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Auditory Stimulation and Its Effect on Spatial Temporal Ability

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**AUDITORY STIMULATION AND ITS EFFECT
ON SPATIAL TEMPORAL ABILITY**

by

Cynthia G Edwards

A Thesis Submitted to the
Department of Human Factors and Systems
in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Human Factors & Systems

Embry-Riddle Aeronautical University

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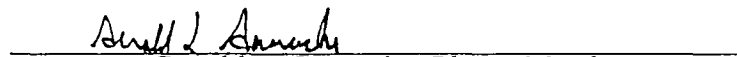
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This thesis was prepared under the direction of the candidate's thesis committee Chair, Christina M. Frederick-Recascino, Ph.D., Department of Human Factors & Systems, and has been approved by the members of her thesis committee. It was submitted to the Department of Human Factors & Systems and has been accepted in partial fulfillment of the requirements for the degree of Master of Science in Human Factors & Systems.


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ABSTRACT

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This thesis was designed to detect the type of spatial ability most effected by auditory stimulation, as described in the Mozart effect. Previous research has shown enhancement of performance on the paper-folding and cutting subtest of the Stanford-Binet Intelligence Scale IV with failures to replicate in research using other measures. Seventy-five college students enrolled in introductory psychology classes were exposed to one of three types of auditory stimulation, followed by two measures of spatial ability. The Purdue Visualization of Developments test correlates with tests of spatial orientation and require analytical processing, while the Vandenberg and Kuse Mental Rotation Test is a test of spatial visualization, not confounded with analytical processing. Neither of the two tests displayed a significant treatment effect, lending to the possibility that the enhancement of performance seen previously on the Stanford-Binet Intelligence Scale IV subtest is the result of a factor of the test other than the spatial aspect.

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INTRODUCTION

Understanding how the brain functions presents itself as one of the most challenging, yet fundamental quests of science. Through the years, much understanding has been gained through the study of implicit and explicit tasks, cognitive abilities and/or impairments of patients with brain lesions, and the development of theories and models (Searleman & Herrman, 1994). Recent advancements in this scientific quest have also been achieved through examination of developing human fetal brains as well as the brains of small lab animals such as rats and rabbits, providing enlightenment on the inherent organizational processes of development. Technology has provided scientists with the ability to view brain functions through observation of blood flow changes and electrical activity during information processing in the post-natal brain as it is affected by environmental stimuli (Johnson, 1999). In recent years two venues have received a significant amount of research, the relationship between music and higher brain function, and the role of long-term potentiation in learning and memory. Both topics are indicated to contain aspects that are universal to all fully functional humans in that it is a fundamental assumption that all humans are biologically equipped with a basic music ability and experiment early in life with the production of a variety of vocal sounds (Sergent, 1993), while long-term potentiation is a prominent physiological characteristic of synapses in the normally functioning brain (Teyler & DiScenna, 1985). But, what characteristics do they possess that would enable us to study brain function?

The relationship between music cognition and other higher brain functions has been noted for thousands of years, dating back to ancient Greeks and Babylonians. Music was actually considered by the ancient Greek Pythagoreans as one of the four branches of mathematics (Sarton, 1966). Likewise, mathematics is foundational to music theory, precisely, the concept of proportional mathematics, or ratios. Anecdotally, it has long been observed that many great mathematical minds share special musical abilities along with their mathematical abilities. For example, Einstein, one of the most celebrated scientists of the twentieth century, was also an accomplished violinist and was enlightened to the mathematical structure of music through the compositions of Mozart (Clark, 1971).

It should be noted here that there are two types of reasoning involved in learning mathematics, spatial-temporal reasoning and language-analytic reasoning. Language-analytic reasoning involves thinking and reasoning using human language and equations and is the type of reasoning most commonly associated with the mention of mathematics (Shaw, 2000). Spatial-temporal reasoning, on the other hand, is required for cognitive tasks involved in thinking by using pictures that evolve in space over time, as seen in a person's ability to visualize the problem and a solution when doing word problems. As used in science, chemistry in particular, spatial visualization is the ability to mentally manipulate or restructure a visual stimulus and involves recognizing, retaining, and recalling a figure when all or part of that figure is absent or moved (McGee, 1979). This type of cognitive process is especially important in conceptual learning and the ability to think ahead, two characteristics associated with mathematics and science.

Music also involves these two types of reasoning. Language-analytic reasoning is evident in the way duration and pitch is represented through notation, while the spatial-temporal aspect of music can be seen in that it occurs in a spatial manner and progresses over time. Most styles of music also possess highly organized structure in their tonality and form. The organizational structure of tone is evident in the spatial relativity between frequencies of pitch. When notes of the scale are presented on a spiral, a specific pitch recurs in line with the occurrence of the same pitch in other octaves, or repetitions (Goldstein, 1999).

Scientific research in the relationship between music and higher brain function has shown that listening to music results in enhanced scores on tasks of spatial-temporal reasoning (Rauscher, Shaw, & Ky, 1993). The enhancement, as quantified on the paper-folding and cutting subtest of the Stanford-Binet Intelligence Scale IV, following eight and one-half minutes of exposure to Mozart, has been coined the "Mozart Effect". As people from all walks of life attempt to use it as a possible path to increased intelligence, it has taken on a life of its own.

Peretz et al. (1994) have proposed that music may function as a type of "pre-language" because it can access primary cortical firing patterns. Although children at the age of three years cannot be taught higher math, they do demonstrate a love for music, which could serve a special role in the brain and its development. In speech, utterances are organized into a hierarchy of words, phrases, and clauses, while in music, tones are structured into segments of rhythmic measures, motifs, and phrases (Seigmeister, 1965). In a study of the preferences of infants' responses to complete and incomplete phrase

structure of 16 different Mozart minuets, as well as, natural and unnatural versions of the minuets. Participating infants showed significant preference for phrases played in forward direction, broken into segments of naturally occurring phrases as opposed to segments that started and ended unnaturally within phrases. The results of this study show evidence that infants possess sensitivity to musical phrase structure, potentially, a precursor to the innate mechanics of language acquisition (Jusczyk & Krumhansl (1993)

The second venue of study, long-term potentiation (LTP), is a naturally occurring neural process and is universal to normally functioning brains in vertebrates. The operative definition of LTP states that it is an increase in synaptic efficacy, which is evoked by high-frequency stimulation, lasting from hours to days (Shors & Matzel, 1997). It occurs in a spacial manner as neural firings progress from synapse to synapse and across regions of the brain. Its occurrence over time takes place in that the sum of excitatory signals must reach the firing threshold within a small time frame (Goldstein, 1999). It has been considered to be a cellular model for learning and memory and has received much research in recent years (Oda, Kawasaki, Morita, Korn, & Matsui, 1998). LTP has been studied when high frequency stimulation was the result of electronic stimulation administered through electrodes (Bliss & Lomo, 1973), as well as during its natural occurrence as a result of a learning task or other stimulus (Richter-Levin, Canevari, & Bliss, 1997, Oda, et al , 1998)

The theory of LTP fields association with Hebb's rule of learning (Hebb, 1949) and Mountcastle's theory of organization in the cortex (Mountcastle, 1979). Precisely, Hebb proposed that repetition of connective activity between neurons increases the

strength between those particular synapses. In turn, the connections that are the strongest are most likely to fire when re-exposed to the same stimulus and assumes that continual repetition of an activity tends to bring about lasting cellular changes. Through the synaptic learning rule, Hebb predicted and explained the formation of assemblies of neurons. Recent research conducted by Engert & Bonhoeffer (1999) confirms this association through the use of a two-photon imaging technique, during which new dendritic spines were found to appear after the induction of LTP. Hebb also makes note of the innateness of the intrinsic organization of cortical activity based on observation of the presence of large slow waves in infants' ECGs, and the ECGs of comatose and sleeping older subjects (Hebb, 1949).

Mountcastle's theory is a principle of organization theorizing that the highly structured cortex, as its basic network, is operatively organized into columns of neural firing which are made of processing units called minicolumns (Mountcastle, 1979). The basic principle of organization is similar throughout the cortex although the microscopic structure of the cells vary in relation to differences in function in different areas of the cortex (Kalat, 1998). This primary network starts out at birth with a naive repertoire of spatial-temporal firing patterns. Mountcastle also proposed that a type of neural language exists within the cortex which creates a manner of communication through excitatory and inhibitory neural firings of minicolumns within the columns, creating complex firing patterns. The repertoire of firing patterns change somewhat in response to various stimuli, with the majority of all possible stimuli capable of mapping, in part, onto the original naive repertoire of spatial-temporal firing patterns.

The internal processing of external stimuli involves mapping onto firing patterns according to properties the stimuli possess. Stimuli that differ from one another will select out different responses from the repertoire, but stimuli can also each select out the same response, indicating similarity between the stimuli (Leng, Shaw, & Wright, 1990). In research conducted by Starkey, Spelke, & Gelman (1990), it was demonstrated that six to eight month old human infants are not only capable of perception of colors, sounds, shapes, and movements, but are also capable of detecting the number of entities in a sequence of sounds or a visual scene, exhibiting knowledge of equivalent and nonequivalent relationships. It is indicative from these results that infants detect relationships between entities and groups of entities and supports the innateness of the intrinsic organization of the cortex as noted by Hebb (1949), and theorized by Mountcastle (1979). These results also show evidence that this level of operating with numerical equivalence is not dependent upon the development of language, complex actions, or the acquisition of culture-specific counting systems.

The detection of the relationship between entities of sounds and visual scenes by infants depicts that although not a conscious process, humans look for symmetry in relationships and patterns in space and time. Shaw (2000) states that symmetry is a significant factor in perceptual organization, a critical component of the structure of the brain and its innate ability to recognize symmetries, and is a key component of how we think, reason, and create. Research has confirmed the human's tendency to use symmetry heuristics, in that, figures and scenes are remembered as being more symmetrical than they really are (Tversky & Schiano, 1989). Humans not only recognize symmetries but

also prefer objects that display symmetric operations. Two often used symmetries are those of rotation and mirror reflection. Without detailed mathematical knowledge of analysis, we recognize rotated figures through angle changes, as well as mirror reflections.

Research-based Work on Long-term Potentiation

While some researchers purpose their research on LTP for its theorized involvement in memory and information storage (Bliss & Lomo, 1973, Teyler & DiScenna, 1986, Xu, Anwyl & Rowan, 1998, Staubli, Scafidi & Chun, 1999), others propose its involvement in other aspects related to the learning process such as arousal, attention, and temporary information storage (Shors & Matzel, 1997, Trepel & Racine, 1998). All seem to have a common thread in their hypotheses and that common thread is that the process of LTP is somehow involved in the storage of information, either temporarily or permanently. Skelton, Miller, & Phillips (1985) demonstrated that high-frequency stimulation produced LTP and accelerated subsequent behavioral responses, documenting the ability of LTP to serve as a component of the neural bases of learning and memory. Trepel & Racine (1998) found that LTP can be induced in the hippocampus in one administration of high frequency stimulation.

In accordance to the organizational principal of Mountcastle (1979) and the learning theory of Hebb (1949), Teyler & DiScenna (1986) assert that the hippocampus stores a map of locations of other brain regions, and relays incoming sensory information to appropriate regions of the brain. Shors & Matzel propose that the potentiation of the synapses could serve as a maintenance device for sustained attention, allowing an

organism to focus its attention on details in their environment and process information more speedily

Research-based Work Supportive of Mozart Effect

Also in assumption of Mountcastle's organizational principle is the basis of the research that led to the Mozart effect, the trion model (Leng et al , 1990) The trion model features neural firing patterns that are highly structured in time and possess spatial connections Utilizing the Hebb learning rule, this model is a mathematical realization of an idealized minicolumn, with three levels of firing Leng, et al propose that the model could also serve as a Rosetta Stone to understanding the internal language of higher brain function Shenoy Kaufman, McGrann & Shaw (1993) make note in discussion of the trion model that its role in learning is proposed to be associated with established patterns of neural firing as stimuli "selects" out the most highly related response from the naive repertoire of firing that already exists

Motivation for recent studies examining the relationship between music and spatial-temporal reasoning originated in the publication of results from research in neural theory of higher brain function conducted by Leng, et al (1990) in which they used a Monte Carlo evolution method of probability The evolutions were coded onto pitches and instrumental timbres to produce music Using patterns of firing from the theorized six minicolumns of the cortical column, with each minicolumn at three possible levels of firing, the characteristics of pitch, octave, and instrumentation were assigned A Music Instrument Digital Interface (MIDI) with sophisticated software was used as the means by which firing patterns were converted to music patterns Various combinations of the

three firing levels for trions one and two determined whether pitches were A, B, C, D, E, F, G, a repeat of the previous pitch, or silence. Trion three determined the octave in which the pitch existed. With three levels of firing possible, octaves were assigned either as the octave in which Middle C is found, or the octaves immediately higher or lower. Trions four, five, and six determined the combination of instrumentation. The resemblance of the music to that of familiar styles was remarkable in that it produced recognizable approximations of Western and Eastern styles of music. To further demonstrate the trion model through music, Leng was able to compose variations on a theme in the software through the enhancement of any of the mappings through utilization of the Hebb learning rule.

