TRY TO DESCRIBE THIS OVER THE PHONE: AN INVESTIGATION OF THE COMMUNICATION OF SHAPE

by

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Submitted to the Media Arts and Sciences Section on August 11, 1989 in partial fulfillment of the requirements for the degree of Master of Science.

Abstract

This thesis is an examination, through verbal protocol analysis, of the one-way transmission of shape information. A communication model was developed, and the hypothesized attributes of a "good" description were experimentally tested. The methodology consisted of several steps: Twenty-eight subjects viewed nine objects from a range of relatively simple 3D shapes. The subjects verbally described each object. The transcribed descriptions were analyzed for information content and syntactic features. Selected object descriptions were then presented to a second group of thirty subjects for reconstruction (i.e., drawing). The descriptions were evaluated with respect to the objects and subsequent reconstructions, and the reconstructions were evaluated with respect to the objects and their descriptions. It was found that the accurate positioning and placement of object parts is the most important attribute of a successful description. The describers' use of scale, surface texture and color was infrequent. The majority of descriptions used static description techniques. Overall, it was found that the closer the descriptions were to the hypothesized attributes, the more likely they were to result in accurate and recognizable reconstructions.

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Chapter 1

Why Describe It Over the Phone?

This thesis is an examination, through verbal protocol analysis, of the communication of shape. A communication model and associated theories are developed, followed by a detailed examination of the communications model. The thesis concludes with a discussion of the results and directions for future work.

Current human-machine interfaces for three dimensional (3D) modeling programs force the user to design an object according to the program's paradigm. A survey of current 3D modeling interfaces reveals that often the modeling software forces the user to create 3D objects by using 2D representations. Typically, the user enters a set of points or edges, then selects from a menu of algorithms which construct a 3D object from this 2D representation. For example, to generate a cube, the user first draws a square, which is extruded to create the cube. Other examples include drawing a 2D profile, which is used to create a solid of revolution, or drawing a set of 2D cross-sections and a path to create a swept volume. The human is not free to conceive objects naturally, but must conform to the constraints enforced by the program. The user must decide what is required, then translate his conceptual model to a restricted language the program understands. In effect, the designer must create a program to inform a machine how to create a shape.

I suggest that for specific applications, humans think in 3D: for example, if I am designing a chest of drawers, I do not first think in 2D terms. My "modeling primitives" are planks of wood and the tools used to manipulate the wood. I don't imagine extruding a square. I think in natural 3D terms: cutting a plank, turning a block, planning the joints required to attach the separate boards to create a chest of drawers. This method of work is direct and spontaneous. I believe new means of communicating geometric definitions should be developed which allow the user to relate these cognitive processes as directly as possible to computer design systems.

Historically, user interfaces have been developed in response to how a person interacts with an established program or computational problem. I would like to examine the topic by studying 3D human cognitive processes. This requires a basic cognitive science approach to explore how humans think about shapes.

To begin, it is important to answer a few basic questions:

- How good are humans at shape description?
- What is important to humans in shape description?
- How do humans use shape primitives? What are the differences between the use of 2D and 3D?
- Do humans create compound primitives from simple primitives?
- What sort of transformations and deformations do humans apply to shape primitives?
- What manipulations do humans use to transform these shape primitives into objects?
- Do humans think about the physical tools they use for deformation operations? I.e. does the notion of "knife" get translated into a "mental cutting operation"?)

My long-term goal is to define a set of methods for how machines should conform to the models of human spatial thought and how these methods may be applied to current and future 3D applications. While it is clear that machines are "simple" compared to humans, humans must be able to communicate with machines: just how to communicate spatial and shape information is the aim of this inquiry.

Chapter 2

Review of the Literature

How people think about shape has been approached from many disciplines. Work in cognitive science on visual imagery, robotics work on machine vision, AI research on reasoning paradigms, as well as current trends in constructive solid geometry, all provide important insights into this question. In this chapter, relevant work is examined.

2.1 Visual Imagery

Visual imagery is an important subject of study for psychologists because it serves a number of valuable functions in human spatial cognition. Subjects, when asked to recall the location of an object, commonly report visualizing a scene which enables them to report on the object's exact placement. Likewise, when a subject is questioned about spatial relationships, visual imagery has been found to play a key role in the subject's ability to solve these problems [Pinker 86]. This mental imagery work suggests people utilize visual imagery when asked to recall a shape.

Do humans mentally manipulate visualizations of 3D objects? For an answer, we turn to the work of Metzler and Shepard on mental rotations of 3D objects. They found that the time required to recognize that two perspective drawings portray objects of the same 3D shape increased linearly with the degree of rotation. That is, an 80 degree rotation required more time than a 20 degree rotation. These findings held true for 2D drawings rotated in their own picture plane. All subjects reported that in order to make the comparison, they first had to imagine the object and then mentally rotate the object to fit the other drawing [Metzler 86] & [Shepard 86]. Further evidence of the ability of humans to manipulate mental images is presented by Glushko and Cooper. When given enough time, subjects could mentally assemble the components (cubes, angles, triangles) of a described figure into a coherent image [Glushko & Cooper 86&Cooper].

Stephen Kosslyn theorizes that images have two major components: the surface representation is a quasi-pictorial entity, accompanied by a subjective experience of an image. After studying a map, subjects were asked if city A was on the same path as city B. The response time indicated the subjects mentally traveled down the path; the larger the distance, the longer the response time. When asked if city C were on the map, the subjects response time was independent of the placement of the city on the map, indicating the subjects simply consulted a list of cities. [Kosslyn 83]

In spite of the relevance of visual imagery to spatial cognition, for purposes of this thesis, I will not examine issues relating to how humans construct and represent internal images or models of shapes. I will restrict my work to consideration of the processes of communicating shape descriptions among humans, and between a human and a machine. However, the work on visual imagery is important since it helps delineate those issues which will be included or not included in this work, and will provide a theoretical basis for future work on shape representation for extensions of the current experiment.

2.2 Linguistics

The linguist Leonard Talmy is especially interested in the relation between language and spatial concepts. In the paper *How Language Structures Space*, he describes a structure that is ascribed to space and the objects within it by language's semantic, pragmatic, and cognitive components. For example, consider a man going from one side of a wheat field to another. If it is stated, "The farmer went ***across*** the wheat field," the phrase implies a bounded horizontal land parcel and disregards the fact that there is wheat growing atop this land. If it is stated, "The farmer went ***through*** the wheat field," then the wheatstalks, conceived together as a medium, are abstracted from the wheat field, and now, the presence of a land surface underneath is irrelevant. If it is stated, "The moon beam falls ***across*** the wheat field," the spatial relation is no longer *in* the wheat field, but *between* the moon beam and the surface of the wheat field. [Talmy 83]

Such linguistic insights regarding spatial concepts are of considerable significance to my work. The ability of humans to communicate and interpret these fine points of spatial reasoning are quite meaningful and often dependent on context and cultural influences. Therefore, I will have to take into account the implied spatial relationships for such terms as "across" and "through," but also be alert for the ambiguity of these terms.

2.3 Artificial Intelligence and Machine Vision

Researchers in Artificial Intelligence have long been interested in understanding the kinds of representations and operations fundamental to human and machine vision.

The Marr-Nishihara theory on visual cognition and representation is the cornerstone of modern research in shape recognition [Marr 82]. This theory is also the basis for Winston's work on building programs that can recognize structures [Winston 86]. Nevertheless, this research has focussed on the internal representations for recognizing and reasoning about visually acquired data, and its usefulness for my investigation is limited.

Hoffman and Richards have pointed out that many classes of objects do not fit into the Marr-Nishihara model of shape representation [Hoffman 87]. Although they don't propose a vocabulary of shapes, they believe that decomposition of visual data into recognizable substructures is a crucial step in object representation. Their work is guided by the hypothesis that the perception of the part structure of objects is based partly on local geometric minima, using mathematical and geometric analysis of 2D image arrays to infer the structure of the 3D scene represented.

Biederman has suggested a set of shapes for use in object recognition called *geons*

[Biederman 85]. As these shapes may be useful in constructing a wide range of objects for visual recognition, they were not developed from empirical studies of human shape communication, but instead are derived in large part using generalized cones.

Pentland has suggested a representational system which describes a variety of natural and man-made forms [Pentland 85]. He has proposed that a family of parameterized shapes known as *superquadrics* may be used as virtual "lumps of clay" to form objects. This work provides a foundation for the present experiment, Pentland's hypothesis on the importance of intuitively-based decomposition of objects into recognizable parts as a starting point for my investigation. However, I am interested in describing objects at a single level of detail, with no consideration of part or sub-part recognition, abstraction, or feature aggregation.

Other work in artificial intelligence has focussed on internal representations and mechanisms for reasoning about objects, with little emphasis on the communication of these representations among humans. However, work on natural language understanding, particularly the work of Roger Schank, is of interest [Schank 80]. Schank's research on the theory of conceptual dependency as a language-free representation of text is analogous in some respects to my own hypothesis of shape description. Schank has claimed that text is decomposed into a small set of primitive *ACTS*, relationships, and operations on agents and objects. While I make no claims regarding the internal representations of objects, future work may clarify the relationship between the implications of conceptual dependency theory, its hypothesized primitives, and shape description, which is, after all, embedded in linguistic processes.

2.4 Robotics

Representing and reasoning about shape is crucial for work in robotics. Brady, for example, has suggested that inferring an object's function from its shape is critical to the construction of autonomous robot agents [Brady 84]. If I am able to identify a useful set of shape descriptions, this may prove useful for providing an unambiguous means for communicating with and among robot agents, say, for describing mechanical assembly tasks in cluttered environments.

2.5 Computer Graphics

Computer graphics has always been concerned with the representation and manipulation of 3D objects. However, these representations and manipulations have been approached from a mathematical basis. Currently, many modelers rely on splines and Bezier curves and surfaces. Constructive Solid Geometry (CSG) has proven to be a powerful tool for the construction of objects. However, these modelers' geometric constraints require in depth understanding of geometric and Boolean principles. For example, to create a hole in an object, a cylinder must be created and then manipulated to the desired size. Once placed in the correct position, the cylinder is then converted into a "negative" object. A subtractive Boolean operation is performed with the cylinder to create the hole. Eventually, I would like to see such operations performed not by the user, but by the computer program; the user simply states "drill a two inch hole here." Hopefully, based on the understanding of human shape description and object relationships the number of CSG shape operations will be expanded.

