirely as characterized by topological relationships.

APPENDIX A

Directions For Administration

Topological Items

1. Look at this. Be sure to look at it closely for I am going to take this one away and see if you can find one just like it for me.

Now can you find one of these that looks just like the one you looked at? Look carefully. Then point to the one which you think is just like the one which you have just looked at.

2. Now look at this one. Be sure to look at it very closely for I shall take it away and see if you can find one just like it.

Now look at all these. Can you find one that looks just like the one you have just looked at. Look carefully. Then point to the one which you think is just like the one which you have just looked at.

3. What is this? Look at it closely for I am going to take it away in a few moments and see if you can find one that looks almost like this one.

Can you find one that looks-almost like the one which you have just looked at? Look carefully--then point to the one which you think is almost like the one which you have just looked at.

4. See this string of beads. Look closely for in a few moments I am going to take it away and I shall want you to find one exactly like it for me.

Can you find a string of beads just like the one which you have just looked at. Look carefully and then point to the set of beads which looks just like the set which you have just looked at.

5. Look at this carefully for I am going to take it away in a few moments and I shall want you to find for me a figure that is most like this one.

Which of these looks most like the one you have just looked at. Look carefully--and then point to the one which looks the most like the one which you have just looked at.

6. See this piece of string. Be sure to look at it very closely for in a few moments I am going to take it away and I shall want you to find one just like it.

Look at these different pieces of string. Which one looks just like the one which you have just looked at? Look carefully then point to the one which looks just like the one which you have just looked at.

7. See this piece of string. It is all tied up in a fancy bow. Look at it very closely for in a few moments I am going to take it away and ask you to find one just like it for me.

Look at these fancy bows made out of pieces of string. Can you find the one that looks just like the one you have just seen? Look carefully--then point to the one that looks just like the one you just looked at.

Projective Items

1. Look at this table which has a line on it. Be sure to look carefully for in a few moments I shall take it away and ask you to find one just like it.

See these tables. Which one looks just like the one you have just looked at? Look carefully--then point to the one that looks just like the one you have just looked at.

2. See this ice cream cone. What would the cone section (piece) look like if I cut it right through here. Watch me closely for in a few moments I shall ask you to find for me a picture of how this piece would look.

Now which one of these would the piece look like if I had cut it out. Look carefully--then point to the one which the piece would look like.

3. See this box. I want you to think of how a piece would look if I cut it out right here. Think carefully for in a few moments I shall ask you to find for me a picture of how this piece would look.
4. Look at this little house. If I should cut a piece out of it right here what do you think it would look like? Think carefully for in a few moments I shall ask you to find for me a picture of how this piece would look.

See all these pieces. Which one do you think the piece out of the house would look like? Look carefully--then point to the one which would look like the piece cut out of the house.

5. See this picture. Look closely at it for in a few moments I am going to take it away and I shall ask you to find for me one just like it.

Can you find for me a picture just like the one you just saw. Look carefully--then point to the one just like the one which you have just looked at.

6. Look at this. Suppose I shine a light through this hole and I get a picture on this side which looks like this. Look closely for in a few moments, I shall take this away and I shall ask you to find for me the picture which shows the same thing.

Can you find for me the picture which shows the same thing as the one you have just looked at? Look carefully and then point to the one which shows the same thing as the one which you have just seen.

7. See these mountains. The doll sees the mountains. What do you think the doll would see if she looked at the mountains from over here? Look closely for in a few moments I shall take these mountains away and we shall look at some other mountains and see if you can tell me what the doll would see if she was looking at the mountains from over here.

See all these mountains. Which ones would the doll see? Look carefully and then point to the ones which the doll would see.

Affine Items

1. Look at this. Look closely for in a few moments I shall take it away and I shall ask you to find one that is almost like it.

Can you find one that is almost like the one which you have just looked at? Look carefully--and then point to the one which is almost like the one which you have just looked at.

2. Look at this. Look carefully for in a few moments I shall take it away and ask you to find one that is almost like it.

Can you find the one that is almost like the one you have just looked at? Look carefully and then point to the one that is almost like the one which you have just looked at.

3. See this. I am going to take it away in a few moments so look at it carefully. I shall want you to find one that is almost like it.

Now, can you find the one that is almost like the one you have just looked at? Look carefully and then point to the one that is almost like the one which you have just looked at.

4. See this. Look at it closely. I shall take it away in a few moments and I shall ask you to find for me the one that is nearest like it.

Look closely at all these figures. Now point to the one which is nearest like the one which you have just looked at.

5. Here are a number of figures. Look at them closely for I shall take them away in a few moments and I shall ask you to find the ones that are nearest like them.

Which set of figures is nearest like the set which you have just looked at? Look carefully and then point to the ones which are nearest like the ones which you have just looked at.

6. Look at this. Look at this closely for I shall take it away in a few moments and I shall ask you to find the picture that is nearest like it.