Rauscher and Shaw, along with associated teams of researchers (Rauscher, et al, 1994, Rauscher, et al, 1995, Rauscher and Shaw, 1998), successfully replicated the enhancement originally seen in the study of (Rauscher, et al, 1993). In this study it was demonstrated that listening to 10 minutes of Mozart's Sonata for Two Pianos in D major prior to testing resulted in increases of up to nine points on the paper-folding and cutting tasks of the Stanford-Binet Intelligence Scale IV. Subsequent replications by these teams have included several variations on the variables of the experiments. These variations include musical training, the inclusion of different age ranges, and an alternate style of music.

The first of two subsequent studies incorporated the use of college students who were repeatedly exposed to the conditions of either silence, 10 minutes of Mozart, or a mix of various styles of music, varying each day of the five day time span (Rauscher, et

al., 1994a) All groups of participants experienced no treatment on the first day, and the treatment of their assigned condition for days two through five. Each treatment exposure was followed by either a paper-folding and cutting task, or a memory task composed of random letters. Enhancement in performance of spatial-temporal reasoning, as seen in the research of Rauscher, et al. (1993), was replicated with the greatest difference seen between day one and day two of the experiment for the Mozart group. Test scores increased at least slightly on each subsequent day, displaying a practice effect and learning curve. The Mozart group displayed its greatest increase from day one to day two after its first exposure to the sonata, while the silence group displayed its largest increase from day two to day three. The mixed group experienced exposure to a variety of listening activities including a minimalist work by Philip Glass, an audio-taped story, and a trance piece with no significant increase in performance seen.

The second study conducted by these teams of researchers included the musical training of preschoolers. Participants' spatial reasoning was tested prior to beginning treatment conditions, and repeated after four and eight months of treatment conditions. Spatial reasoning tasks were taken from the Wechsler Preschool and Primary Scale of Intelligence-Revised and the Stanford-Binet Intelligence Scale IV. These tasks included object assembly tasks in which the child was asked to arrange pieces of a puzzle to form a meaningful whole, geometric design tasks consisting of visual recognition and figure drawing, as well as block design (where the child matches illustrated patterns using flat two-colored blocks), and animal pegs for placing the correct colored pegs in holes below a series of pictured animals. The group of children in the musical training condition

scored significantly higher than the non-training group on the object assembly tasks. Of the five tasks in the tests, the music group's scores on the Object Assembly tasks were significantly greater after music lessons than the scores for the no-music control group. Rauscher, et al (1994b) attribute enhancements to the requirement of the child to form a mental image and then orient physical objects to reproduce that image. These are all qualities that exist within a spatial reasoning task, and propose that improvement in this task was the result of cortical pattern development facilitated by the music lessons.

Enhancement was also seen in the results of a study conducted by Rideout and Laubach (1996), who also used the Stanford-Binet Intelligence Scale IV as the measure of performance. Included in this study were electroencephalographic (EEG) correlates of performance changes after listening to the music. Of interest in this study was the possibility of associations between changes in EEG characteristics and changes in performance on the spatial tasks. The EEG results suggest that music facilitated enhancement in performance by facilitating specific changes in brain state. Petsche, Richter, von Stein, Etlinger & Filz (1993), using EEG analyses found that listening to music is processed in many areas of the cortex. They were able to see large differences in how music by Mozart is processed as opposed to music that was composed by Schonberg.

Several successful attempts to replicate the Mozart effect have also shown that certain other compositions produce a similar effect. Nantais and Schellenberg (1999) used a completely computer controlled version of a paper-folding and cutting task and found that not only did the main effect of the condition reveal that scores were higher

after listening to Mozart than after sitting in silence, but, listening to Schubert produced the same magnitude of effect. And, in a second experiment, exposure to music showed a significant increase in performance, as did that of exposure to narrated story instead of silence. Rideout, Dougherty, Shannon & Wernert (1998) also had similar results in their experiment. In their attempt to replicate and generalize, they also used the Mozart Sonata for Two Pianos in D Major as one condition and a Yanni (modern composer) composition as another condition. Subjects displayed significantly enhanced performance on a paper-folding task under both conditions.

Some researchers have questioned the role that arousal and mood plays in the Mozart effect (Steele, 2000). Thompson, Schellenberg, Glenn & Husain (2001) conducted a study in which they directly studied the effect of these aspects on the Mozart effect. Included in the study was the Mozart Sonata for Two Pianos in D Major, which was expected to increase arousal and mood, while an Adagio by Tomasi Albinoni was selected with an expectation that it lowers arousal and conjures up a mood of sadness. The task used was the paper-folding and cutting sub-test from the Stanford-Binet Intelligence Scale IV. Results produced performance enhancement for the Mozart group, while the Albinoni group displayed no effect of music exposure.

Research Not Supportive of Mozart Effect

On the other hand, Carstens, Huskins, & Hounshell (1995) were unsuccessful in their attempt at replication and generalization of the results of Rauscher, et al. (1993). The Revised Minnesota Paper Form Board Test Form A was used as the dependent measure in this experiment. In each question of this measure, participants were presented

with a picture of a two-dimensional figure cut into two or more parts. Participants were tasked to choose the display in which showed how the pieces would look when put together. This task required mental rotation of the two dimensional figures.

Failure to replicate was also seen in a study conducted Newman, Rosenbach, Burns, Latimer, Matacha & Vogt (1995) who used the Raven's Progressive Matrices-Advanced Form as the measure of spatial-temporal ability. This measure is considered an excellent test of general intelligence and requires participants to conduct a series of visual analyses of a two-dimensional pattern and a figure from a set of alternatives to complete the pattern.

Steele, Ball, & Runk (1997), were also unsuccessful in inducing enhancement when they used Backward Digit Span Performance as a measure of performance. This measure involves the task of listening to a string of digits, followed by the participants being asked to reproduce the string in reverse sequence, requiring the rotation and transformation of the sequence.

In 1998, Rauscher and Shaw published a paper to provide a neurophysiological context for the enhancement. They suggested in failures to replicate the enhancement, the choice of dependent measures is quite likely a contributing factor. Criteria in the selection of performance tasks should include aspects that require ability to recognize and classify physical similarities among objects in order to take advantage of the previously excited complex firing patterns of the trion model. Rauscher and Shaw suggested researchers consider both spatial aspects of mental imagery and temporal order when selecting dependent measures. As seen in a review of the literature, the enhancement

appears to be most apparent in the specific tasks that incorporate both spatial and temporal characteristics. In an effort to broaden the window through which to study higher brain function, failures to replicate in other measures have served to be informative in the quest for generalization of the Mozart effect. Thus far, enhancement in adults has been limited to the paper-folding and cutting subtest of the Stanford-Binet Intelligence Scale IV.

The Neurophone and Enhanced Ability to Learn and Remember

In recent years, claims of enhancements in ability to learn, as well as increases in intelligence have also been attributed to the use of an external device called Neurophone. It has been accounted as responsible for the development of photographic memory, as well as accelerated ability learn and memorize, and increased ability to form mental images (Flanagan & Lloyd, 2000). The neurophone works by energizing, or stimulating parts of the brain, through the administration of ultrasonic energies directly onto the skin (Royal Body Care, 2001). Research has shown increases in speech reception as a result of transdermal electrostimulation (Hughes, Arthur & Whitaker 1974, Puharich and Lawrence, 1969). Puharich and Lawrence (1969) conclude that the high frequency in the ultrasonic content has the effect of increasing blood flow to the brain. The listening experience as encountered through the neurophone includes the provision to listen to any type of music, books on tape, relaxation tapes or anything available on cassette tape or CD. The listener hears through a headset that is attached to the player, while the administration of the ultrasonic energies is received through two electrodes, which are attached to the skin at the temple areas.

The inventor of the neurophone, Patrick Flanagan, explains the effect as the result of stimulation of a detector in the inner ear called the saccule. The function of the saccule is two-fold. One function relates to head position in gravity, letting one know if he or she is upright, tilted, or upside down. Another function of the saccule is the detection of ultrasonic energy. It detects this energy through physical vibration in the skin (Finneran and Hastings, 2000). The ultrasonic energy is transmitted by the use of electrodes, which are attached to the temple area and/or the forehead. Sound from a tape or compact disc is then transmitted through the skin in the form of electrostimulation (Royal BodyCare, 2001).

Lenhardt, Skellet, Wang & Clarke (1991) present evidence of the possibility of the existence of an alternate receptor that senses ultrasonic frequencies. The possible receptor of these frequencies is the saccule and is capable of encoding speech signals that have been modulated into ultrasonic frequencies. The saccule picks up the frequencies as they are transmitted through electrostimulation of the skin, bypassing the air conducted sound waves received and translated through the ear. Oda et al (1998) substituted acoustical stimulation for electrical stimulation in goldfish, demonstrating that LTP occurs for synaptic responses evoked by natural sensory inputs. The possibility of LTP induction through auditory means, lends possible explanation for performance enhancements following the listening conditions for particular compositions. The correlation between the nature of the function of the neurophone and the nature of the claims of enhancements associated with LTP, leads to the possibility that the neurophone could be a source for the induction of LTP. As also seen in the correlative bases of the

theories of columnar organization and neural firings and the mathematical realization of probable firing patterns of the Trion model, LTP could also be component in understanding the Mozart effect, as well. Failures to induce performance enhancements could be due to failure on the part of certain compositions to induce LTP, or the measures used did not coincide with the neural firings that were experiencing LTP.

Spatial-temporal ability been defined as mentally flipping and turning objects in the absence of a physical model. This definition is commensurable with the definition used for tasks which fall into the category of spatial visualization, as defined by McGee (1979). The measures of Minnesota Form Board A, Backward Digit Span Performance, and Raven's Progressive Matrices-Advanced Form A are all considered as spatial visualization measures or to have high loading on a spatial factor (Carstens, et al, 1995, Fjeldsenden, 1996, Newman, et al, 1995). The failure to replicate enhancement as seen in the Mozart effect hints to the possibility that the paper folding and cutting subtest of the Stanford-Binet Intelligence Scale IV may be sensitive to an aspect other than spatial visualization that is enhanced through auditory stimulation.

McGee (1979) delineates spatial ability into several factors. Spatial visualization involves the ability to mentally manipulate, rotate, twist, or invert pictorially presented stimuli, while spatial orientation requires the arrangement of components of a visual stimulus pattern and the aptitude for remaining unconfused when orientations of stimuli have been changed or to determine spatial relations when the body orientation is a vital part of the problem. The Purdue Visualization of Developments Test has been examined as a test

for the relationship between spatial ability and performance in introductory courses of chemistry. This test has been shown among the spatial tests to be complicated by analytical thinking and has been found to be highly correlated with the Revised Minnesota Form Board Test, as they both appear to measure spatial orientation. The Purdue Visualization of Developments test requires analytical and holistic processing strategies. The Vandenberg & Kuse paper-and-pencil Mental Rotation Test was developed based on the paradigm of Metzler & Shepard's mental rotation task., which has been found to have high construct validity in the domain of spatial visualization ability, uncomplicated by analytical processing (Guay & McDaniel, 1979).