Chapter 3

Towards a Theory of the Communication of Shape

3.1 The Transmission of Shape Information

This thesis will examine "one-way" communication about shape rather than a dialogue. Communication between humans generally involves communication back and forth to clarify or request additional information. This model is a one-way pipe line. There is no mechanism for the listener to gather additional information. Hence, in this model of communication, the describer must strive to provide all of the relevant information. As this work is aimed at improving human computer interaction, it is essentially trying to create a framework which makes the directives we send to the computer as cognitively penetrable as possible.

3.2 A Model of Communication

To develop a theory of how humans may communicate their thoughts about shape to a machine, one avenue of investigation is the examination of the methods with which humans communicate with one another about shape.

Clearly, humans are quite good at perceiving 3D objects, and we describe objects every day. But how good are these descriptions? Verbal communication is fraught with ambiguity, and often descriptions are incomplete or inconsistent. Nevertheless, another human is usually able to understand a given description of an object.

Imagine the following: One day, Sydney discovers the sculpture of her dreams. She rushes to phone Fred. Carefully, she describes the sculpture's color, size, and shape. Later, when Fred views the sculpture, how does the actual sculpture correspond with the mental image Fred formed from Sydney's description?

How accurate is our understanding of a description? Do humans build a mental approximation of the object described? What is the structure of the description? Do humans routinely ignore or assume some aspects of a description? For the listener, what elements are essential to interpret the description?

The story of Sydney and Fred provides an informal example for the model of shape communication, and the experimental study. In particular, I will consider objects as information, and the subject as an information filter. The information (object) is processed through the first filter (Sydney), which results in a description. The description is then processed by the second filter (Fred), which results in a mental reconstruction which we can examine by having Fred draw the object he imagines. It is then possible to compare the original object and the reconstruction to determine the quality of the reconstruction. By correlating the quality of the reconstruction with features of the corresponding descriptions, we can determine what features characterize a good description.

3.3 Hypothesized Attributes of a Good Description

Hypotheses about what makes a "good" description were developed in hopes of identifying a useful set of attributes. I suggest there are elements of a description essential to accurate communication. In developing a list of these attributes for examination, I selected what were to me intuitively obvious ones. I chose to keep the list sparse and the attributes simple, as this is a preliminary examination of the topic. Would all of the attributes be utilized by the describers? Could I discover additional attributes given the protocol analysis? By the analysis of descriptions and reconstructions, I identified attributes which are important for the communication of shape. The following are the hypotheses about what features characterize a good description.[1]

---

[1]A "good" description is defined as a description which is capable of accurately communicating a shape.

A description should contain:

An introduction, to give the listener a framework and a point of reference. The introduction serves to establish communication protocols between the describer and listener. The introduction must establish a common coordinate system. The correct interpretation of many word phrases (e.g. behind, to the left of, on the other side), rely on a working understanding of a shared coordinate system. In addition, the introduction should explain the describer's plan for describing the object. An overview of the object stating the number of parts or general size and appearance is also included. The introduction is vitally important. As you would inform a blind person as to where the two of you are going to go and how you'll get there, the introduction is the framework from which the description is developed.

The description should be *organized.* The organization is the structure of the description. As noted above, the description should start with an introduction and proceed in an orderly fashion. A part must be fully described before moving on to the next part. The describer cannot "jump around" in a description without losing the listener. It is very difficult for the listener to move their focus of attention to randomly selected areas of the object.

All parts of the object must be explicitly defined. No parts should be neglected or assumed to exist.

Relationships from one part of an object to another should be clear and concise. There are two aspects of the relationships between parts: is the placement and positioning of a part in relation to a pre-defined part, and the relationships derived from real world knowledge i.e., analogies or a comparison with other familiar objects.

Scale should be noted either overall and/or incrementally for each part.

The *vocabulary* used in a description must be accurate. The term "square" should not be used to denote "cube." Hence, an accurate mapping of a term or word phrase to a shape primative is essential and should be common knowledge between the describer and listener. Terms of placement and positioning should be clear and accurate: "Place the square behind the circle so that only the corners of the square are visible from the front."

Generally, the description should not be *repetitious*. That is, the structure or overall shape of a part should be described once. However, the describer may return to a part to add detail. If the describer does return to a previously described part, this should be noted in the description.

If a describer starts to describe another part of the object, this *transition,* or *change of focus*, must be clearly expressed to the listener.

To summarize, a description should be well *organized* with an *introduction*, avoiding *repetition*. *All parts* should be described completely using *accurate vocabulary*. *Relationships* between parts should be clear, concise and as accurate as possible, noting the *change of focus or transitions* between parts. *Scale* should be noted.

In order to examine the model of communication, the following project methodology was developed:

- Subjects viewed several objects.[2]
- The subjects then carefully described each object.
- The transcribed descriptions were then analyzed for information content and syntactic features.
- Selected object descriptions were then presented to a second group of subjects for reconstruction (drawing).
- Evaluation of data.
    - The relationships between the original objects, descriptions and reconstructions are examined. Of particular interest is the "good" descriptions which lead to accurate reconstructions.

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[2]Reproductions of the objects may be found in Appendix A.20. The reader is directed to Section 4.2 for a discussion on the selection of the objects.

A complete discussion of the development of the project methodology follows in the next chapter.

Chapter 4

Methodology

4.1 Introduction

This is a discussion of the experimental methodology. The low level protocol analysis details are discussed in the following chapter.

In review, the methodology consists of several steps:

- Subjects viewed several objects.
- The subjects then carefully described each object.
- The transcribed descriptions were then analyzed for information content and syntactic features.
- Selected object descriptions were then presented to a second group of subjects for reconstruction (drawing).
- Evaluation of data.
    - Descriptions were evaluated with respect to the original objects and reconstructions.
    - Reconstructions were evaluated with respect to the original objects and descriptions.

4.2 The Objects

For an experiment on shape description, selection of the objects for description is critical. The objects were formed from a range of relatively simple 3D shapes. Complex objects, (e.g., plants, buildings), contain large amounts of detail that would overly burden the subject. As avoidance of cultural terms was a concern, the objects could not be recognizable, everyday objects. With these constraints in mind, I looked for sculptures as a source for objects. Nine objects were chosen at random from "**Woodworking: The New Wave**" by Dona Z. Meilach. [Meilach 81] Photographs from the book were mounted for presentation to the subjects. Reproductions of the objects can be found in Appendix A.20.

These objects range from simple shapes (Object 5) to complex shapes with free-form surfaces (Object 9).

4.3 Some Considerations on Verbal Protocol Analysis

This section examines in detail the issues encountered when considering the instructions for the describer. A copy of the instructions can be found in Appendix A.1.

4.3.1 Why Vocal Protocol?

During the pilot study, written object descriptions were investigated. However, written descriptions increased the subjects' time to such an extent that they could not maintain their concentration to the completion of the task. It was observed that the subjects spent a great deal of time on linguistic and grammatical issues. I viewed this as a distraction from the task; the subject's responses were to be as spontaneous as possible. In addition, in order to extract a range of results, it was important to maintain a suitable number of objects for description (nine), consequently, shortening the task by reducing the number of objects, was impossible. Therefore, to keep the duration of the experiment manageable, and to obtain spontaneous descriptions close to an actual "working" situation, oral descriptions were chosen.

4.3.2 Avoidance of Culturally Dependent Phrases

For this work, it was important for subjects to describe shapes in a way that avoids the use of world knowledge and culturally dependent phrases. For instance, if I say "cup," you understand the reference -- you know it is an object generally used to drink a liquid. You know the orientation of the object, i.e., a hollow cylinder or hemisphere with the open end up. But that is where the understanding ends, since most of the details of the object are unspecified, e.g.:

How is it shaped?
How thick is it?
Does it have a handle?
Is it shaped like a hemisphere or a cylinder?
Is it tapered at the bottom?
What color is it?
Is it ceramic or styrofoam?
etc.

As a consequence, the subjects were instructed to avoid culturally dependent phrases, such as "handle" or "cup."

4.3.3 Mathematical and Geometric Terms

While culturally dependent descriptions were not allowed, the instructions explicitly allowed the use of mathematical and geometric terms. This is because geometric objects such as, cube, square, cylinder, and sphere, are well defined shapes generally known to the sample population. In addition, many geometric shapes are utilized by existing 2D and 3D computer applications.

4.4 The Descriptions

Each description was evaluated by impartial raters to determine which attributes were present in each description.[3] Because it was necessary to have a range of description qualities with which to generate and judge reconstructions, the descriptions were segmented into three categories; good, medium, and bad. See section 5.6 for more information. The categorization was based on an overall quality rating assigned by the judges. Three sets of descriptions were then submitted to the reconstructors; each set contained ten descriptions; three good, three medium, and three bad, and the description of "Object 0", a control object.

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[3]See Evaluation Form for Descriptions in Appendix A.2 and Evaluation of Descriptions and Reconstructions, Section 5.4.

4.5 Object 0

I speculated if it could it be possible to create a description which fulfilled the requirements of the attributes to produce a "good" description? How would the judges evaluate such a description? Would such a description result in a greater number of good reconstructions? If there was an exemplary description, could the data from this description be used as a metric to rate the "good" descriptions?

The inclusion of a developed description would solve these problems. Another object was selected in the same manner as the other objects. It was labeled "Object 0" in accordance with the established numbering system[4]. The single digit number 9 was selected as the speaker number.[5] Hence, description 0-9. Development of description 0-9 was an iterative process. Several volunteers reconstructed Object 0 from the description. When completed, the volunteers were shown a reproduction of Object 0. Comments and suggestions were then requested from the volunteers for improving the description. This process was repeated (with different volunteers), until an acceptable level of reconstruction quality was achieved. Hence, when the description was submitted to the reconstructors, I was assured of a reliable description. As the description 0-9 was to be an "equalizing factor," it was presented as the first description to every reconstructor. The description of Object 0 can be found in Appendix A.7.1 and a reproduction of Object 0 can be seen in Appendix A.20.

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[4]See Section 5.5 for more information

[5]See Section 5.5 for information on labeling of descriptions and reconstructions.

4.6 Drawing Ability

As the experimental design was developing, there was a need to address a criticism, i.e., there wasn't an "equalizing factor" of "drawing ability" among the reconstructors. Each group of ten subjects would have a different set of descriptions i.e., there wasn't a measure of the performance of a subject in relation to the performance of all the subjects. Here, performance is defined as "drawing ability" and the subject's ability to perform the reconstruction task. However, as all of the subjects were randomly selected and assigned, this was not viewed as a problem.

Chapter 5

Protocol Analysis

This chapter contains all of the low level protocol analysis details.