Which of the figures looks like the one which you have just looked at. Look carefully and then point to the one which looks the nearest like the one you have just seen.

7. See this. Look closely for I shall take them away in a few moments, and I shall ask you to find a picture that is nearest like this one.

Look carefully. Point to the one which looks the nearest like the picture which you have just seen.

Euclidean Items

1. See this bottle with water in it. Look closely for I am going to take it away in a few moments and then I shall ask you to find for me the bottle in to which I have poured this water.

Which of the bottles did I pour the water into? Look carefully and then point to the one which is the one into which I poured the water.

2. Look at this. See the suckers. Look closely for I shall take these away in a few moments and I shall ask you to find for me the suckers that cover the same distance from the outside to the outside.

Which set of suckers covers the same distance from the outside to the outside as the suckers which you have just looked at? Look carefully and then point to the set which has the same distance from the outside lolly pop or sucker to the other sucker.

3. See this. Look carefully for I shall take this away in a few moments and ask you to find me one that has the same size--that has the same room inside it.

Look carefully and then point to the one which is the same size as the one you just looked at. Point to the one which has the same room inside it.

4. Look at this piece of string. Here it is slack for no one is holding it tight. What do you think it would look like if it were held tightly? Look closely for in a few moments I shall take this one away and ask you to find for me the one which you think this one would look like if you held it tightly.

See these pieces of string. They all have been pulled tight. Which one looks like the one you have just looked at. Look carefully and then point to the one which looks like the one you have just looked at if it had been pulled tight.

5. Look at this. See the school house and the children going to school. Here comes a cowboy on the horse riding down the road. Over here is a railroad. Now the cowboy on the horse is turning around and riding back into the village. What do you think the cowboy will see when he turns around? Look closely for in a few moments I shall take this village away and ask you to find for me the one which the cowboy would see when he comes riding back into the village.

Which one of these did the cowboy see when he came riding back into the village? Look carefully and then point to the village which the cowboy would see.

6. See this box. Let us pretend it is filled with candy. Look at it closely for in a few moments, I shall take it away and I shall ask you to find for me the box that would hold twice (double) as much candy.

Here are other boxes. Can you find the one that would hold twice as much candy as the one you have just looked at.

7. See this box. Let us pretend that it is filled with candy. Look at it closely for in a few moments I shall take it away and I shall want you to find for me the box that will hold the same amount of candy.

See all these boxes. Now can you find the one that holds the same amount of candy as the box which you have just looked at? Look carefully and then point to the box that would hold the same amount of candy as the box which you have just looked at.

APPENDIX B

The Early School Personality Questionnaire*

R. W. Coan and R. B. Cattell

Factors: A, F, and H

1. Would you rather play school or cowboys and Indians?
2. If you were in a play, would you rather be a teacher or a hunter?
3. Who usually has better ideas--you or your friends?
4. Does your mother let you do almost anything you want or are there lots of things she won't let you do?
5. Are you always pretty lucky or do more bad things happen to you than to other children?
6. Do you like to run or just walk?
7. Do you like to talk to teachers?
8. Would you rather be in a play or make something out of wood?
9. Are you pretty good at everything or just a few things?
10. Are you stronger than other children or are they stronger than you?
11. On the playground do you make a lot of noise or are you mostly quiet?
12. Do you have a lot of friends or just a few friends?
13. Would you rather go to a party or stay home and play?
14. Would you rather have a new baby come to live with you or have a little dog come to live with you?
15. Do you like to tell stories to other people?
16. When you want to say something do you just say it or do you think it over first?
17. Would you rather build things with your friends or build things by yourself?
18. On the playground do you run most of the time or do you stand still a lot?
19. Which would you rather be a doctor or a teacher?
20. If another child has your coat do you take it away from him or tell the teacher?
21. Would you rather listen to a story or watch two dogs fight?
22. Which do you like better: hearing stories about what a boy or girl does or really doing things yourself?

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23. Does anyone ever call you a cry-baby?
24. On the playground, do you play by yourself or mostly with other children?
25. Would you rather fly an airplane or be a teacher?
26. Do you like to see other children cry or does it make you sad?
27. Are you getting along pretty well or do you have a lot of problems and troubles?
28. When you argue with people do you sometimes find out that you were wrong or are you nearly always right?
29. Is your teacher nicer to other children or just as nice to you?
30. Do you know any children who are so dumb that it's no fun to play with them?
31. Do you ever talk back to your mother?
32. Do you ever feel like running away from home?
33. Do you usually do what other people say or do what you want to do?
34. Do you have to do things you don't want to do or do you always do what you want to?
35. Do you think people ever say bad things about you behind your back?
36. Do you like to help your mother and father with things or just play?

Children's Personality Questionnaire*

R. B. Porter and R. B. Cattell

Factors: A, F, and H

1. Do you speak first to a new child or do you wait for him to speak to you?
2. Would you rather be a good hunter or a school teacher?
3. Would you rather be a minister in a church or a doctor in a hospital?
4. When you are angry do you break things or only want to break things?
5. Do you like to cross a busy street or are you afraid to cross?
6. Would you like better to have bears here now or to hear stories about bears?
7. When a visitor comes to your house do you talk to him first or do you feel too shy?