Hypotheses

The purpose of this study is to attempt to broaden the window through which to study the relationship between higher brain function and enhancements in spatial-temporal performance that result from auditory stimulation. It is hypothesized that the two measures of spatial ability will further the study of the Mozart effect by delineating two specific types of spatial ability as they are effected by the auditory stimulation. Rauscher and Shaw (1998) express the necessity to include a temporal aspect in the measures used in Mozart effect research, but fail to define the parameters of the temporal aspect. The Purdue Visualization of Developments Test requires time to conduct the folding of developments into three-dimensional objects as does the Vandenberg and Kuse Mental Rotation Test to mentally rotate the target object. It is hypothesized that, if the spatial ability factor of the paper-folding and cutting subtest of the Stanford-Binet Intelligence

Scale⁴ is the factor that is enhanced by 10 minutes of listening to Mozart, the Purdue Visualization of Developments Test and the Vandenberg and Kuse Mental Rotation Test will delineate the type of spatial ability most effected in the enhancement associated with the Mozart effect. It is further hypothesized that high frequency experienced through transdermal- electrostimulation via a Neurophone listening experience, as well as the range of frequencies as combined to produce white noise, will produce a similar priming effect, resulting in enhanced performance of spatial ability as measured on the Purdue Visualization of Developments and the Vandenberg and Kuse Mental Rotation Test

METHODS

Participants

Participants were 75 males recruited from undergraduate psychology courses, who were offered extra credit for participation. Due to ambiguous research findings regarding the existence of gender differences in spatial ability, only males were included in this research. Participants were between the ages of 17 years and 27 years. Twenty-five participants were randomly assigned to each of three conditions.

Apparatus

A compact disc recording of the first movement of Mozart's Sonata for Two Pianos in D Major, K 448 as recorded on compact disc and provided in accompaniment of the book Keeping Mozart in Mind by Gordon Shaw (2000) was used in the Mozart listening condition. Running time for the performance of this composition is approximately eight and one half minutes. The compact disc was played on a portable JVC player, model XC-RC1 and heard through a Koss headset, model TD/60. The Neurophone condition included electro-stimulation as delivered via the Flanagan Neurophone. The Neurophone is an electronic device that transmits ultrasound frequencies through the skin. The frequency is a 40 KHz energy frequency and is delivered through sensors placed on the skin near the temples.

The two measures of spatial ability used were the paper-folding subtest of the Purdue Visualization of Developments Test (Guay, 1977) and the Vandenberg and Kuse Mental Rotation Test (Vandenberg & Kuse, 1978). The Purdue Visualization of

Developments Test was developed at Purdue University by Guay and found to be internally consistent through the Kuder-Richardson 20 reliability coefficients of .80, .78, and .80 on three administrations of the test. The mean scores for males was 8.36 with a standard deviation of 2.71, when administered to a sample of 50 males enrolled in freshman psychology courses at Purdue University. To examine validity, it was used as one of five measures of spatial ability and found most highly correlated to the Minnesota Form Board Test (Guay & McDaniel, 1978). The test consisted of 15 test items in which the inside view of an unfolded three-dimensional object was presented, (development). The test was graded according to the number of correct selections made by the participant.

The Vandenberg & Kuse Mental Rotation Test (Vandenberg & Kuse, 1978) was included in tests conducted on large samples, the internal consistency was found to be .88 through Kuder-Richardson 20, with a test-retest reliability of .83. The mean score for males on this test was 9.92 with a standard deviation of 4.42 when administered to a sample of 115 undergraduate males from the University of Hawaii. The Mental Rotation Test contains 20 items, each includes a target item and four dissimilar items. Two of the four choices are the same item as the target item, presented at a different angle. In order to receive a correct score for a test item, one must choose both correct rotations, reducing scores based on guessing. This method of presentation requires multiple rotations, providing a temporal aspect to the task for both measures. The test was graded on the basis of the number of test items in which the participant correctly chose both items that rotated to match the target item.

Procedure

The research was a simple randomized, 3 x 2 between subjects design. There were three listening conditions, White Noise, Mozart, and Neurophone, and two testing conditions. The experiment was conducted in a small room with workstations, and included no more than two participants and one experimenter present per session. One treatment condition was administered per session. In the Mozart condition, participants listened to the first movement of the Mozart Sonata, while in the white noise condition, participants listened to eight and one-half minutes of white noise. In these two conditions, participants listened through the Koss headset, followed immediately by the two tests, counter balanced, as in all conditions. The Neurophone group experienced eight and one-half minutes of the Neurophone through two electrodes placed on the temple area of head, while wearing Silencio Hearing Protection (model number RBW-71), rated at noise reduction of 25 over head decibels. As in all conditions, the treatment was followed immediately by administration of the two tests. Each test booklet included instructions and two sample test items. Directions were read aloud by the experimenter and participants gave assurance of their understanding of the directions before beginning the timed test.

RESULTS

Test results were analyzed using one-way multilevel ANOVA statistical analyses to test the null hypothesis for each of the measures used. An ANOVA was conducted on the means for the Purdue Visualization of Developments Test on the basis of the null hypothesis, there are no mean differences between groups on the Purdue Visualization of Developments Test. A separate ANOVA was conducted on the means for the Vandenberg and Kuse Mental Rotation Test, also on the basis of the null hypothesis, there are no mean differences between groups on the Vandenberg and Kuse Mental Rotation Test.

Table 1 displays the means and standard deviations for Purdue Visualization of Developments Test. A one-way multilevel analysis of variance conducted on the test scores for the Purdue Visualization of Developments Test exhibited negligible differences between group variances, leading to failure to reject the null hypothesis.

Table 1.

Descriptive Statistics for Purdue Visualization of Development Test Scores by Auditory Condition

Purdue Visualization of Developments					
Auditory Condition	Mean	Standard deviation	N	95% Confidence Interval	
				Lower Bound	Upper Bound
White Noise	5.44	2.55	25	4.37	6.51
Mozart	5.56	3.04	25	4.49	6.63
Neurophone	5.32	2.41	25	4.25	6.39

The mean differences in all pairwise comparisons also fall well within the upper and lower bounds of the 95% confidence interval for difference, which are comprised of relatively small ranges in either direction from zero. The mean differences were no larger than 1/4th of one point, less than one standard deviation away from zero in either direction.

Examination of the results revealed no significant difference between the groups, $F(2, 72) = 0.50, p = .951$. The non-significant F value allows no statistical basis for predictability between treatment and test score. Sample size and power are positively correlated, meaning that if the sample is large enough, significant differences between treatment groups can be found. A total of 75 participants, 25 in each condition, resulted in an observed power of .057, low for the number of participants in this research. Eta squared is an index of the treatment effect size regardless of whether or not a significant F value is attained. According to Cohen's definition of effect size, .01 constitutes the lower limit of what would be considered as a meaningful effect from which inference can be drawn. As seen in Table 2, the eta squared value of auditory stimulation on spatial ability as measured by the Purdue Visualization of Developments Test is .001, less than 1%, meaning that any effect the treatment has is very small and practically meaningless for spatial ability as measured by this test.

Table 2.

Source Table for Purdue Visualization of Development Test Scores by Auditory Condition

Purdue Visualization of Developments						
Source	df	SS	MS	F	η^2	P
Between Group	2	.720	.360	.050	.001	.951
Error	72	517.760	7.191			

Means and standard deviations are displayed in table 3. A one-way multilevel analysis of variance of test scores for Vandenberg and Kuse Mental Rotation Test also showed negligible differences between group variances, another failure to reject the null hypothesis.

Table 3.

Descriptive Statistics for Vandenberg and Kuse Mental Rotation Test Scores by Auditory Condition

Vandenberg and Kuse Mental Rotation Test					
Auditory Condition	Mean	Standard deviation	N	95% Confidence Interval	
				Lower Bound	Upper Bound
White Noise	8.56	3.90	25	7.08	10.04
Mozart	9.08	4.08	25	7.60	10.56
Neurophone	8.56	3.07	25	7.08	10.04

Examination of the results revealed no significant difference between the groups, $F(2, 75) = 1.64, p = .849$. Again, a non-significant F value supports the conclusion that the observed differences were too small to confirm that the group treatment means are different. Group means again were well within the 95% confidence interval and the confidence intervals for mean differences which ranged slightly on either side of zero. The means for the white noise group and the Neurophone group were equivalent, with no mean difference between them. The mean difference between the Mozart group and the other two groups was less than $\frac{1}{2}$ of a standard deviation away from zero. The eta squared value was .005 (see Table 4) implying that one can account for less than 1% of the variance of scores on the Vandenberg and Kuse Mental Rotation Test, again a very small and practically meaningless effect on spatial ability as measured by this test.

Table 4

Source table for Vandenberg and Kuse Mental Rotation Test Scores by Auditory

Condition

Vandenberg & Kuse Mental Rotation Test

Source	df	SS	MS	F	η^2	P
Between Group	2	4.507	2.253	1.64	.005	.849
Error	72	990.160	13.752			

The Purdue Visualization of Developments is a spatial ability test considered to be confounded by an analytical factor, while the Vandenberg and Kuse Mental Rotation

Test is considered a true test of spatial ability, not confounded by an analytical factor (Guay & McDaniel, 1978) The observed Pearson correlation value for the test was .504 in common This interprets to mean that some individuals who scored high on one test tended to score high on the other test and some individuals who scored low on one test also tended to score low on the other test

DISCUSSION

In 1993, Rauscher, Shaw, & Ky reported that listening to 10 minutes of Mozart increased spatial ability as measured on the paper-folding and cutting subtest of the Stanford-Binet Intelligence Scale IV. Attempts to replicate have had mixed results. Replication has been limited to research in which the subtest of the Stanford-Binet Intelligence Scale IV was used as the measure (Rauscher, Shaw, Ky & Wright, 1994a, Rideout & Laubach, 1996, Rideout, Dougherty, & Wernert, 1998, Nantais & Schellenberg, 1999, Thompson, Schellenberg, & Husain, 2001). Subsequent research in which other measures of spatial ability have been unsuccessful in attaining the Mozart effect (Carstens et al., 1995, Newman, et al., 1995, Steele, et al., 1997). Negligible effect sizes were also observed in the current research, in which two additional measures of spatial ability were used.

Hypothesis 1

It was hypothesized that categorization of the type of spatial ability most affected by auditory stimulation, as measured by the Purdue Visualization of Developments Test and the Vandenberg and Kuse Mental Rotation Tests, would be seen in the results of this research. The measures of spatial ability used in this research failed to demonstrate enhancement beyond a negligible effect. Both tests are considered reliable and valid measures of spatial ability (Guay & McDaniel, 1978, Vandenberg & Kuse, 1978). The observed mean for the Purdue Visualization of Developments was slightly lower than the mean obtained during reliability testing. The observed means for the Vandenberg and Kuse Mental Rotation Test were within one point of the means obtained during reliability

testing, with a standard deviation within one point of the previously obtained standard deviation

The power of these two tests to measure the Mozart effect has not been established through previous research. Keppel (1991) suggests for initial research the use of a greater significant level, such as .10 or .25, in order to lower the risk of a Type II error. If the design of the experiment itself is carefully planned to control for Type I error, the greater significant level, along with sufficient power would allow the detection of a treatment effect that would otherwise fall just outside the null range. Table 5 displays power estimates for significance levels ranging from .05 to .25 for a large range of N per cell for the Purdue Visualization of Developments Test.

Table 5

Power Estimates for Number of Participants per Cell for Significant Levels of .05, .10, .15, .20, and .25 for Purdue Visualization of Developments

Power Estimates for Number of Participants								
Alpha	60	100	140	180	220	280	340	440
.05	19	30	41	52	61	72	81	90
.10	31	43	54	64	72	81	88	95
.15	36	51	63	72	79	87	92	96
.20	45	58	69	77	83	90	94	98
.25	51	64	74	81	87	92	95	98

Although not a magic number of power, .80 is assumed to be sufficient to attain a significant F value for the rejection of the null hypothesis, and to be replicable.

Approximately 340 participants are required for an estimated power of .80 at alpha .05.

This number is reduced to nearly 180 when alpha of .25 is used, necessitating at least 360 participants for the inclusion of a control group. Table 6 displays power estimates for requirements of N for the Vandenberg and Kuse Mental Rotation Test at selections of alpha from .05 to .25.