5.1 Experimental Design

In review, the project methodology consisted of five steps:

1. Thirty subjects (the describers) each verbally described nine objects.
2. Three judges evaluated the transcribed descriptions, rating each description on 16 questions.
3. The descriptions were then categorized. Sets of descriptions were selected for the reconstructors.
4. Thirty subjects (the reconstructors) drew from the selected descriptions.
5. The judges evaluated the reconstructions (drawings), rating each description on 10 questions.

5.2 Sample Population and Judges

Sixty subjects participated, thirty in the description phase, thirty in the reconstruction phase. All subjects responded to advertisements placed around the MIT community. Gender issues have been avoided, as one-half of the subjects were male and one-half were female. [Ericsson 84]. Subject ages ranged from 18 to 55 with the average age at 29. For their participation in the description phase, subjects were paid $8.00 for a one hour task. For participation in the reconstruction phase, subjects were paid $15.00 for a two hour task.

The judges were respondents to advertisements placed around the MIT community. For their participation, the judges were paid $10.00 an hour. The judges, (two males and one female), did not have detailed knowledge of the experiment's hypothesis. They evaluated both the descriptions and the reconstructions.

5.3 Instruction of the Describers

Each describer subject was provided with a set of instructions. (A copy of the instructions for the describers is included in Appendix A.1). The experimenter then provided the subject with the set of objects for description. The set of objects were sorted in a different random order for each subject. While viewing the object, the subject then verbally described each object in turn. The examiner, if questioned by the subject, was allowed to clarify any issue for the subject. If the subject violated the instructions by using a cultural term (such as "handle"), the examiner requested the subject to describe its shape. Thirty subjects were interviewed, but, two subjects' data were omitted from evaluation as in one case the tape recorder failed in the middle of the interview, and the cassette of another subject was lost. In all 252 descriptions (9 objects * 28 subjects) were collected.

5.4 Evaluation of Descriptions and Reconstructions

The next phase of the experiment required judges to rate the descriptions along various dimensions. The following describes the procedure for evaluation of the descriptions and reconstructions.

The judges were trained on data obtained from the experiment development period. Each judge was supplied with pictures of the objects, sample forms and explanations of each question on the form. (Explanations may be found in Appendix A.3.) Each question was discussed and issues clarified. The judges evaluated several descriptions, then their results were discussed. I answered questions and explained fine points. Eventually, the judges were encouraged to discuss among themselves the results. When the judges had reached a high degree of agreement on the training data, they were then furnished with real data. While evaluating the actual data, the judges were *not* allowed to discuss the descriptions or their scoring. Each judge was supplied with a set of all descriptions sorted by object.[6] The judges were instructed to read all of the descriptions of one object, then proceed to complete one evaluation form per description. Rating all of the descriptions of one object in one session provided a controlled and accurate evaluation. (The description evaluation form may be found in Appendix A.2.)

Evaluation of the reconstructions followed the same format and was administered by the same three judges. The reconstruction evaluation form may be found in Appendix A.5.

5.5 Labeling of Descriptions and Reconstructions

For practical purposes, each object was assigned a number (1 to 10). (Object 8 was dropped during experiment development, so that the description task could be kept within agreeable time constraints (1 hour).) Each subject was also numbered. To identify a description, it was assigned first the object's number, then the describer's (speaker's) number. Hence description 4-28 is a description of object four by speaker 28. The reconstructions are labeled first with the object, then the describer, then the reconstructor. Hence drawing 4-28-73 is the drawing of object 4 as described by speaker 28 and drawn by reconstructor 73.

5.6 Segmentation of the Descriptions into Good, Medium and Bad Groups

As a "good," "medium" and "bad" description for each object was required, care was taken in the categorization of the 252 descriptions. The descriptions were categorized by the sum total of the judges response to question 16: "Do you think someone could draw a reasonable representation of the object from this description?" The judges had three choices: "NO" (a value of 1), "MAYBE" (a value of 2), and "YES" (a value of 3). The

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[6]The reader is reminded that the judges did have their own copy of reproductions of the objects, sample forms and explanations of each question and any personal notes they made during their training period.

possible scores being from 3 (lowest) to 9 (highest). The distribution of descriptions based on this score may be viewed in Appendix A.6.

The selection of the "good" description was straightforward; the highest rated description was used. In the cases where there were two or more equally rated descriptions, a random number was generated to select a description. Next, for the "medium" descriptions, the mean score was computed for each object:

Obj 1: 4.75, Obj 2: 3.78, Obj 3: 5.07, Obj 4: 5.00, Obj 5: 5.53, Obj 6: 5.53, Obj 7: 5.07, Obj 9: 3.78, Obj 10: 4.85

The mean was then rounded to the nearest integer and a description with the mean score was chosen at random. For the "bad" descriptions, a description was chosen at random from the descriptions with the lowest score of 3. These steps produced the following list of descriptions.

Good 1-12, 2-20, 3-27, 4-12, 5-16, 6-11, 7-27, 9-12, 10-27
Medium 1-26, 2-22, 3-18, 4-25, 5-11, 6-36, 7-37, 9-21, 10-11
Bad 1-14, 2-23, 3-19, 4-19, 5-29, 6-14, 7-26, 9-14, 10-15

The careful reader will notice a speaker may have more than one description. This tends to be unavoidable in that a few speakers have a higher percentage of "good" descriptions.

One more step was required before the descriptions could be submitted to the reconstructors. The "good," "medium" and "bad" groups had to be evenly distributed. Hence, the final grouping of descriptions for reconstructors. Each group contains 3 good, 3 medium and 3 bad descriptions, plus the description of Object 0. No speaker or object is repeated in a group. These descriptions may be found in Appendix A.7.

Group 1 - 0-9, 1-12, 2-22, 3-27, 4-25, 5-29, 6-11, 7-37, 9-14, 10-15
Group 2 - 0-9, 1-26, 2-23, 3-19, 4-12, 5-16, 6-14, 7-27, 9-21, 10-11
Group 3 - 0-9, 1-14, 2-20, 3-18, 4-19, 5-11, 6-36, 7-26, 9-12, 10-27

In order to train the judges on the evaluation procedures, sample data was required. A group of descriptions were selected with the same procedure as above. Reconstructions resulting from these descriptions were then utilized during training.

Test - 1-21-B, 2-15-B, 3-28-M, 4-13-G, 5-25-G, 6-37-G, 7-38-M, 9-26-B, 10-13-M

5.7 The Reconstruction Phase

Each subject was supplied with a ruler, a ream of paper, several pencils, instructions (see Appendix A.4) and one of the groups of descriptions. The descriptions were sorted in a different random order for each subject, with the constraint that, the Object 0 description was always the first description. After reading the instructions, the subject was then allowed as much time as needed to complete the drawing of the ten objects (remember object 0 was included). The subjects could stop at any time to ask questions. This resulted in 300 reconstructions. (30 reconstructions of object 0, all from the same description. 30 reconstructions of each object, 10 from each group of descriptions.) Each reconstruction was labeled according to object-describer-reconstructor numbers. The subjects for the reconstruction phase were balanced according to gender (45% women, 55% men).

Five female subjects and one male subject interrupted their sessions and refused to continue. These sessions were deemed a failure and were not included in the data. These subjects reported that they "simply could not do it," and upon further questioning, a few stated they could not "visualize" an object from a description. The differential drop-out rate for men and women may have been due to innate differences in spatial ability, or perhaps because most of these particular women were not native speakers of English. Regardless, the loss of these subjects does not threaten the validity of these findings because the relationship between drop-out rate and sex of subject is not significantly different than would be expected by chance alone. (Chi-square = 3.2, $p < .05$)

5.8 A Quick Recognition Experiment

The observation had been made that it had not been proven subjects could *recognize* an object from a transcribed verbal description, much less draw a reconstruction. An informal experiment was performed to address this question. 45 descriptions were selected at random from the 252 descriptions (5 of each object). Each of 15 volunteers were provided with 3 descriptions (no duplication of objects or speakers) and a set of pictures (3 target pictures and 15 distractor pictures). The volunteers were instructed to place all images in front of themselves in clear view. They then read a description and matched the description to the object. The procedure was repeated until all three descriptions had been matched. An 88.89% accurate recognition rate was realized. Out of the 45 possible correct matches, 5 matches were in error. Of the 5 errors, two subjects were responsible for four of the errors (two each). Two of the errors were the same exact mis-match, that is, they matched the same description with the same object.

Chapter 6

Results

6.1 Reliability of Judges' Ratings

Judges were asked to rate various aspects of both the descriptions and reconstructions. Before these ratings can be used, it is necessary to determine that the judges agreed on their ratings; the correct way to determine the judges' level of agreement is to measure the reliability of their judgements [Rosental & Rosnow 84&Rosnow]. Using the Spearman-Brown formula for reliability, the judges' ratings of both the descriptions and the reconstructions were found to be very reliable (R = .917 for the descriptions, and R = .949 for the reconstructions; note that a reliability estimates should typically be R = .80 or higher). Reliability estimates of the judges ratings broken down by object and questions can be seen in Appendix A.8.

A less formal but more intuitive way of determining the agreement of the judges is to examine the percentage of agreements and near agreements. If two of the three judges gave a score of 3, did the other judge respond with an answer "next door"? That is, a score of 2 or 4? Hence, I defined an "agreement" as when two judges agreed on one score, and the third score was "next door." Conversely, what was the number of complete disagreements,[7] and where were they? What object or questions affected this rate?

On the evaluation of the descriptions, the overall agreement rate was 89%. Out of 3276 possible agreements, all three of the judges came to the same conclusion 30% (1004) of the time. 11% (381) of the scores were completely different. In 57% (1891) of the scores, two of the judges evaluated the description exactly the same. Of the instances

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[7]"Complete disagreements" are defined as instances were no two judges assigned the same score.

where the two judges agreed, the third judge's score was "next door" 89% (1689) of the time. Note that these figures do not include questions 1, 2 or 16, as they cannot receive a five point spread.

For the evaluation of the reconstructions, the overall agreement rate was also 89%. Out of a possible 2880 possible agreements, all three of the judges gave the same score 38% (1103) of the time. 11% (329) of the scores were completely different. In 39% (1148) of the scores, two of the judges evaluated the description exactly the same. Of the instances where the two judges agreed, the third judge's score was "next door" 89% (1252) of the time. Note, these figures do not include question 1 as it cannot receive a five point spread. Agreement breakdown by object and question can be found in Appendix A.10.

These high agreement rates serve to point out the consistency and accuracy with which the judges evaluated the data.

6.2 Formulation of Evaluations

This section is a boring but informative outline of the procedures for statical evaluation of the descriptions and the reconstructions. It is most helpful for understanding the groups from which many of the results are derived. For a discussion of the results of the evaluation and the conclusions, the reader is directed to Section 6.5, Conclusions from the Evaluations.