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8. Can you easily stand up in class and talk or do you feel shy?
9. Does your mother say you talk too much or are you quiet?
10. Does your mother think you are too lively and excited or quiet and calm?
11. Should everyone have an airplane or are cars enough?
12. When your friends argue, do you join the argument or keep quiet till they finish?
13. Who should talk first, younger children or older children?
14. Do grown-ups talk all the time or often listen to you?
15. When people tell about things you have seen, do you want to tell them too or just listen and agree with them?
16. When a child laughs at you do you feel badly or do you laugh too?
17. Can you work while people laugh and talk or would you rather they keep quiet?
18. Do you like to tell stories or don't you like to tell stories?
19. When people start talking as you listen to TV or radio does it bother you or don't you hear them talking?
20. If you were high upon a big rock would you be scared or would you look around?
21. If children don't play with you do you start another game or do you feel badly?
22. When you get angry do you want to cry and sulk or to smash things on purpose?
23. Are you afraid in the dark or is there nothing to be afraid of?
24. Have you ever sold things to people or would you not want to sell things?
25. Have you never fainted or do you have fainting spells?
26. Do you have many friends or just a few close friends?
27. When something of yours needs fixing do you ask father to see to it? Or do you fix it yourself?
28. When you grow up would you rather be a lawyer in an office or fly a plane?
29. Are your parents always ready to hear you talk or are they sometimes too busy?
30. Does your father do things with you or do you not like to bother him when he is busy?

High School Personality Questionnaire*

R. B. Cattell, H. Beloff and R. W. Coan

Factors: A, F, and H

1. When you are asked to write an essay about your private thoughts and emotions, do you:
 - A. Enjoy expressing yourself
 - B. Prefer to keep your feelings to yourself?
2. Do most people seem to enjoy your company?
 - A. Yes, a lot
 - B. Just average.
3. Do you sometimes feel, before an exciting party or outing, that you are not so interested in going?
 - A. Yes
 - B. No
4. At a picnic, would you rather spend some time:
 - A. Exploring the woods alone?
 - B. Playing around the campfire with the crowd?
5. With people you know, can you usually talk them into joining you in things?
 - A. Yes
 - B. No
6. Are you always ready to show, in open competition, that you can do most things as well as other people?
 - A. Yes
 - B. No
7. In putting on a play would you rather act the part of:
 - A. A salesman?
 - B. A lone prospector for uranium?
8. If you had a job in a theater, would you rather be:
 - A. The person in charge of scenery and lights?
 - B. An actor, even of small parts?
9. When talking in front of several people, do you sometimes stammer a bit, and find it hard to say what you want?
 - A. Yes
 - B. No
10. Do you feel hurt if people borrow your things without asking you?
 - A. Yes
 - B. No
11. Would you rather spend an evening:
 - A. At a gay party?
 - B. With the hobby you like most?
12. Can you work just as well, without making mistakes, when people are watching you?
 - A. Yes
 - B. No
13. Do you enjoy studying best:
 - A. In school?
 - B. At home?

14. In a group of people, are you generally one of those who tells jokes and amusing stories?
A. Yes B. No
15. Do you sometimes feel unwilling to try something though you know it is not really dangerous?
A. Yes B. No
16. Do you go out of your way to avoid crowded buses and streets?
A. Yes B. No
17. When you are ready for a job, would you like one that
A. Is steady and safe, even if it needs hard work? B. Has lots of change and contacts?
18. Do you stand up before a group without looking nervous and ill-at-ease?
A. Yes B. No
19. In discussion with your classmates, do you feel that you dislike telling them all your most private opinions?
A. Yes B. No
20. Do you get on better with people who:
A. Know exactly what their own views are? B. Consider everything very carefully and hesitantly?
21. Are you sure your friends never speak badly of you behind your back?
A. Yes B. No
22. When people quarrel can they always be stopped if someone laughs them out of it?
A. Yes B. No
23. When you plan something, are you generally full of:
A. doubts, expecting things to go wrong? B. hope, and sure that all will go well?
24. Do people still treat you as if you were younger than you actually are?
A. Yes B. No
25. Do you feel hurt if older people do not take your ideas and opinions seriously?
A. Yes B. No
26. Do you have gifts and possibilities in your personality that you have never shown people at all?
A. Yes B. No
27. Do people say, "You are in a mean mood today," as if you disliked people and were unkind to them?
A. Yes B. No
28. When a new teacher comes to your class, does he or she pretty soon notice who you are and remember you?
A. Yes B. No

29. Do you try to be careful what you say, so that you could not possibly hurt anyone's feelings or startle anyone?
A. Yes B. No
30. Do you feel that people are generally helpful and attentive when you most need it?
A. Yes B. No

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