Table 6.

Power Estimates for Number of Participants per Cell for Significant Levels of .05, .10, .15, .20, and .25 for Vandenberg and Kuse Mental Rotation Test.

Power Estimates for Number of Participants								
Alpha	60	100	140	180	220	280	340	440
.05	.20	.32	.43	.53	.63	.74	.82	.91
.10	.31	.44	.56	.66	.74	.83	.89	.95
.15	.39	.53	.64	.73	.80	.88	.93	.97
.20	.46	.59	.70	.78	.85	.91	.95	.98
.25	.52	.65	.75	.82	.88	.92	.96	.99

The trion model explains the Mozart effect through the relationship of the highly organized structure of the Mozart sonata to the probabilistic evolutions of mapping patterns of neural firings (Leng & Shaw, 1990). LTP explains enhancements in

performance through the excitatory effect that frequency has on neural connections (Skelton, Miller, & Phillips, 1985). The possibility that frequency is the component of music that causes the priming effect, could pose the use of white noise in the control group as a potential confound since it is composed of a blend of all frequencies. However, comparison of the observed means and the previously established means does not allude to enhancements in any of the three listening conditions in this research. Rauscher, et al (1994a) have concluded that spatial reasoning ability was improved after just one encounter with the Mozart Sonata in D Major for Two Pianos, however, the failure of five other measures of spatial ability leads one to question whether the effect is for spatial reasoning or some other aspect of the paper folding and cutting task of the Stanford-Binet Intelligence Scale IV. Rauscher & Shaw (1998) emphasize the importance of the inclusion of a temporal aspect in measures used in Mozart effect research. Possible explanations for the negligible effects seen in the present study include the possibility that the priming effect of auditory stimulation is most affective on the temporal aspect of the subtest of the Stanford-Binet Intelligence Scale IV and our measures were not sensitive enough to temporal aspects. The association of Mountcastle's organizational principle and Hebb's learning rule, both in the development of the trion model and research on LTP, as a neural model of learning also poses the potential that the greater increases in test scores after exposure to Mozart are associated with the learning process itself.

Hypothesis 2

The inclusion of the Neurophone as an auditory stimulus was based on the theory of LTP and its relationship to high frequency stimulation and auditory stimulation (Skelton, Miller, & Phillips, 1985, Trepel & Racine, 1998, Oda et al , 1998) As seen in the Mozart group, the measures of spatial ability used in this research failed to show sizeable treatment effects for the prediction of behavior based on the treatments of auditory stimulation used Failure to reject the null hypothesis in this research does not eliminate it as a potential source for the induction of LTP Based on enhancements associated with the Mozart effect having been limited to the utilization of the paper folding and cutting task of the Stanford-Binet Intelligence Scale IV as a measure, future research in humans should begin with this measure toward the potential effect of the Neurophone as well

Refinement studies of the components of the Mozart effect, and their magnitudes, can prove beneficial in the quest of how the brain functions, as well as neural theories of learning and memory The learning curves of the Mozart and Silence groups (Rauscher, et al , 1994a) display the sharpest spike a day earlier for the Mozart group than for the Silence group Future research should be designed to delineate the components of the Mozart sonata that influence performance, as well as the components of the paper folding and cutting task most affected by auditory stimulation The inclusion of additional research on measures of temporal aspects and the learning curves associated with appropriate tasks as opposed to onetime differences in performance could also serve as beneficial as well as potential age and gender differences in enhancements and learning

patterns. Research on LTP has primarily been focused on the effect of various chemicals in its induction. Animal studies on the effect of LTP and performance enhancement could provide information on the role of LTP in learning and memory, potentially leading to advancement in the quest to understand how the brain functions.

Research advancements in these areas could have ramifications capable of providing a better quality of life to those who have learning delays and disabilities, teaching methodologies that enhance the learning process, and application into devices of artificial intelligence.

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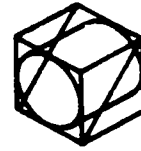
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APPENDIX A

PURDUE VISUALIZATION OF DEVELOPMENTS TEST
and SAMPLE ANSWER SHEET



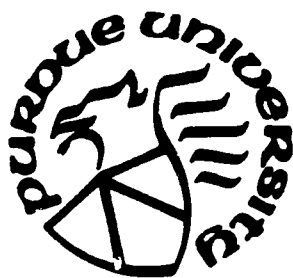
Purdue
Spatial Visualization
Tests



Roland B. Guay

VISUALIZATION OF
DEVELOPMENTS

Do NOT open this booklet until you are instructed to do so.



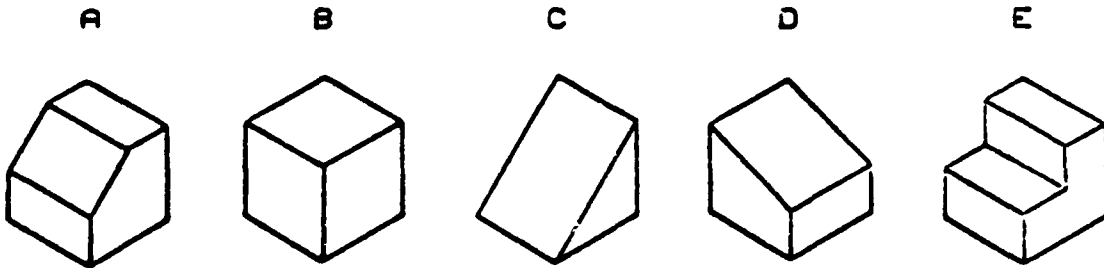
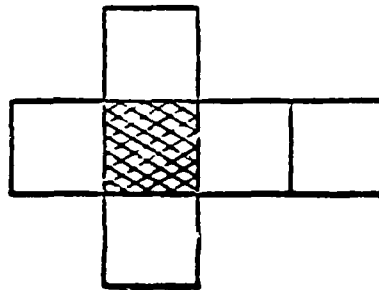
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Do NOT make any marks in this booklet.
Mark your answers on the separate answer card.

DIRECTIONS

section 1

The first section of this test consists of 15 questions designed to see how well you can visualize the folding of developments into three-dimensional objects. Shown below is an example of the type of question included in the first section of this test.



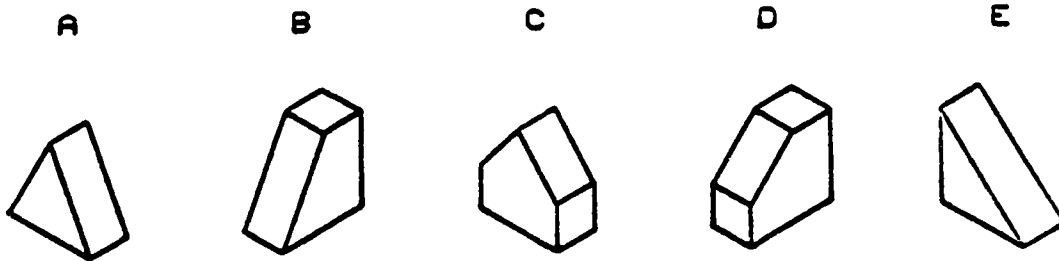
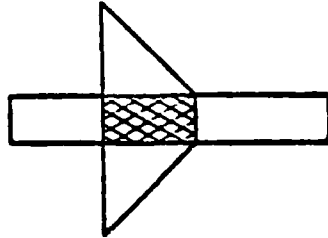
Presented is a development and five three-dimensional objects. The development shows the inside surfaces of a three-dimensional object. The shaded portion of the development indicates the bottom surface of the three-dimensional object. You are to:

1. picture in your mind what the development looks like when folded into a three-dimensional object;
2. select from among the five objects (A, B, C, D, or E) the one that looks like the folded development.

What is the correct answer to the example shown above?

Answers A, C, D, and E are wrong. Only object B can be made by folding the given development. In both sections of this test each question has only one correct answer.

Now look at the next example shown below and try to select the one three-dimensional object that can be made when the given development is folded. Remember that the development shows the inside of the object and the development's shaded portion indicates the bottom of the object.

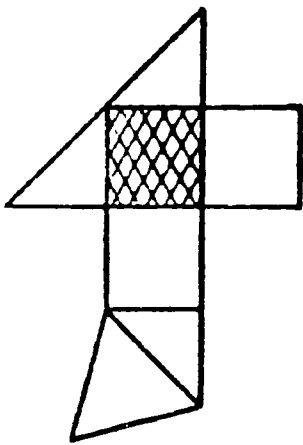


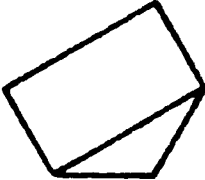
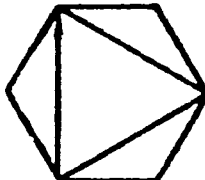
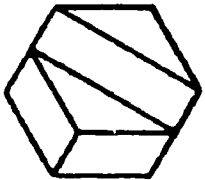
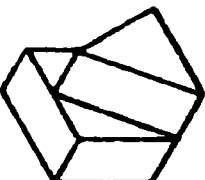
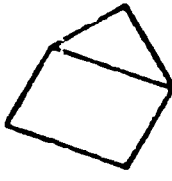
The correct answer for this example is E.

During the test you are to show your choices on the answer card by making a heavy black mark in the space with the same letter as the answer you choose.

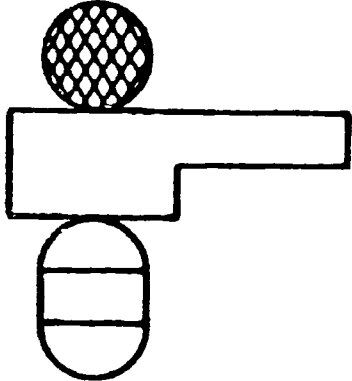
Do NOT make any marks in this booklet.
Mark your answers on the separate answer card.
You will be told when to begin.

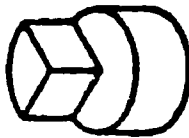
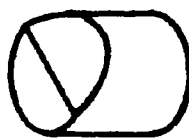
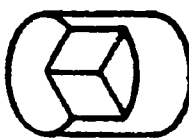
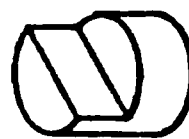
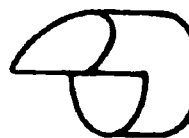
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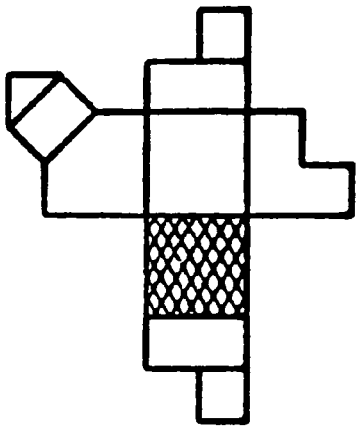
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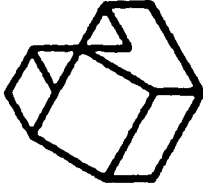
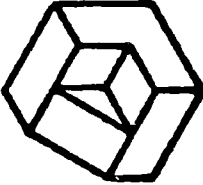
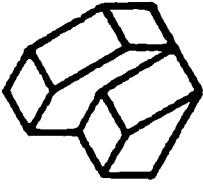
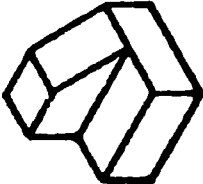
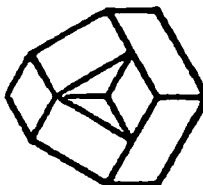
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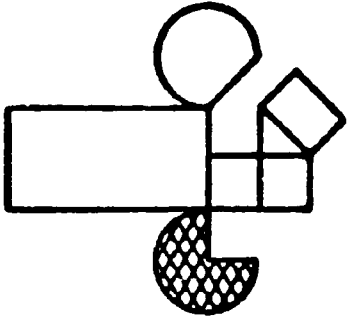
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3