6.2.1 Evaluation of the Descriptions

As I was to segment the descriptions into good, medium and bad groups, the first questions of evaluation were "How many of the descriptions fell into the good, medium and bad groups?" and "How did the response to specific questions vary among these groups?" Based on the score (3 to 9 scale) of the question "Do you think someone could draw an accurate reconstruction of this object from this description?", the 252 descriptions yields:

5 descriptions scored 9
9 descriptions scored 8
35 descriptions scored 7
35 descriptions scored 6
43 descriptions scored 5
44 descriptions scored 4
81 descriptions scored 3

An important fact is that only 2% (5) of the descriptions were unanimously judged to "probably result in an accurate reconstruction." In contrast, 31% (81) descriptions were unanimously judged as "doubtful to result in an accurate reconstruction." This suggests humans may not be good describers of shapes.

For evaluation and comparison, the descriptions which scored 9 or 8 were segmented into a group called "The Top 14," (i.e., 5% of the descriptions), here after referred to as the "good" descriptions. The descriptions which earned a score of 3 were deemed "The Bad 81," (32%). The remainder (157 descriptions, 62%) were simply referred to as "Medium." The set of graphs in Appendix A.11, shows the rating relationships between the three groups. Each graph illustrates the responses (expressed as percentages) to each question on the description evaluation form. A copy of which can be found in Appendix A.2. To further understand the relationships between the groups, the averages of all the descriptions were included to illustrate the mean response for each question.

Next, matrices which correlate data from each question on the description evaluation form were formulated. These may be found in Appendix A.15.

To investigate the differences of one object over another, sets of graphs and correlation matrices segmenting the data by objects were developed. The graphs may be found in Appendix A.12. The correlation matrices may be found in Appendix A.16.

6.2.2 Evaluation of Reconstructions

Evaluation of reconstructions followed the same format as the evaluation of the descriptions. Sets of graphs were generated which segmented the data into the four groups; bad, medium, good and overall. These graphs can be found in Appendix A.13. The graphs of the reconstruction data broken down by object can be viewed in Appendix A.14. The correlation matrix of the reconstruction data (overall and broken down by object) may be found in Appendix A.17.

6.2.3 Correlation Between Description & Reconstruction Data

A matrix correlating each question of the description evaluations with each question of the reconstruction evaluation may be found in Appendix A.18. Formulation of this matrix included the data from all of the reconstructions and the data from the 27 descriptions submitted to the reconstructors. Data from the descriptions not utilized in creating the reconstructions were not included. In addition, data from the Object 0 description and reconstructions were not included.

An attempt was made to analyze the data utilizing multi-variable regression techniques. However, the results produced were inconsistent with the correlation matrices. The inconsistent findings appear to be the result of the statistical phenomenon known as "suppression," perhaps due to the necessity of averaging the data. As this analysis produced faulty results, they are not included in this thesis.

6.2.4 Identification of the "Best" Descriptions

Naturally, I was interested in identifying the descriptions which resulted in the best reconstructions. According to the resemblance score[8] the best descriptions were identified as 1-12, 1-26, 2-20, 5-11, 5-16, 5-29, 6-11, and 7-27.

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[8]The result from the question: "How much does this reconstruction resemble the object?"

The reader may have noticed object 5 is represented thrice. All three descriptions (good, medium and bad) for object 5 resulted in quality reconstructions. Why? I believe one reason may be that Object 5 is the most simple shape in the set of objects. Its shape is very near to that of the geometric primitive "sphere."

Regrettably, time has not permitted proper examination of these descriptions. These descriptions should be closely examined for content and use of vocabulary.

6.3 The Burning Question: Did the Good Descriptions Result in Good Reconstructions?

Of major interest is the question: Did the "good" descriptions actually produce reconstructions which had a close resemblance to the object described? Each reconstruction had a "resemblance score" assigned by the judges. If the "good" descriptions did result in reconstructions with a high resemblance score, the "medium" descriptions in medium rated reconstructions and "bad" descriptions in poorly rated reconstructions, this would suggest the supposition that the judges are accurate predictors of the quality of a description.

Presented are the mean resemblance scores for various groups. (3 to 15 point scale, 15 = very close resemblance).

Overall: 7.28 (Does not include Object 0)

Good Group: 8.16	Medium Group: 8.22	Bad Group: 5.47	
Obj 0: 10.43	Obj 1: 8.68	Obj 2: 7.56	Obj 3: 5.50
Obj 4: 6.90	Obj 5: 8.75	Obj 6: 8.00	Obj 7: 7.37
Obj 9: 6.03	Obj 10: 6.78		

There are three interesting results from this data. First, the slightly larger mean for the "medium" group indicates that the "medium" group produced as many successful reconstructions as the "good" group.[9] Second, Object 0 by scoring the largest mean has proven itself to be the *most* accurate description we have seen so far. Third, the judges are not accurate predictors of successful descriptions.

So that the reader may get an indication of how these resemblance mean scores correspond to reconstructions, the reconstructions of Object 0 with the resemblance scores of 4, 7, 9, 11, 12 and 15 may be found in Appendix A.19, Object 0 may be found in Appendix A.20.

[9]There is no significant difference between the Good and Medium groups ($t = .125, p < .05$). There is a significant difference between the Good and the Bad groups ($t = 6.597, p < .05$), and between the Medium and Bad groups ($t = 5.479, p < .05$).

To further understand the relation between the groups and the quality of their reconstructions, this graph is presented.

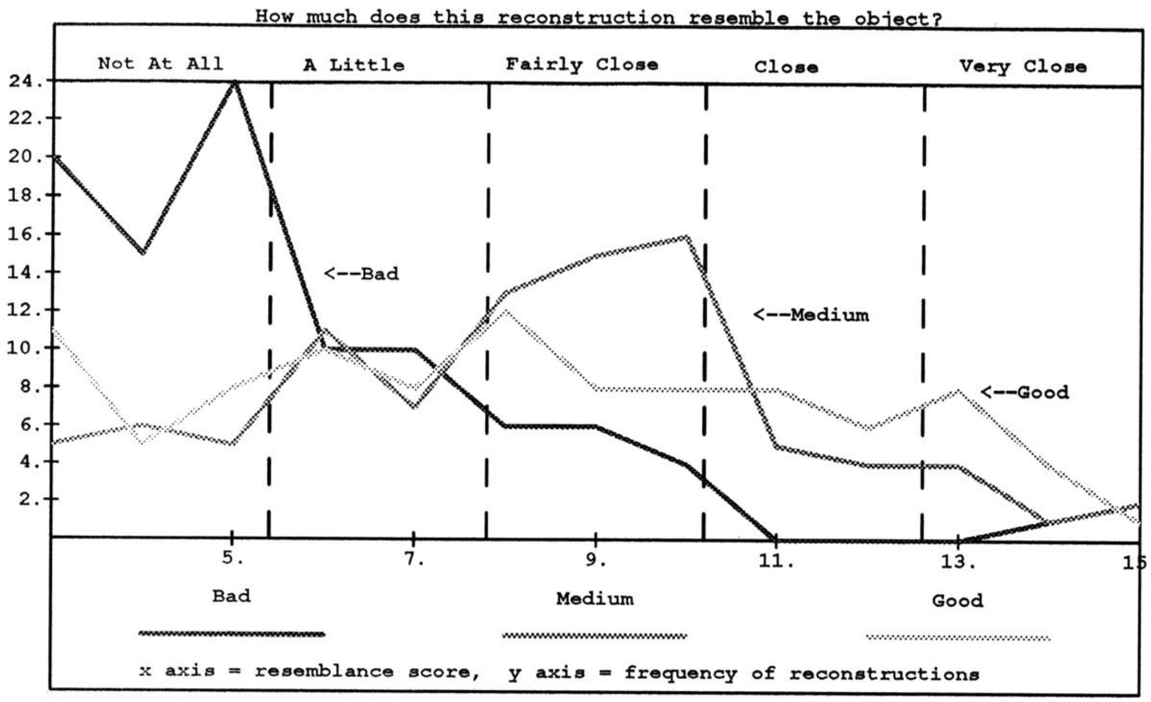

Figure 6-1: Resemblance Graph for Good, Medium and Bad Groups

The x axis (3 to 15) is the resemblance score (15 = very close resemblance). The y axis (2 to 24) depicts the number of reconstructions (frequency). At the top of the chart are the choices given to the judges. Object 0 data is not included in this graph.

The results of these data suggest the judges are not accurate predictors of successful[10] descriptions. However, it should be noted the judges are able to accurately distinguish a bad description.[11]

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[10] A "successful description" is defined as a description which can generate reconstructions that score a high resemblance factor.

[11] The reader is reminded of four points: 1) Each reconstructor received 10 descriptions; 3 good, 3 medium, 3 bad and description 0-9; a description for each object. 2) Ten people drew from each description. 3) The same judges evaluated the descriptions and the reconstructions. 4) The description of Object 0 was drawn by all reconstructors. 5) Only 5% of the descriptions were categorized as "good" descriptions.

6.4 Predicting a Quality Reconstruction

As the quality rating of a description did not prove to be an accurate predictor of reconstruction quality, could an accurate predictor be developed? For each description submitted to the reconstructors, a sum of differences from each of the 16 questions from the rating of description of Object 0 was calculated. Next, from the ten reconstructions produced from each description, a "resemblance mean" (i.e. the average from the ten scores from the question "How much does this reconstruction resemble the object?") was calculated. A "best fit" linear regression resulted in the following graph.

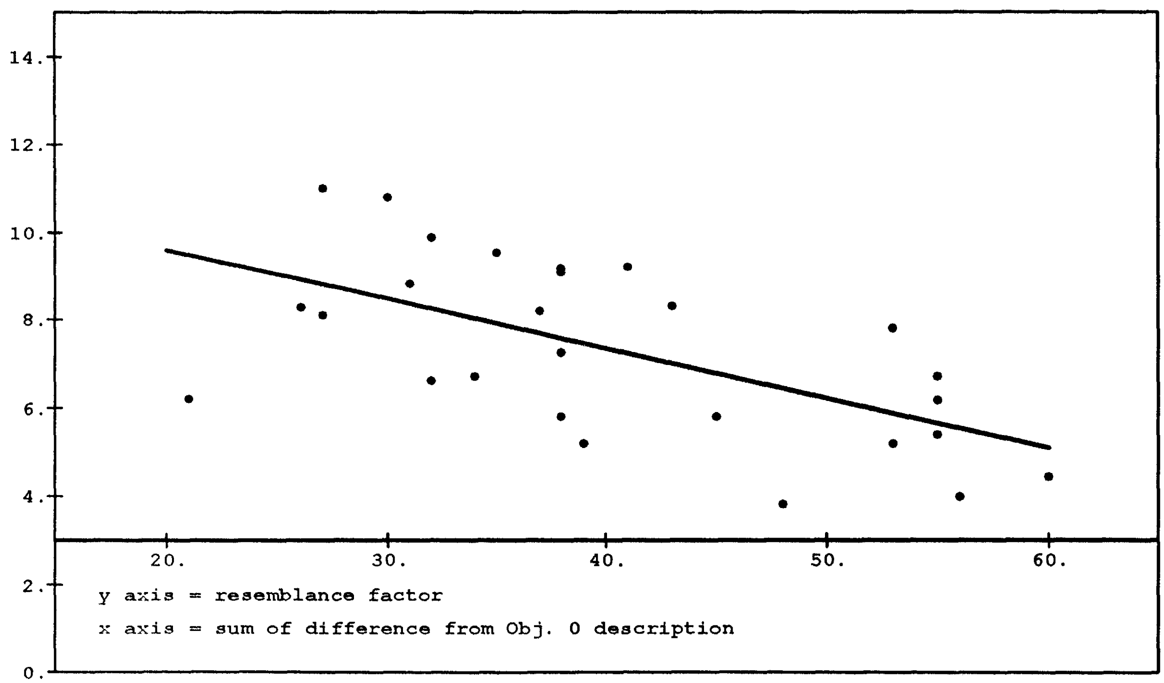

Figure 6-2: Linear Regression

The y axis is the resemblance factor; 3 = no resemblance, 15 = high resemblance. The x axis is the sum of difference of a description from the description of Object 0. (df = 25, r = -.604, t = -3.793, p < .05.) Hence, a substantial relationship is shown to exist between a good reconstruction and the description's proximity to the "ideal" description. In essence, the closer a description is to fulfilling the communication model's proposed attributes, the more likely it will result in a quality reconstruction.

6.5 Conclusions from the Evaluations

This section will briefly discuss the conclusions reached from the evaluations of the descriptions and reconstructions. The reader is urged to refer to the description graphs in Appendices A.11 and A.12, and the reconstruction graphs in Appendices A.13 and A.14.

6.5.1 Global Overview or Introduction

To satisfy the communication model, a description must start with an introduction or overview. The essential element of the introduction is the establishment of a common coordinate system between the speaker and listener.[12] The correct interpretation of many words (e.g. behind, to the left, around) depends on a working knowledge of a common coordinate system. Without this shared knowledge, the description may proceed to a point, only to have the meaning of a phrase or term confuse the listener, which leads to a mis-interpretation of the phrase. Often these mis-interpretations result in positioning and placement errors, which degrade the quality of the reconstruction.

81% of the successful descriptions have an introduction or global overview. The introduction serves to establish communication and provide a coherent starting point. If the describer begins simply with the description of a shape, the listener tends to lose track of the "structure" of the description very quickly. In addition to the establishment of a common coordinate system, I suggest the introduction should consist of a list of parts to be described and an outline of the methods with which the describer will utilize (structure). This gives the listener an indication of the overall view of the object. By specification of which parts will be described in an order, the listener will not be confused with the transition from one part to another.

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[12] In this instance the reconstructor.

6.5.2 Texture or Surface Specifications

To satisfy the description model, surface or texture should be noted. 66% of the descriptions did ***not*** mention color, texture, or surface qualities. However, 50% of the "Best" descriptions did note texture or surface qualities. It is surprising that specification of texture or color is found in so few of the descriptions. Further investigation is required to determine if this surprising statistic may be due to the nature of the describers' task, i.e., describing an object which is represented in a photograph, which is a very different task than the description of an object one is holding.

6.5.3 Use of Scale

One of the most surprising results revealed by this study involves the use of scale. 54% of all descriptions never mentioned scale. (28% = a little, 14% occasionally, 4% often, 0% constantly) The judges were instructed to note any use of size or scale. Therefore, if a describer mentioned the "little part on top" it counted as a use of scale. In light of this broad definition, the lack of use of scale is very surprising. The "Best" descriptions did reference scale more often than the average description. ("Best": 37.5% = never, 37.5% a little, 25% = occasionally. Average: 56% = never, 25% a little, 15% = occasionally, 4% often.[13]) I believe scale is an important element of a description, necessary for an accurate reconstruction. Object 0's description relies heavily on the use of measurements and scale.[14]

Another avenue of investigation may be the development of a vocabulary to communicate scale effectively. Many terms or word phrases communicate a sense of scale. Numbers and fractions such as 1/2, 2/3, 5, ten, may indicate a metric measure or number of

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[13]See Appendix A.11 Question #3

[14]See Section A.7.1 for the Object 0 description.

parts. Many terms indicate size, (big, small, tall, thin, width), while other terms depend on a pre-defined section for comparison, (equal, fattest, smaller, thickest). Further research is necessary to investigate the use of scale in a description and to determine how much scale is required for an effective description.

6.5.4 Positioning, Placement & Accurate Vocabulary

Evidence supports the conclusion that accurate positioning and placement of parts and accurate use of vocabulary contribute significantly to a successful reconstruction. *(pos & place:* $r = .748$, *vocabulary:* $r = .536, p < .05$) The Top-14 descriptions made extensive use of accurate vocabulary and good position and placement methods. (Accurate vocabulary: often = 93%, constantly = 7%. Position & placement: occasionally = 7%, often = 86% constantly = 7%) Accurate use of vocabulary and accurate placement and positioning display a significant correlation with accurate scale and correctly shaped parts in the reconstructions. *(Vocabulary vs scale:* $r = .374$, *vocabulary vs correct parts:* $r = .652$, *pos & place vs scale:* $r = .568$, *pos & place vs correct parts:* $r = .652, p < .05$*)*

6.5.5 Repetition and Organization

Most subjects were not repetitive in their descriptions. (For all descriptions; never = 48%, a little = 48%, occasionally = 4%.) The communication model holds that some repetition may be necessary to return and add details to a part.[15] This view is substantiated by the inverse correlation between the excessive use of repetition and the efficient organization of a description. ($r = -.477, p < .05$) As expected, the better descriptions were more organized. See Appendix A.11, Question 15. The high correlation between organization of a description and how much a reconstruction resembles the object, further emphases the influence of organization. ($r = .584, p < .05$)

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[15]See Section 3.3 for the definition of the repetition and organization attributes.

6.5.6 Constraints, Constructive and Static Techniques

A static description technique is defined as a phrase that depicts a state, e.g., "the bent cylinder." Conversely, constructive techniques are word phrases that describe an action: "...then you bend the cylinder....." Assigning all verb phrases as constructive is an inaccurate oversimplification of the distinction. As this study examines spontaneous verbal descriptions, it was sometimes difficult to differentiate between the two techniques: "The curvey line goes up then down." A constraint is defined as a limiting element; "Bend the cylinder until it is in a "U" shape." or "Cut halfway into the sphere." Given these examples, one expected to see a correlation between constructive and constraint techniques ($r = .406$, $p < .05$).

The describers tended to use static techniques over constructive techniques. (For all descriptions, static; never = 0%, A Little = 17%, occasionally = 40%, often = 37%, constantly = 6% vs constructive; never = 7%, a little = 34%, occasionally = 37%, often = 21%, constantly = 1%) However, there is some evidence that the better descriptions did use more constructive and constraint techniques. Of the Top-14 descriptions, 29% used constructive techniques often and 29% used constraint techniques occasionally, (see Appendix A.11). There is a correlation between the appearance of correctly shaped parts in reconstructions and the use of constraints in descriptions ($r = .388, p < .05$). This suggests the use of constructive and constraint techniques may be a tool for description.

6.5.7 References to Functionality

Few of the descriptions ever referred to functionality. (For all the descriptions; never = 77%, A Little = 14%, Occasionally = 4%) This stands to reason, as the description task strictly forbids the use of "cultural terms." It is difficult to contrive a reference to functionality without violating this directive. Hence, the question on the use of functionality (as well as the use of analogies) is in reality a check on the adherence to the description task. In addition, the use of functionality may be low due to the class of objects described, i.e., wooden sculptures. If functionality was mentioned, it was generally confined to a reference to the use of the bowl, i.e., Object 4. Therefore, I believe if the objects being described were objects commonly used as tools, and if the description task did not forbid the use of "cultural terms," we would have seen a higher frequency of the use of functionality.

6.5.8 Use of Analogies

The describers were not allowed to use analogies, i.e., comparisons to familiar objects. Analogies were described as "cultural references" in the instructions. I watched as subjects groped for a geometric term or phrase. Sometimes, they would knowingly violate the restriction on cultural phrases, as if they could not describe the object in any other way. It is my belief that people are more comfortable using analogies than any other method of description. Therefore, one should not interpret the lack of use of analogies in this study as evidence that people do not use analogies to describe objects. Just the reverse. The use of analogies here is better thought of as a check on the subject's ability to attend to the task. However, it is not surprising to see the use of analogies in a few of the better descriptions.

6.5.9 Geometric Terms; 2D and 3D

Throughout this study, describers tended to predominately use either 2D terms or 3D terms. Most of the better descriptions tended to use more 3D terms than 2D terms. The use of 2D or 3D terms were influenced not only by the type of object described, but also by the describer's interpretation of the image, which as J. B. Deregowski has found, is tied to cultural differences. [Deregowski 89] However, for a description to be accurate, it must utilize terms of the correct dimensionality.

I suggest 2D terms may be used to accurately describe certain classes of objects, e.g., envelopes, lines, 2D objects. Since all of the objects submitted for description were 3D, it follows that the descriptions utilized more 3D terms. However, it should be noted that much of what we have learned about description techniques should apply equally well to the description of 2D objects as well as 3D objects.

The drawback to suggesting the use of mathematical and geometric terms, is that the describer did not feel free to suggest shape primitives outside of this domain. Terms such as "ball," "brick," "donut," etc., were excluded as "culturally dependent phrases" despite the fact that they may be more common terms for "sphere," "rectangular solid" and "torus." There are very few terms outside of geometric primitives that were permissible. Terms such as "bulbus," "squiggly" and "squish," may have some intrinsic value, in that they may be useful in augmenting a core vocabulary, but this has not yet been determined. A study which does not limit the vocabulary is required to clarify this issue.