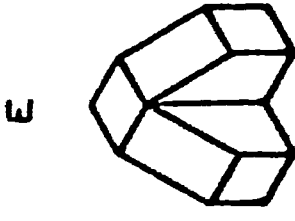
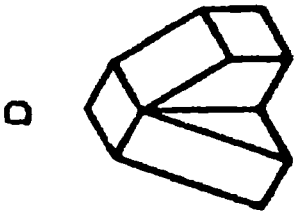
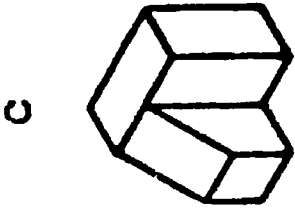
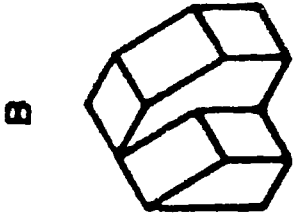
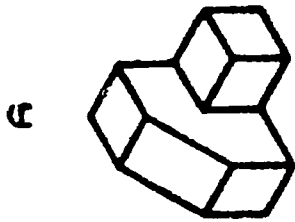
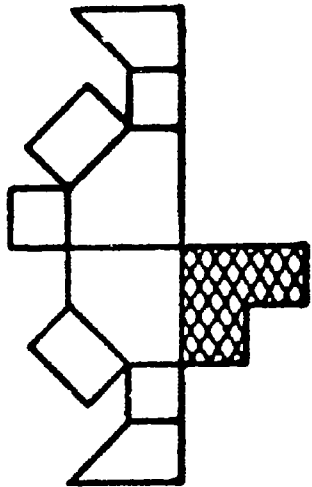
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4

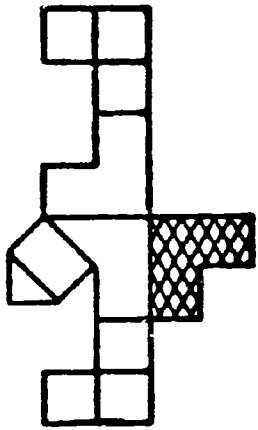


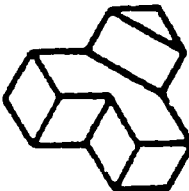
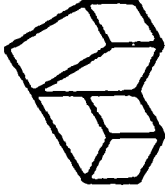
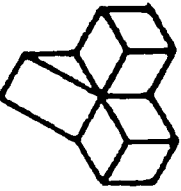
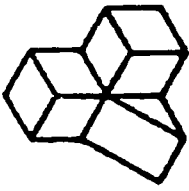
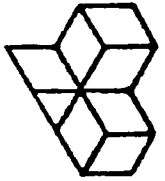
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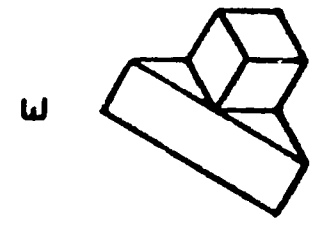
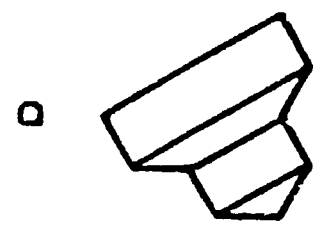
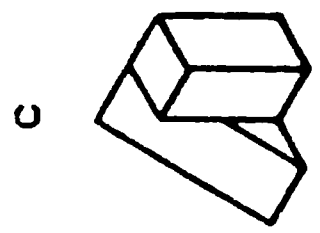
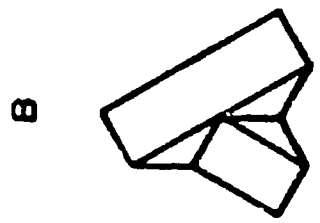
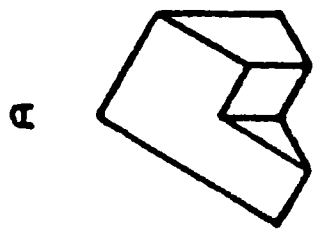
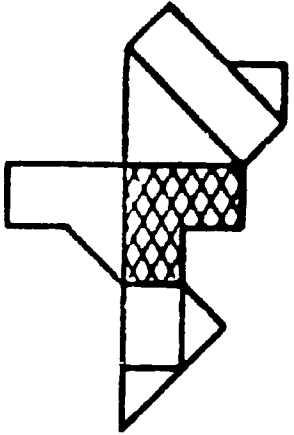


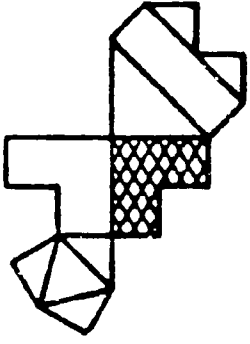
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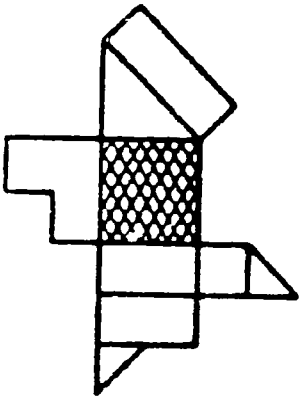
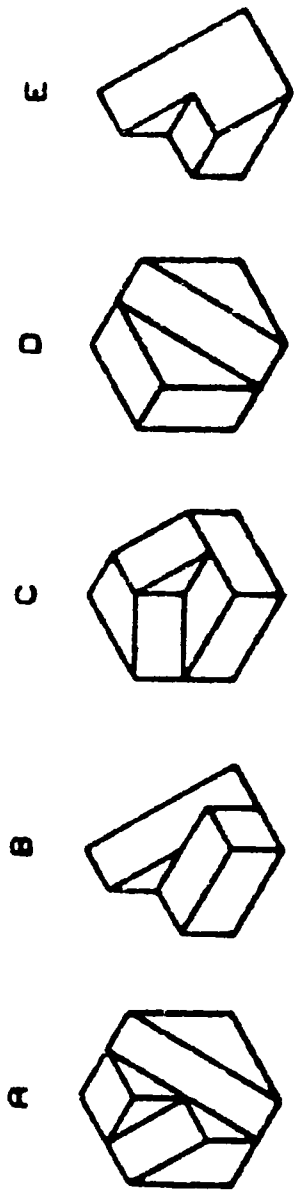
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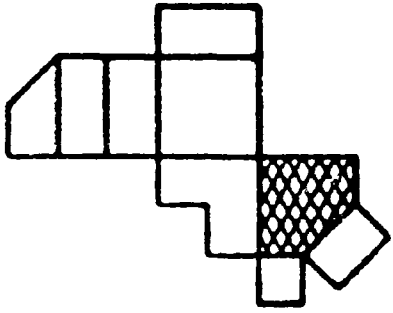
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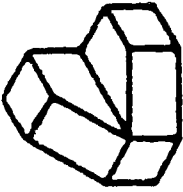
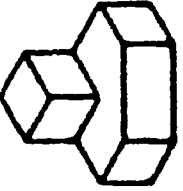
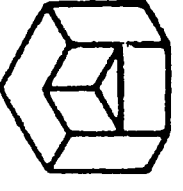
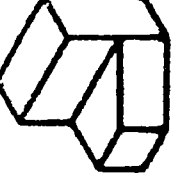
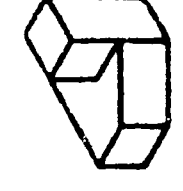


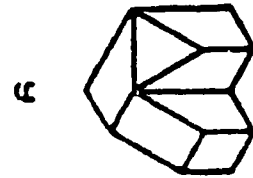
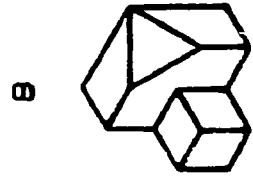
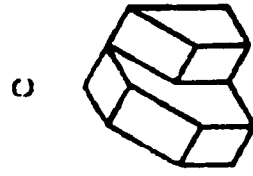
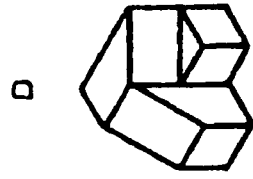
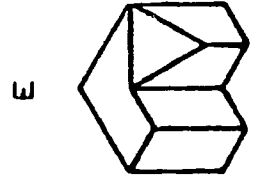
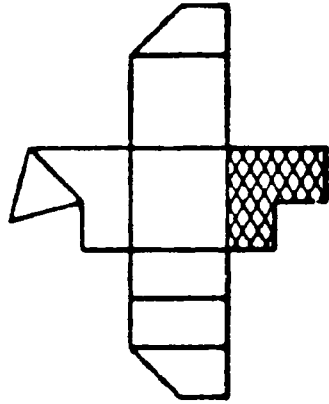


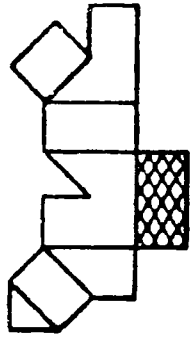
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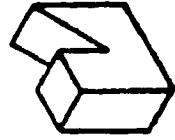


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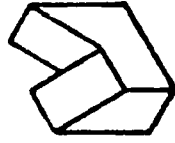




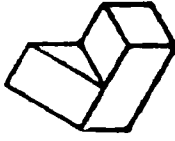
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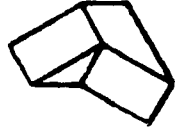
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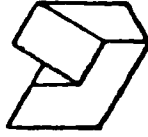
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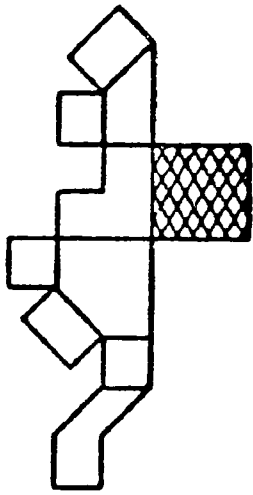


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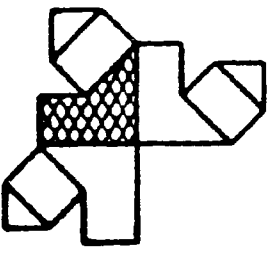


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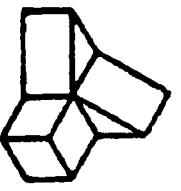




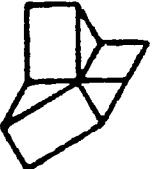
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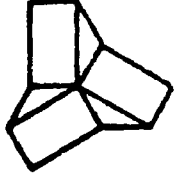
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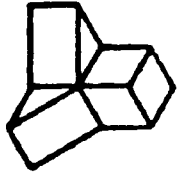
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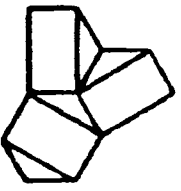
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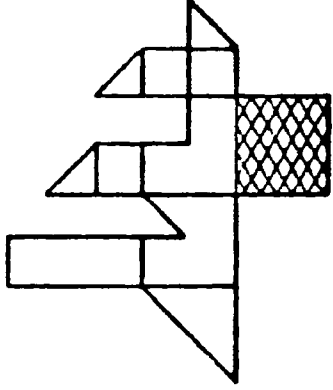


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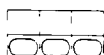


E





- A
- B
- C
- D
- E

Case 	Test 	Condition 
Class Level <input type="checkbox"/> Freshman <input type="checkbox"/> Sophomore <input type="checkbox"/> Junior <input type="checkbox"/> Senior <input type="checkbox"/> Graduate <input type="checkbox"/> Other	Age: _____ Major: _____ Gender: <input type="checkbox"/> Male <input type="checkbox"/> Female	Years of formal music training <input type="checkbox"/> Less than 1 <input type="checkbox"/> 1 - 2 <input type="checkbox"/> More than 2

Purdue Spatial Visualization Developments Test

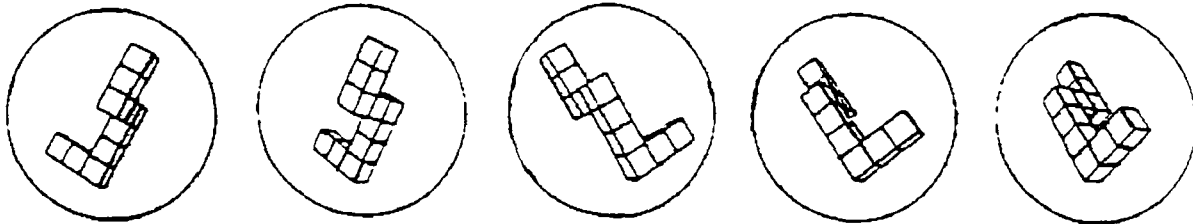
1. (A) (B) (C) (D) (E)
2. (A) (B) (C) (D) (E)
3. (A) (B) (C) (D) (E)
4. (A) (B) (C) (D) (E)
5. (A) (B) (C) (D) (E)
6. (A) (B) (C) (D) (E)
7. (A) (B) (C) (D) (E)
8. (A) (B) (C) (D) (E)
9. (A) (B) (C) (D) (E)
10. (A) (B) (C) (D) (E)
11. (A) (B) (C) (D) (E)
12. (A) (B) (C) (D) (E)
13. (A) (B) (C) (D) (E)
14. (A) (B) (C) (D) (E)
15. (A) (B) (C) (D) (E)

APPENDIX B

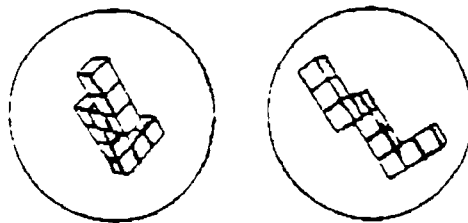
VANDENBERG AND KUSE MENTAL ROTATION TEST
and SAMPLE ANSWER SHEET

Vandenberg Mental Rotations Test

This is a test of your ability to look at a drawing of a given object and find the same object within a set of dissimilar objects. The only difference between the original object and the chosen object will be that they are presented at different angles. An illustration of this principle is given below, where the same single object is given in five different positions. Look at each of them to satisfy yourself that they are only presented at different angles from one another.