It has been observed that occasionally a describer did mention a geometric primitive such as "cube" and the reconstructor did draw a square. The reason for this behavior may be varied. It could be the reconstructor's lack of attention to the task, or it may be the reconstructor draws a square and verbally describes it as a cube. This problem is beyond the scope of this thesis. I simply make the observation that this behavior does occasionally occur and make the suggestion that there must be an agreed upon mapping between the verbal label of a shape primitive and the pictorial representation of the shape.

6.6 How Good are Humans at Shape Description?

In this study, humans have proven to be inadequate describers, i.e., only 3% of the descriptions qualified as the "Best" descriptions. (That is, only 3% of the descriptions resulted in good reconstructions.) If the description is used to identify an object among a group of distractor objects, the descriptions are adequate.[16] But, if humans are required to

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[16]See Section 5.8.

re-create the shape, this task demands a higher level of detail generally lacking in this experiment's verbal descriptions. It is my opinion that humans have a large reliance on the use of analogies for description. Since this study inhibited the use of cultural terms (there by the use of analogies), it is not surprising that so few descriptions resulted in good reconstructions. Since the use of common-sense knowledge for machine reasoning is not yet well-understood, human users will have to be taught how to describe an object to a computer without the unrestricted use of references to culturally-assumed properties and functions of objects.

6.7 Results Summary

Overall, the judges' reliability figures were quite good: R = .917 for the descriptions and R = .949 for the reconstructions. Correlation coefficients averaged .787 among the judges for the descriptions and .871 for the reconstructions. Agreement rates for both descriptions and reconstructions was 89%.

An important fact is that only 2% (5) of the descriptions were unanimously judged to "probably result in an accurate reconstruction." Of the three groups (good, medium & bad), the "medium" group produced the highest mean score for reconstruction quality (good = 8.16, medium = 8.22, bad = 5.47). This suggests the judges are not accurate predictors of successful descriptions. That is, they can distinguish a "bad" description, but are unable to differentiate between a "good" description and a "medium" description. There is no significant difference between the "good" mean and the "medium" mean, $t = .125, p < .05$. There is a significant difference between the "good" and the "bad" means ($t = 6.597, p < .05$), and between the "medium" and "bad" means ($t = 5.479, p < .05$)

Reconstructions produced from the "ideal" description of Object 0 earned the highest mean score for reconstruction quality: 10.43. By the formulation of a linear regression, it has been established that the closer a description is to fulfilling the suggested attributes, the more likely it is to result in an accurate reconstruction.

As important as an introduction is in establishing a framework for the description, many describers neglected to start with one. The use of texture, color and other surface qualities was similarly infrequent. One of the most surprising results is the describers' neglect of scale. The attributes "correct positioning and placement" and "accurate vocabulary" have been identified as the most important attributes essential for a successful description and successful reconstruction. Organization of the descriptions, on the whole, was satisfactory, i.e., most subjects were not excessively repetitive in their descriptions. The majority of descriptions utilized static descriptive techniques. However, some successful descriptions utilized constructive and constraint techniques.

Frequency of reference to functionality and analogies was viewed as a measure of the subjects' attention to the description task. If, however, the objects described were useful everyday items, and the restriction against cultural phrases were lifted, I surmise that there would be a greater frequency of reference to functionality and analogies. As the use of common-sense knowledge for machine reasoning is not yet well-understood, however, human users will have to be taught how to describe an object to a computer without the unrestricted use of references to culturally-assumed properties and functions of objects.

In this study, 3D terms dominated the better descriptions. This is due, I believe, to the nature of the objects presented for description. I believe that both 2D objects and 3D objects can be described using the attributes I have identified in this thesis.

Chapter 7

Future Work

Interesting work is never completed. This chapter suggests several avenues for further investigation.

7.1 The Next Step

I'd like to continue the protocol analysis utilizing the principles of description which are presented in the next section. I suggest the same methodology; the only change would be the inclusion of the principles of description with the instructions for the describers, as given in the next section.[17] The restrictions on cultural phrases would stand, and in addition, the describers would describe the same nine objects. I surmise this procedure would improve the quality of the descriptions and therefore the reconstructions. The resulting data then can be examined for failures: providing information to improve the principles of description. The successful descriptions can be examined for additional information in regards to the creation of core vocabularies.

7.1.1 A Formula for Description

The ***organization*** is the structure of the description. First, the description should begin with an ***introduction*** or ***global overview***. The essential element of an introduction is the establishment of a shared coordinate system, followed by an overview of the object and the methods with which the description will proceed.[18] It has been observed the subjects tend to describe the largest and most simple element of an object *first*. This is permissible,

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[17]For the original instruction text, see Instructions for the Describers, Appendix A.1.

[18]See Section 6.5.1 for a full discussion of an introduction.

as long as other parts of the object can be described and placed in ***relationship*** to the first part described. Which brings us to the next principle of organization: Each part must be positioned in relation to an existing part. Hence, the first part that is described serves as a "corner stone" on which the remaining parts rest. Once all of the parts have been described, the speaker may return to a section to add detail. The ***change of focus*** or ***transition*** from one part to another must be explicitly expressed by the describer. ***All parts*** should be described completely noting size or ***scale***.

7.2 Linguistic Issues - Development of Core Vocabularies

I have only cast an eye down the avenues of linguistic exploration. This study has produced 252 verbal descriptions of 9 objects. Preliminary identification of a core vocabulary and the associated definitions of phrases may be accomplished by examination of selected descriptions. These phrases and terms should then be tested to find if their meaning is totally context dependent.

A core vocabulary could be broken down into different categories; 1) shape descriptors: e.g., "cube" and "cone". 2) prepositional phrases: on top of, to the left, behind. 3) actions: e.g., "cut", "bend", "twist".

The selection of a core vocabulary for shape descriptors brings us to an interesting problem: Assumptions about geometric shapes. Is a cylinder hollow or solid? Is a sphere hollow or solid? Some subjects assumed hollow, others did not, a few subjects determined the cylinder was hollow, but the sphere was solid. Future work in this area would include analysis of this question. This would be in effect, a definition of shape primitives and their verbal labels.

It has been observed that many of the best describers were computer graphics graduate students. They had a familiarity with geometric shapes, and most of all they were aware of the usefulness of a coordinate system. They would use phrases like "normal to the plane" which is a term most non-specialists would not know or understand. Hence, I need to develop a core vocabulary defining the coordinate system. Once the core vocabulary for the coordinate system is in place, the next step is to define a set of operations which position and place parts in relation to one another. This implies setting definitions for many terms or again developing a core vocabulary just for this purpose.

The creation of a core vocabulary for actions has a few interesting problems associated with it also. Right away I may use the term "cut," but how much should I cut? The delimiters for the actions must be flexible and easy to use. At this point in the work, I do not believe it is a matter of selecting vocabulary. Rather I believe the use of delimiters can be defined as "methods." (e.g., cut the sphere in half, cut the sphere into two portions of equal size, cut 1 inch off of the top of the sphere.) The definition of these "methods" will define the transformations, deformations, and manipulations humans use to transform shape primitives into objects.

7.3 Computer Simulation

Naturally, I am interested in teaching people to become better describers. One approach is to build a constrained natural language parser which uses the principles of description as a user interface. A user could describe the object and the object (as described) would appear on the screen. This tool would help to explore the methods and structures humans utilize to describe and create an object.

7.4 Robotic Applications

For some time to come, it appears that robotic agents will require guidance and advice from human operators in all but the most routine situations. Nevertheless, the use of robots for maintaining and repairing equipment in hostile environments -- e.g. damaged nuclear power plants, equipment on the ocean floor, space station exteriors -- is increasing. There will almost certainly be situations in which robot servicing agents encounter unexpected difficulties while the human operator is not able to view the work area wholly or in part. Therefore, verbal and textual communication techniques will be important to allow a human to instruct the agent how to effect the repair operation, utilizing geometric instructions in an unambiguous manner.

Similarly, it would be useful to provide robot vision systems with unambiguous geometric operators and descriptors for communicating with humans. This would provide a robot with a convenient means of describing recognized objects, but is perhaps more important in just those cases when objects cannot be recognized: it would allow the agent to describe -- in some detail -- the unidentified objects in view, allowing the human and robot to collaborate on the vision task.

Chapter 8

Thesis Summary

This thesis is an examination, through verbal protocol analysis, of the one-way transmission of shape information. A communication model was developed, and the hypothesized attributes of a "good" description were experimentally tested. The methodology consisted of several steps: Twenty-eight subjects viewed nine objects from a range of relatively simple 3D shapes. The subjects verbally described each object. The transcribed descriptions were analyzed for information content and syntactic features. Selected object descriptions were then presented to a second group of thirty subjects for reconstruction (i.e., drawing). The descriptions were evaluated with respect to the objects and subsequent reconstructions, and the reconstructions were evaluated with respect to the objects and their descriptions.

It was hypothesized that the following attributes are important to shape description: a description should be well *organized* with an *introduction*, avoiding *repetition*. *All parts* should be described completely using *accurate vocabulary*. *Relationships* between parts should be clear, concise and as accurate as possible, noting the *change of focus or transitions* between parts. *Scale* should be noted.

Overall, it was found that the closer the descriptions were to the hypothesized attributes, the more likely they were to result in accurate and recognizable reconstructions.

Appendix A
Appendix

A.1 Instructions for the Describer

You will be presented with several pictures of objects. The task is to verbally describe each object so that a person may reliably and unambiguously pick out this object from a large set of similar objects.

Do not use culturally dependent phrases, such as "It is shaped like a snake," or "This is a 'U' shaped object." This means that you cannot use functional terms such as "handle" or "container."

You may, however, use such phrases if you first define them in terms that do not contain cultural references.

You may use geometric or mathematical terms such as "cube" or "parallel."

Take all the time you need to make a complete description, but please try to make descriptions as CLEAR and CONCISE as is possible.

A.2 Evaluation Form for Descriptions

_________ Description Number

1) Did this description start with a global overview or introduction?

```
yes       no
 |----------|
```

2) At any time was appearance or texture of the surface specified?

```
yes       no
 |----------|
```

3) Was scale specified?

```
never   a little   occasionally   often   constantly
  |----------|------------|------------|------------|
```

4) Was the vocabulary used to specify a shape accurate?

```
never   a little   occasionally   often       always
  |----------|------------|------------|------------|
```

5) Was the description repetitious?

```
never   a little   occasionally   often   constantly
  |----------|------------|------------|------------|
```

6) Was the positioning or placement of each part clear and understandable?

```
never   a little   occasionally   often       always
  |----------|------------|------------|------------|
```

7) Did the describer use constraints?

```
never   a little   occasionally   often   constantly
  |----------|------------|------------|------------|
```

8) Did the describer refer to functionality?

```
never   a little   occasionally   often   constantly
  |----------|------------|------------|------------|
```

9) Did the describer use constructive techniques?

```
never   a little   occasionally   often   constantly
  |----------|------------|------------|------------|
```

10) Did the describer use static descriptions?

```
never   a little   occasionally   often   constantly
  |----------|------------|------------|------------|
```

11) Did the describer use analogies?

never a little occasionally often constantly

|----------|------------|------------|------------|

12) Did the describer use geometric terms?

never a little occasionally often constantly

|----------|------------|------------|------------|

13) Did the describer use 2D terms?

never a little occasionally often constantly

|----------|------------|------------|------------|

14) Did the describer use 3D terms?

never a little occasionally often constantly

|----------|------------|------------|------------|

15) Rate the organization of the description.

very bad bad average good very good

|----------|------------|------------|------------|

16) Do you think someone could draw an accurate reconstruction of this object from this description?

doubtful maybe probably

|----------|------------|

A.3 Explanation of Description Evaluation Form

1. Did this description start with a global overview or introduction? Yes or No

   "A global overview or introduction" is defined as any indication used by the describer to give the audience a frame of reference from which to start. Examples: "This object is made up of three parts." "This object is large and round." "I will first describe the top then..."

2. At any time was appearance or texture of the surface specified?
   Yes or No

   Did the describer mention that the surface was smooth, rough, wooden, colored, etc.?

3. Was scale specified?
   never - a little - occasionally - often - constantly

   "Never" indicates that scale was not mentioned in the whole description. "Constantly" indicates that scale was mentioned for each part; i.e. scale was cited enough times to give an accurate indication of the relationships of size between all parts.

4. Was the vocabulary used to specify a shape accurate?
   never - a little - occasionally - often - always

   Did the describer use the term "square" when the term "cube" was required? Was the vocabulary imprecise or inconsistent?

5. Was the description repetitious?
   never - a little - occasionally - often - constantly

   Did the describer "skip around?" Did they repeat descriptions of a part?

6. Was the positioning or placement of each part clear and understandable?
   never - a little - occasionally - often - always

   Did the describer clearly indicate the location of a part? "Place X so that it sits on top of Y." "The block is pushed into the center of the circle." "The circle is placed on the top of the block, but off center, so that it touches the left edge."

7. Did the describer use constraints?
   never - a little - occasionally - often - constantly

   "Constraints" are defined as limiting phrases. "Bend it until it is in a U shape." "Push it until the surface breaks."

8. Did the describer refer to functionality?
   never - a little - occasionally - often - constantly

   "Functionality" is defined as referring to an object's use or application. "Make a small cut such that if you filled the bowl up with water, the water would drip out." "Bend it so that a hand may grasp it easily."

9. Did the describer use constructive techniques?
never - a little - occasionally - often - constantly

"Constructive techniques" are defined as methods that a person would use as if building an object. "First you cut off a corner, then you glue the top on..." "Saw the cylinder in half."

10. Did the describer use static descriptions?
never - a little - occasionally - often - constantly

In contrast, with a static description, there is no action. For example, "This object looks like a pyramid on its side."

11. Did the describer use analogies?
never - a little - occasionally - often - constantly

"Analogies" are references to real world objects. "This is like a big toe." "This is like a 5 year old tree." This includes direct substitutions. For example, using "beach ball" instead of "sphere."

12. Did the describer use geometric terms?
never - a little - occasionally - often - constantly

"Geometric terms" are terms or phrases commonly used in mathematics such as "solid of revolution," "sine wave," "axis," "cross-section," "parallelogram," "sector of circle," etc.

13. Did the describer use 2D terms?
never - a little - occasionally - often - constantly

Did the describer use 2D terms such as line, square, outline, etc.?

14. Did the describer use 3D terms?
never - a little - occasionally - often - constantly

Did the describer use 3D terms such as cube, sphere, bulbus, etc.?

15. Rate the organization of the description.
very bad - bad - average - good - very good

Did the describer describe all of the parts in an organized, ordered manner?

16. Do you think someone could draw an accurate reconstruction of this object from this description?
doubtful - maybe - probably

A.4 Instructions for Reconstructors

Your task is to draw from the following descriptions of objects. Please draw object as completely and precisely as possible. There is no time constraint. Each description describes one single object. Read all of the description before starting to draw. If there is a term or a phrase you do not recognize (such as "normal to the plane"), the investigator will define it for you.

A.5 Evaluation Form for Reconstructions

```
________    Reconstruction Number             ________    Judge

1) At any time was appearance or texture of the surface specified?
    (e.g. coloring, shadowing, wood grain, etc.)
      no        yes
      |----------|

2) How accurate was the use of scale?
   very bad     bad          ok          good     very good
      |----------|------------|------------|------------|

3) Are all the parts present?
    none       a few         most      almost all      all
      |----------|------------|------------|------------|

4) Was the positioning or placement of each part accurate?
    never    a little    occasionally    often        always
      |----------|------------|------------|------------|

5) How many parts have the correct shape?
    none        a few        most      almost all      all
      |----------|------------|------------|------------|

6) How inaccurate are the incorrectly shaped parts?
   completely   mostly      moderately  some what  slightly
   inaccurate  inaccurate  inaccurate  inaccurate inaccurate
      |----------|------------|------------|------------|

7) Did the reconstructor use 2D elements?
    never    a little    occasionally    often        always
      |----------|------------|------------|------------|

8) Did the reconstructor use 3D elements?
    never    a little    occasionally    often        always
      |----------|------------|------------|------------|

9) Overall, how much does this reconstruction resemble the object?
   not at all  a little   fairly close   close     very close
      |----------|------------|------------|------------|

10) In your opinion, how good was the reconstructor's drawing ability?
   very bad     bad          ok          good     very good
      |----------|------------|------------|------------|
```

A.6 Distribution of Descriptions

Distribution of descriptions based on the score of question "Do you think someone could draw an accurate reconstruction of this object from this description?" The left column is the score (between 3 and 9). The descriptions are labeled individually; the first digit is the object number, the second number is the describer number. A "NIL" indicates no descriptions received that score.

For OBJ 1
score
3 (1 38) (1 35) (1 34) (1 32) (1 21) (1 15) (1 14) (1 10)
4 (1 31) (1 29) (1 25) (1 23) (1 20) (1 19)
5 (1 36) (1 26) (1 18) (1 11)
6 (1 37) (1 33) (1 30) (1 28) (1 24) (1 22)
7 (1 27) (1 16) (1 13)
8 (1 12)
9 NIL

For OBJ 2
3 (2 38) (2 37) (2 34) (2 32) (2 31) (2 30) (2 29) (2 27) (2 26) (2 25) (2 24) (2 23) (2 19)
(2 15) (2 14) (2 12) (2 10)
4 (2 36) (2 22) (2 21) (2 16) (2 11)
5 (2 28) (2 13)
6 (2 35) (2 33) (2 18)
7 (2 20)
8 NIL
9 NIL

For OBJ 3
3 (3 34) (3 33) (3 32) (3 31) (3 19) (3 15) (3 14)
4 (3 29) (3 25) (3 22) (3 21) (3 16)
5 (3 37) (3 28) (3 20) (3 18) (3 11)
6 (3 38) (3 36) (3 23) (3 10)
7 (3 35) (3 30) (3 26) (3 13) (3 12)
8 (3 24)
9 (3 27)

For OBJ 4
3 (4 38) (4 34) (4 28) (4 26) (4 24) (4 20) (4 19) (4 14) (4 10)
4 (4 35) (4 32) (4 23) (4 16) (4 15)
5 (4 36) (4 33) (4 31) (4 30) (4 29) (4 25) (4 22)
6 (4 37) (4 27)
7 (4 21) (4 18) (4 11)
8 (4 13) (4 12)
9 NIL

For OBJ 5
3 (5 29) (5 23) (5 15) (5 14)
4 (5 34) (5 31) (5 20)
5 (5 32) (5 30) (5 28) (5 26) (5 25) (5 21) (5 12)
6 (5 38) (5 27) (5 11) (5 10)
7 (5 37) (5 36) (5 35) (5 33) (5 22) (5 19) (5 18) (5 13)
8 (5 24) (5 16)
9 NIL

For OBJ 6
3 (6 38) (6 34) (6 33) (6 31) (6 15) (6 14) (6 10)
4 (6 35) (6 32) (6 29) (6 26)
5 (6 30) (6 19) (6 16)
6 (6 36) (6 25) (6 23) (6 13)
7 (6 28) (6 22) (6 21) (6 20)
8 (6 27) (6 24) (6 18)
9 (6 37) (6 12) (6 11)

For OBJ 7
3 (7 36) (7 31) (7 26) (7 20) (7 15) (7 14) (7 10)
4 (7 34) (7 32) (7 19) (7 13) (7 11)
5 (7 38) (7 37) (7 29) (7 24)
6 (7 25) (7 23) (7 21) (7 18) (7 16)
7 (7 35) (7 33) (7 30) (7 28) (7 22) (7 12)
8 NIL
9 (7 27)

For OBJ 9
3 (9 37) (9 36) (9 35) (9 34) (9 31) (9 29) (9 27) (9 26) (9 25) (9 22) (9 19) (9 18) (9 15)
(9 14) (9 11) (9 10)
4 (9 38) (9 32) (9 30) (9 23) (9 21)
5 (9 33) (9 28) (9 24) (9 13)
6 (9 20) (9 16) (9 12)
7 NIL
8 NIL
9 NIL

For OBJ 10
3 (10 38) (10 34) (10 29) (10 21) (10 15) (10 14)
4 (10 37) (10 33) (10 32) (10 30) (10 25) (10 22)
5 (10 36) (10 35) (10 31) (10 28) (10 23) (10 13) (10 11)
6 (10 26) (10 18) (10 12) (10 10)
7 (10 27) (10 24) (10 20) (10 19) (10 16)
8 NIL
9 NIL

A.7 Descriptions Submitted to Reconstructors

A.7.1 Object 0 Description

0-9 This is a wooden object consisting of three parts. The first part is a rectangle, the second part is a triangular solid, the third part is a bent cylinder.

The first part is a rectangle of dimensions 9 inches tall by 3 1/2 inches wide by 3 inches deep. It is positioned such that it is standing 9 inches tall, and a 3 1/2 inch side is facing you.

The second part is a right triangle which is 1 1/2 inches thick. (A right triangle is a triangle where one of the vertices is a 90 degree angle.) The triangular solid is positioned in front of the rectangle such that the right angle of the triangular solid is on the lower right and the back plane of the triangular solid meets the front plane of the rectangle. The triangular solid is 9 inches tall, 5 1/2 inches wide and 1 1/2 inches thick (deep). Both the triangular solid and the rectangle are positioned such that their right side faces form one contiguous plane 9 inches tall by 4 1/2 inches deep (1 1/2 + 3).