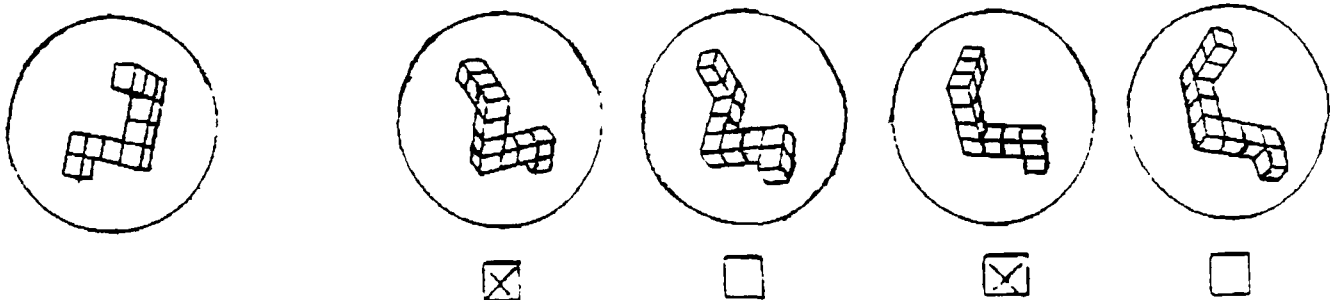


Below are two drawings of new objects. They cannot be made to match the above five drawings. Please note that you may not turn over the objects. Satisfy yourself that they are different from the above.

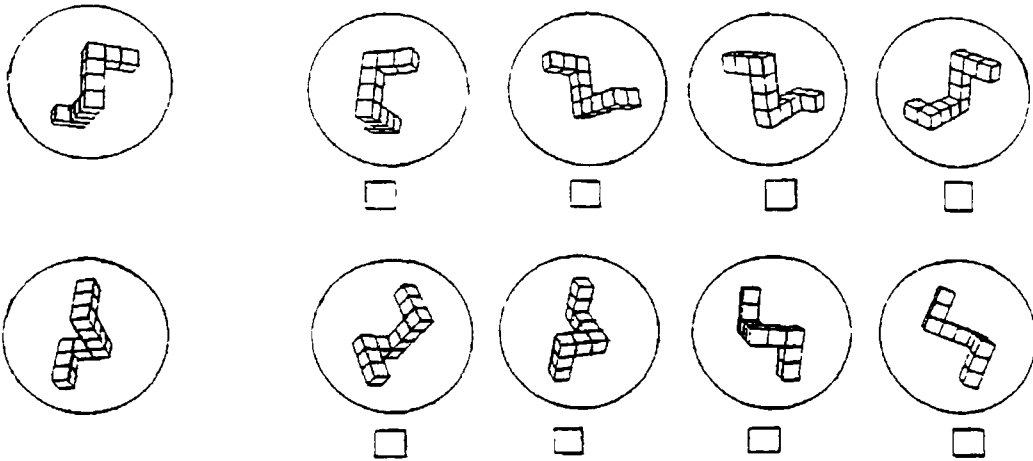


Now let's do some sample problems. For each problem there is a primary object on the far left. You are to determine which two of four objects to the right are the same object given on the far left. In each problem always two of the four drawings are the same object as the one on the left.

The first sample problem is done for you.



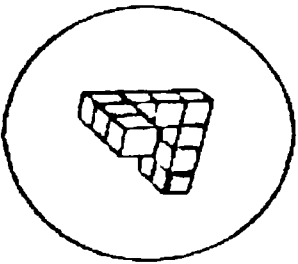
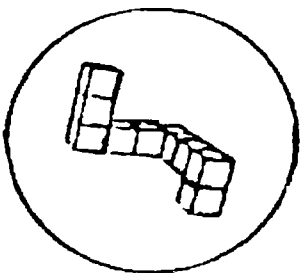
Do the rest of the sample problems yourself. Which two drawings of the four on the right show the same object as the one on the left? There are always two and only two correct answers for each problem.



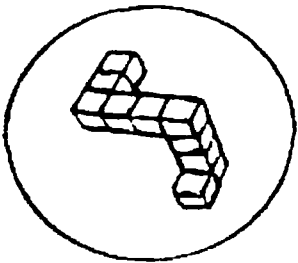
Work as quickly as you can without sacrificing accuracy. Your score on this test will reflect both the correct and incorrect responses. Therefore, it will not be to your advantage to guess unless you have some idea which choice is correct.

DO NOT TURN THIS PAGE UNTIL ASKED TO DO SO

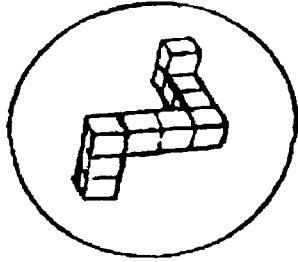
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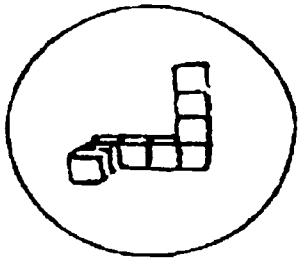
A



B

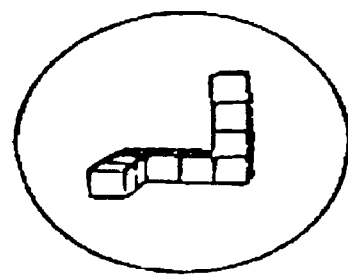
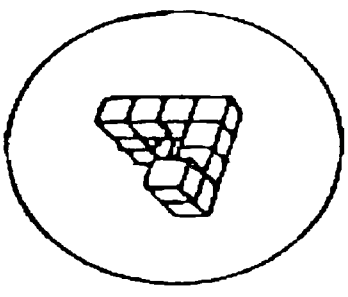


C

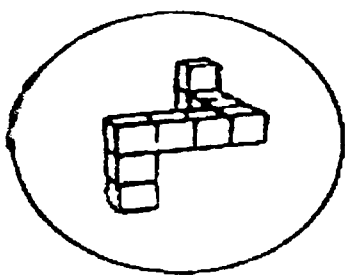


D

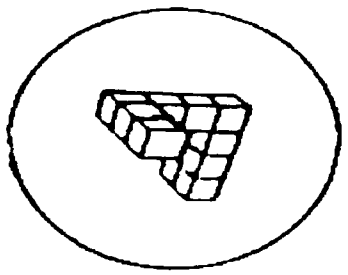
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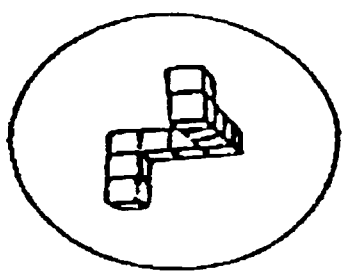
A



B

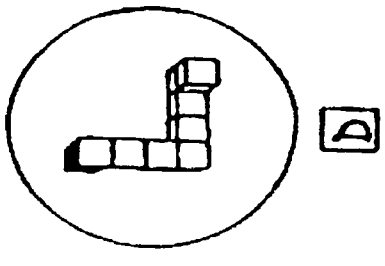
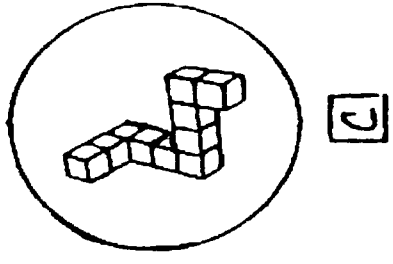
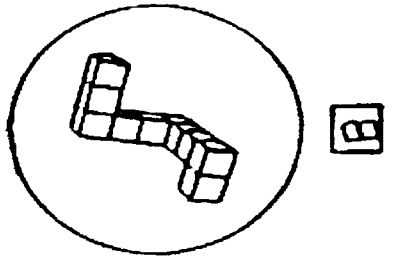
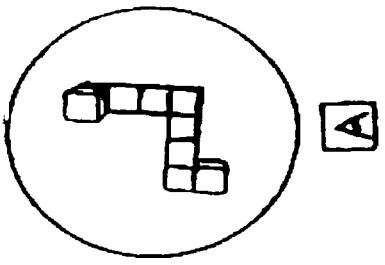
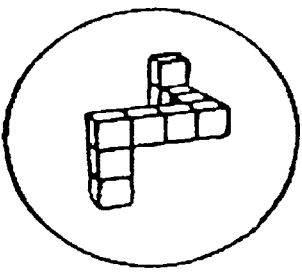


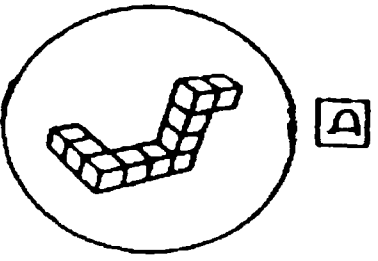
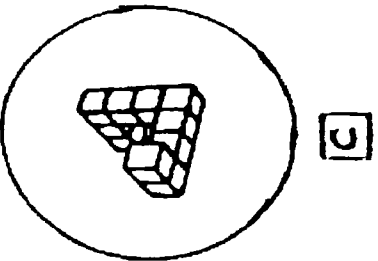
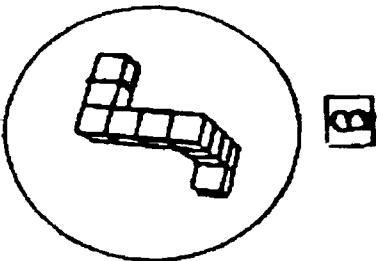
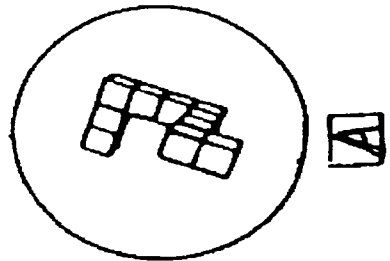
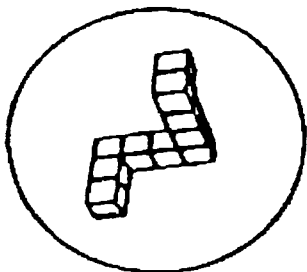
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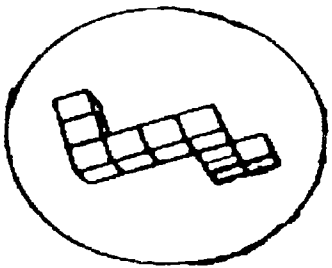
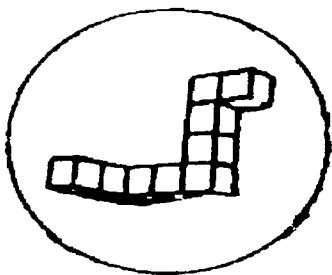


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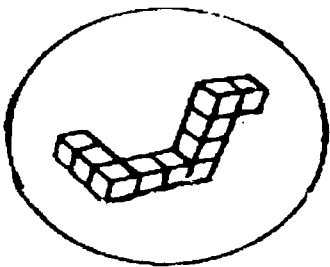
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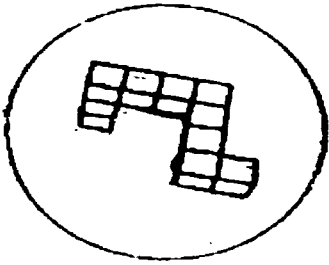




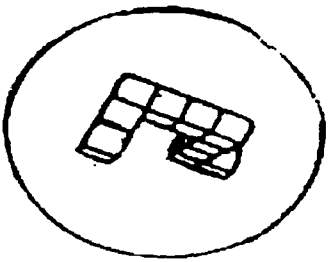
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B

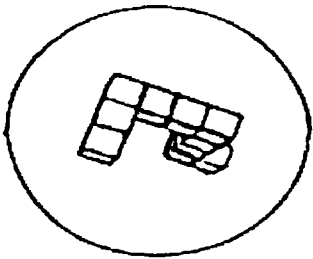
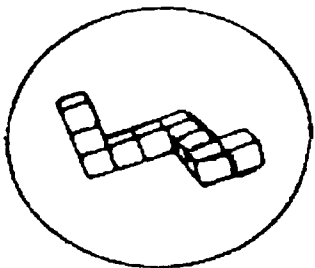


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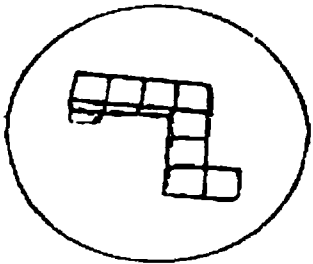


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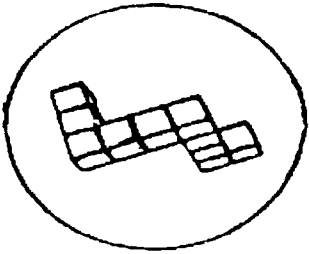
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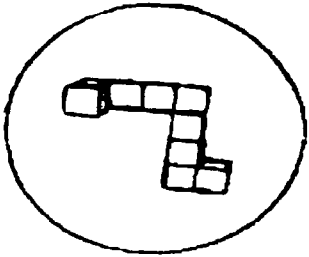
A



B

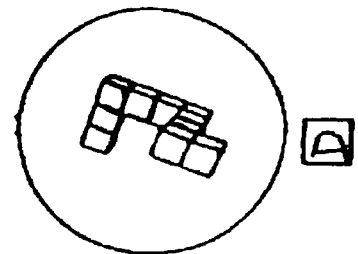
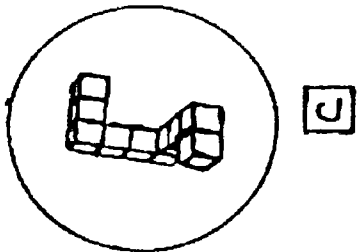
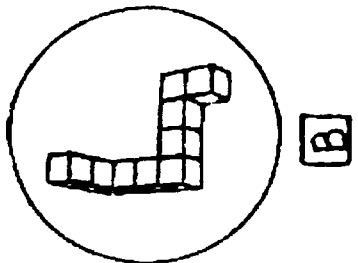
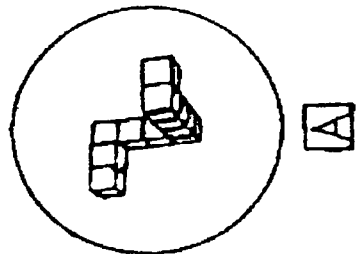
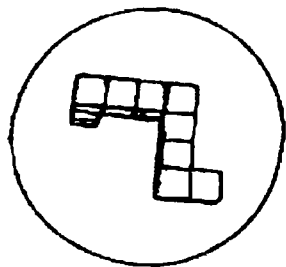


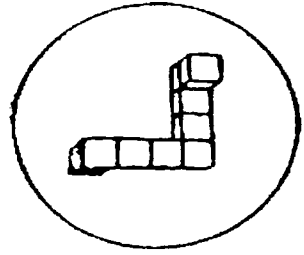
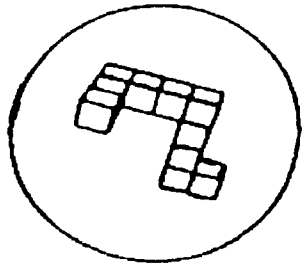
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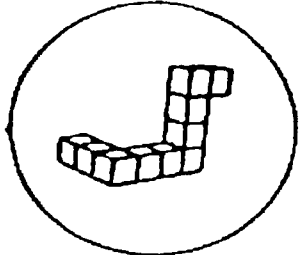
D

7

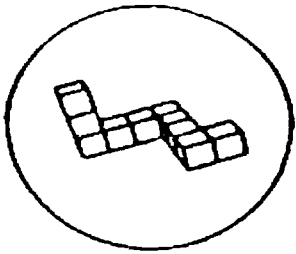




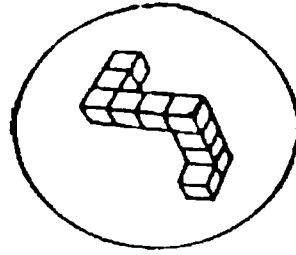
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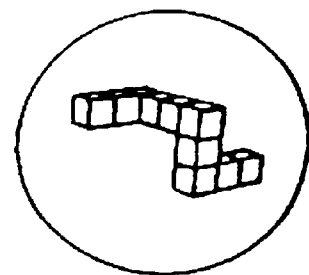
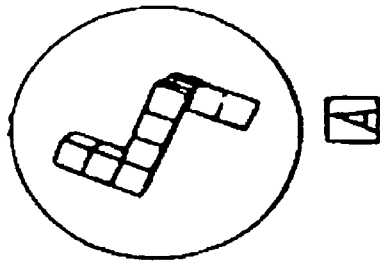
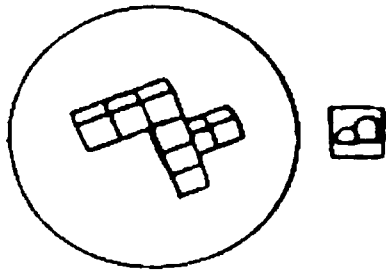
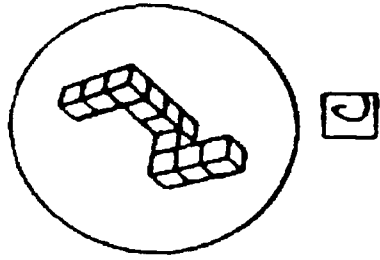
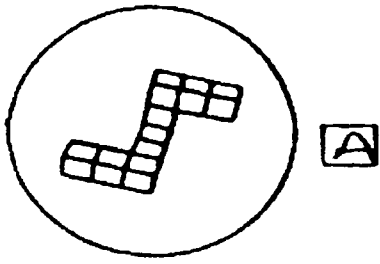
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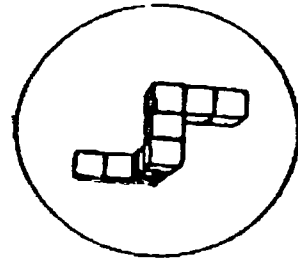
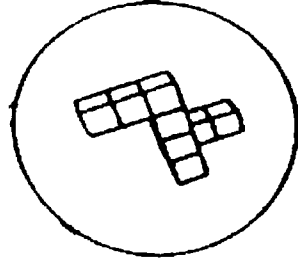
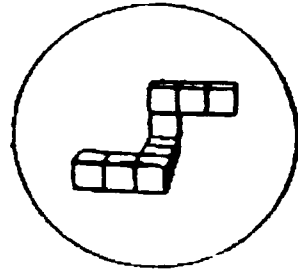
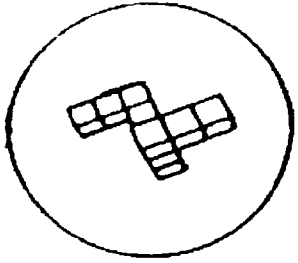
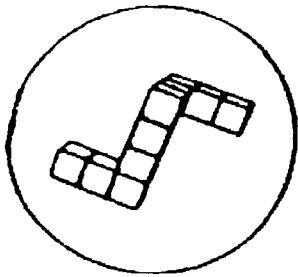


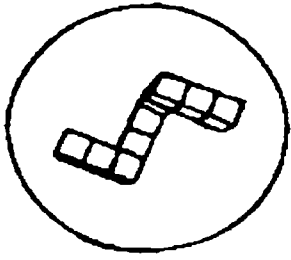
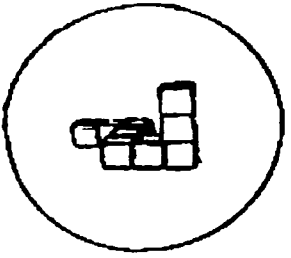
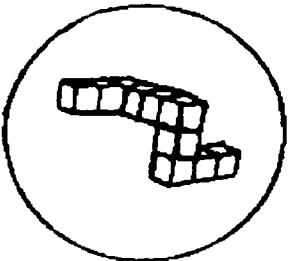
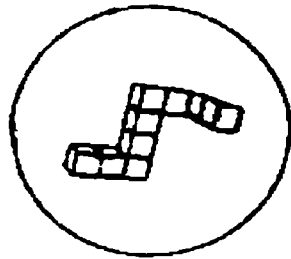
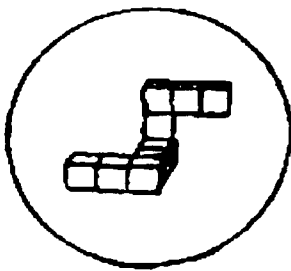
C



D





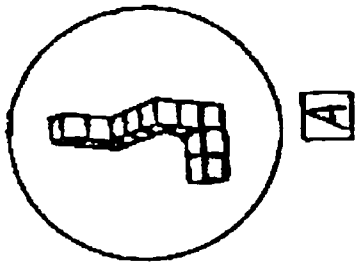
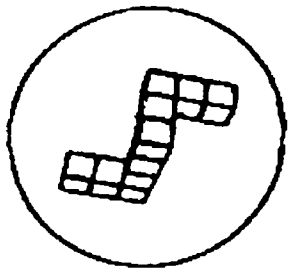


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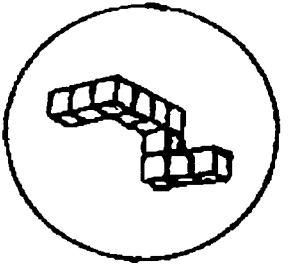
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B

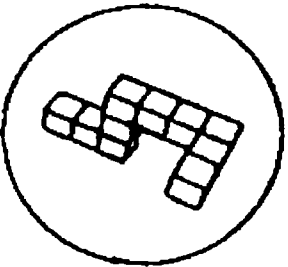
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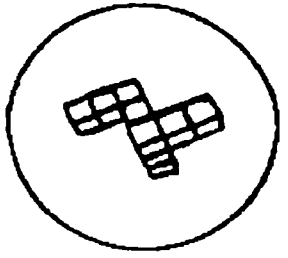
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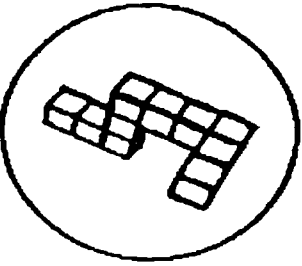
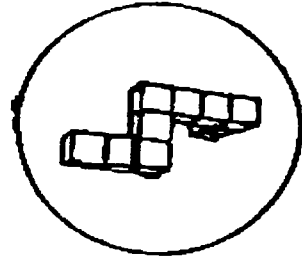
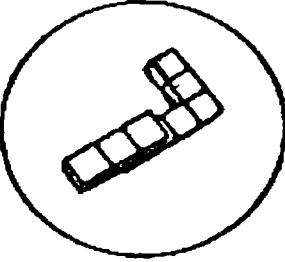
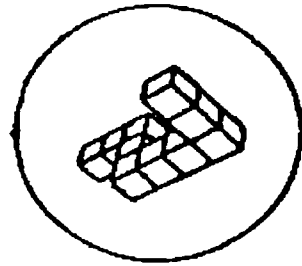
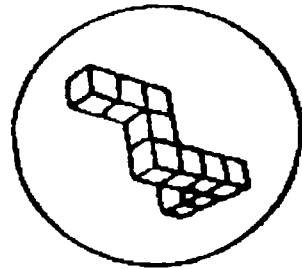
B



C



D

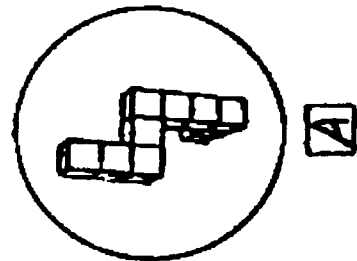
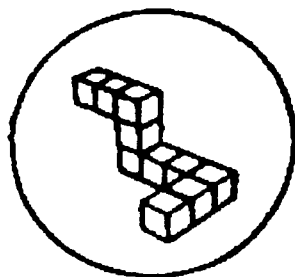


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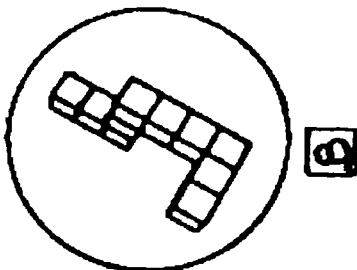
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C

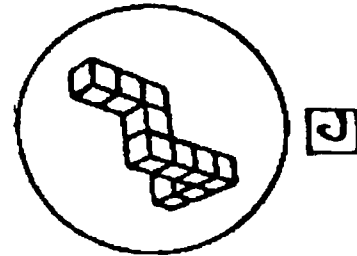
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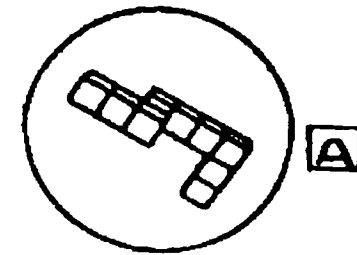
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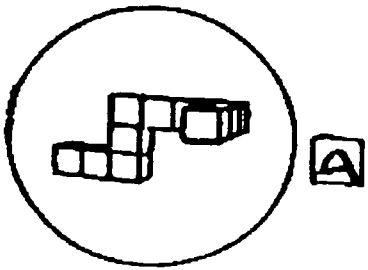
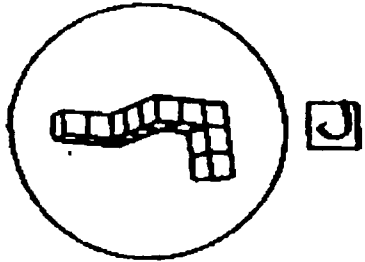
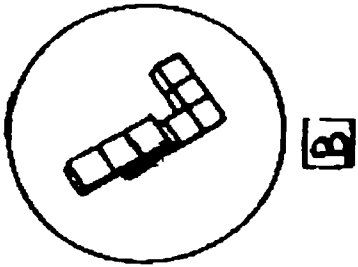
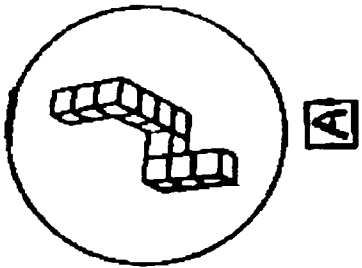
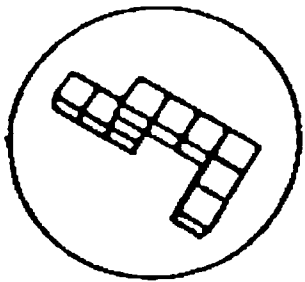
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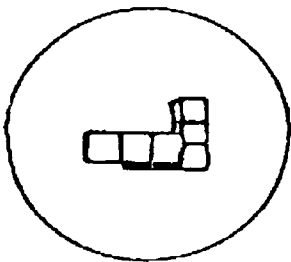
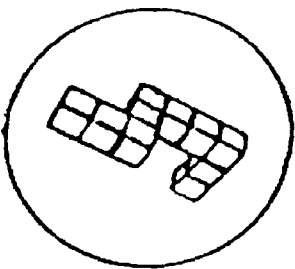


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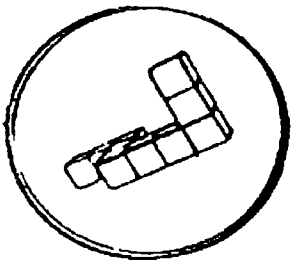


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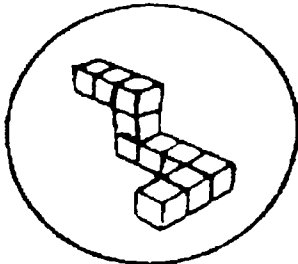




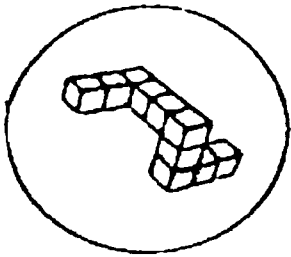
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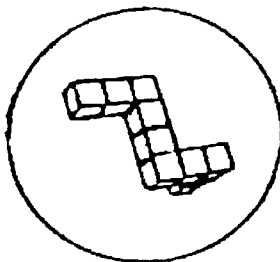
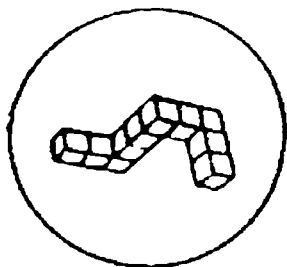
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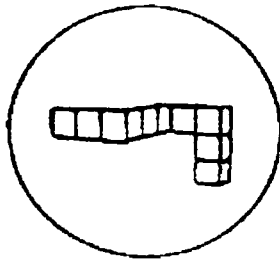
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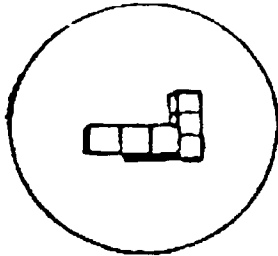
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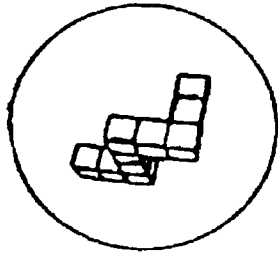
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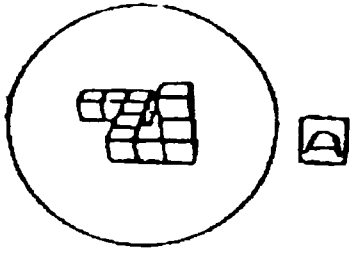
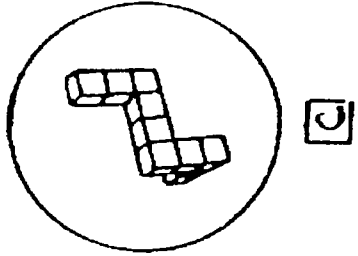
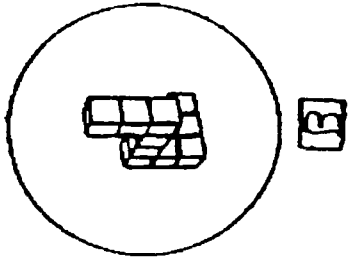
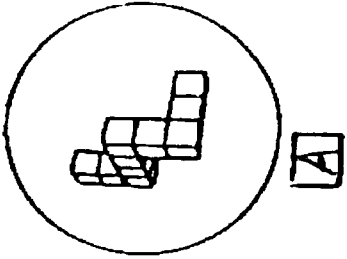
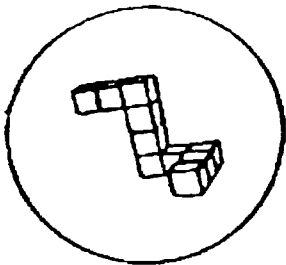
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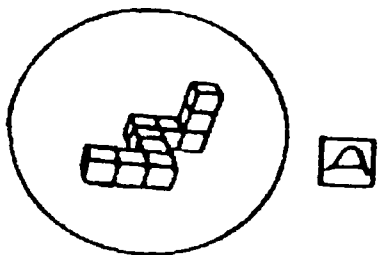
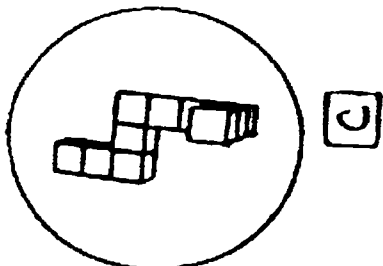
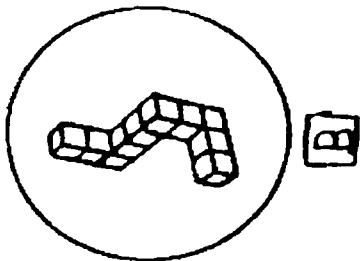
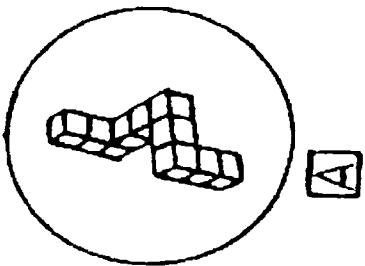
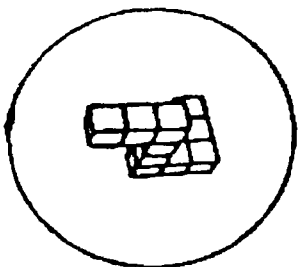


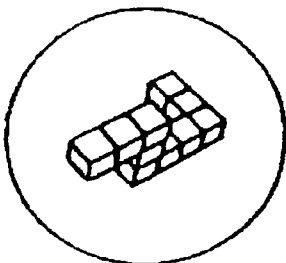
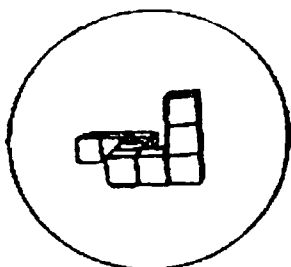
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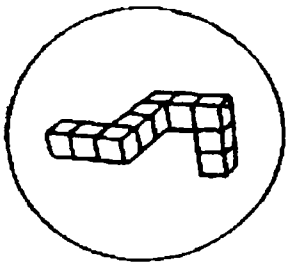
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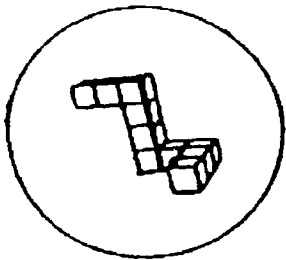




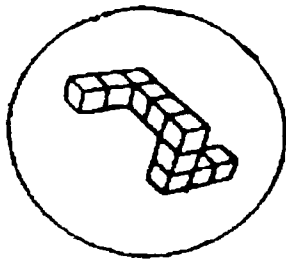
A



B



C



D

Case

○	○	○

Test

○	○

Condition

○	○	○

Vandenberg Mental Rotations Test

1. (A) (B) (C) (D)

2. (A) (B) (C) (D)

3. (A) (B) (C) (D)

4. (A) (B) (C) (D)

5. (A) (B) (C) (D)

6. (A) (B) (C) (D)

7. (A) (B) (C) (D)

8. (A) (B) (C) (D)

9. (A) (B) (C) (D)

10. (A) (B) (C) (D)

11. (A) (B) (C) (D)

12. (A) (B) (C) (D)

13. (A) (B) (C) (D)

14. (A) (B) (C) (D)

15. (A) (B) (C) (D)

16. (A) (B) (C) (D)

17. (A) (B) (C) (D)

18. (A) (B) (C) (D)

19. (A) (B) (C) (D)

20. (A) (B) (C) (D)