The third part, is a cylinder, 6 inches in length, which has been bent into an arch. The cylinder maintains a 3 inch width all along its form. One end of the cylinder is attached to the left side of the standing rectangle, with the cylinder's center positioned 3 1/2 inches down from the top of the rectangle. The other end of the cylinder comes around to the front of the object.

Overall the object has been sanded to a fine smooth surface. However, on the front face of the triangular solid part, a triangle has been outlined about 1/2 inch away from the edge of the face. Inside the outline the surface has been dappled. All parts are made out of dark wood, except the cylinder, which is made of a blond color wood.

A.7.2 Group 1

1-12 Take the standard definition of a box that we have covered, it's a box, rectangular prism, much flatter than it is longer than it is flat and on the right side of this rectangular prism is a slightly flattened tube that wiggles that tapers to its end away from the box and it's wavy. If you were to graph a very flat sine wave it would look like that. On the other side is a foreshortened mirror image of what was on the right side, with fewer curves. It's about half the length so it only has . . . The one on the right starts from the box, comes down on the page, goes up on the page and then comes down again, this on on the right, the one on the left goes down and up.

2-22 Is a whole that is made up of two parts, its sort of like a body and a cover but if it weren't for the line between the body and the cover you could say that its just one shape and this one shape looks like three cylinders with there flat side down, sitting next to each other and except that the top isn't just three circles, but at the top they seem to melt into each other and they melt into each other so they are all touching, not just by this two point set which each of the circles, that would be the top .. .but there is sort of a thicker surface at top and this surface is certainly curved and its irregular but it's got something spiral to it and the, as the top really starts, the limitation between the top part and the bottom part is, the top part stops where you see, where the top begins is also where the shape starts becoming irregular and there is a very clear dividing line between the two so it looks as though you could just lift the top of and the surface again looks like wood and it has a few lines on it, random outlines.

3-27 This is the first object that doesn't appear to be all wooden, or necessarily all wooden. There are two bent cylinders, one is a little bit shorter than the other. You can describe them as maybe three and five units or 3 1/2 and 5 units long, and they are bent to about a 1/5 of a circle into an arc, they are not uniformly bent. They tend to straighten at the ends, and they appear wooden. They are bent in the same direction so that they are parallel. There is an equal space between them. The caps at the end, I should describe their diameter, it is, the diameter of the bent cylinders are equal and are about 1/4 or a 1/5 of the length of the shorter cylinder. I'll describe the caps at the ends. Very thin ring cylinders, slightly larger than the bent cylinders, but much shorter. They have a slightly larger diameter but they are very very short, so they can be called rings, and there are three rings at the end of each cylinder, at one end of each cylinder. But the last ring is pulled out. If you looked at them end on, you would actually see a square and then the first of the large rings and the square comes out about as far as the three rings combined do, about as wide and it's width is about half the length of one it's square sides. They do not appear to be wooden, they might be but they are not grained, so you would suspect they would be something else, perhaps, maybe a little shinier than the wood is. And the caps on the ends of the two bent cylinders are the same size and the same shape. At the other end of the two cylinders there is, you could say that the cylinders appear to be at the other end, going into two holes and they fit snuggly with the holes, each of them. Then you could guess that they might be joined somewhere inside what is a semicircular piece of wood. The semicircular piece of wood is roughly half a toroid, and if you sliced a toroid in half you would have one hole that appeared at two ends of it, and it is into each end of that hole that you would put the other end of one of the, each of the cylinders except there is more to this wooden toroid than usual. There is a darker, a black, I think, outcropping from the top. Looked at directly from above so that you'd see the toroid is a half circle, the outcropping would be a circle facing you and it is about, it comes up about the height, or the circle is raised about the height of and is about the same diameter as the caps, the capping rings on the other ends of the cylinders. And coming out of the circle is a cube raised on..., raised above the cylinder by some extension, raised above the circle by some extension of it with four outcroppings, I suppose. And they are rounded on the ends and are about, an increase in size to the ends and are about twice as long as they are tall, but they do not extend outside the circle that you would see if you looked down on the toroid from above. They go to the edge of it but do not extend beyond.

4-25 Is an object which looks like a bowl, again it is a bulbous object, hollow, and the top of it, the top of it fans out and is jagged as if it were peeled away or had exploded from the inside out. It looks like it is made of something hard, a hard substance and it has a marbled effect on the outside, and it rests on a little base. On the outside is marble, the inside is dark.

What shape is that base?

Round, it is a round base.

Can you describe the shape bulbous?

It is round and full, almost not quite spherical. It is not quite half a sphere, but it is rounded and it is hollow.

5-29 Incredibly beautiful. It is very rounded, but at the bottom of its roundness it seems to be becoming like a..., it goes in and comes to a flat, so it is sitting on itself. So imagine something sitting on itself, coming out in a roundness, getting very full and then coming to the top. Around the edges of the top it flips all the way inside because there is an interior to it so you know you can put something in it, like jewelry or flowers. It is made out of incredible piece of wood because the grain, again, is a very woodish looking grain but through it is a thin black line in the shape of either continents or you can almost make many many many pictures out of the little shape that the black lines are making on the object. It seems very lightweight, it is highly reflective and it is very pretty. You can't say what it looks like.

What is the overall shape?

It looks like a big eyeball.

But an eyeball is a sphere...

Yes, but an eyeball is pointed at the end.

6-11 It's primarily sort of a flattened cube, square on the top but not as tall as it is square, an inset into the top, off-centered so that it's touching one edge is a sort of domed disc thats sitting in the top of this block.

Can you describe what shape "domed" is?

It appears to be a piece of a sphere, something that's curved, under the top, a thin ledge of a sphere.

7-37 The basic shape of #7 is a circle, or I shall say since it is three dimensional, a slice of a cylinder, the slice made perpendicular to the central axis of the cylinder. So now there is a circular slice, it is wood, it appears to be from a tree. It appears to be a slice taken out of a tree trunk and then placed so that all the rings within the tree trunk are visible to the front. So that is standing on its end and it is slightly flattened on the bottom so it will stand up without rolling to either side. The central rings of this tree trunk are darker and then it is light on the outside of the circular slice. Sitting on top of this wooden circular slice is a small darker object, it would resemble the shape of a hyperbole, and then the lines of the hyperbole forming the boundaries of the object which appear to be also made of wood. It is dark in color and sitting on top of the slice. That smaller object is flat on top, so I guess the hyperbole has just been cut flat on top.

9-14 Starts from the base as a straight line moving up and then is bent, protrudes to the left, goes down, loops back up and continues upwards again.

10-15 It looks like a smooth piece of wood reminding of a mountain like structure, starting narrow at the bottom and going up higher, it appears to be going the same way on the other side. Smooth and of different pieces, as though put together. It has a triangular shape on one side. A mountain usually reminding one of a triangle, very high on the top, larger on top then the bottom.

A.7.3 Group 2

1-26 There is a rectangular piece of wood with a long curve running side to side through it. It extends out on either side, one side extends further than the other, and it tapers off to a thin point at either end, it's thickest where it enters the wood on either side. It goes up and down in a series of curves, two curves on the left hand side, three curves on the right hand side. It appears to be resting on the ground.

2-23 This piece also has references to landscape, very much like Wayne Higbe piece, it is a segmented piece, three curvilinear segments and on the backside it has two opposing bulges, so it is very much like and "E." My references to these are very much like a California Valley landscape. She's using spalted wood, in this case it is Maple, with a spalted fungus. How I would describe the shape, I would say it is a humped shape. It's humped like the humps on a camel. I wouldn't say it..., the clear mathematical reference is towards a sine wave, two sine waves put side-by-side. But the form does not allude to that because it is a much fuller form, much rounder form, much more like earth. It's composed, you could say that this object is composed of two cylinders on either end, connected by a triangle with another triangle cut out of that as a wedge, giving general shape.

3-19 Here we are dealing with a pair of tubes, a cylindrical cross-section and part of a circular or sections of tubing that bend, two separate cylindrical cross sections curved tubes meeting at, in another member which is, into which they fit they other member having circular or cylindrical forks for the two tubes and a another port perpendicular to these two cylindrical ports into which the two tubes fit. This other port is sealed of by a four headed knob, it's like a..., the shape would best be described, by a knob or a control on this cylindrical cross-section with at right, a pair of grips at right angles to each other. Okay, let me back off from that part of the structure and return to the cylindrical tubes. The tubes at the other end, at their other end, are sealed off by bolts, square headed bolts, they have square headed bolts that close off the cylindrical tubes at their other end while this cylindrical opening which is a third port of that member, into which the tubes go in, is sealed off by a structure which is, which consists of a member, a tapered pair of grips at right angles to each other, extending from a central square block. Do you think that would suffice? cylindrical tubes with sealed off at one end at one of their ends by what seem like bolts and meeting at the other end.

And you described the bolts as cubes?

Yea, square heads, rectangular head.

4-12 Take a sphere 8 1/2 inches in diameter and cut off the top and drop it so the bottom gets flattened a little, then pretend it's made out of clay, pull the edges so they flare out, because it's made of clay they'll break, it's a rounded bowl with a slightly flattened bottom and the edges flare out so the rim is very wide that's broken and has wide and deep cracks, underneath the bowl is a disc about 1 1 1/2 high that supports this bowl. The edge of the bowl is slightly jagged, it's not as if it was a clean cut.

5-16 If you took a sphere and then hollowed out the inside, so now you have this hollow, spherical outer shell. From the bottom of this hollow, spherical shell you then carved away uniformly around in all directions as if you were using a lathe to make it narrower at the base as you go up, so that the widest part of the object is not in the middle but maybe 2/3 of the way up, so that it is not a sphere but it is sort of a warped sphere in that the widest part of the object is not equal distance from the radius as the bottom of the sphere. The image of this, another way to describe that would be to take the sphere and pull from the bottom, elongate, pull it downwards, so it makes a sagging image. Anyway, that's the basic idea of the whole shape. The pulled-out sagging bottom is obviously cut horizontally to make a flat surface on the bottom so it stands upright. So the thinnest, most narrow sagging bottom is what it rests upon and it goes up so that the fattest part is high up in the object. It then curves in sharply at the top and as I mentioned before, it is hollow in the inside, the reason you can tell is because it has circular hole in the top of the object and you can see that the object is cut very thinly. You hollowed it out very well so that there is a very thin, the whole object is very thin in depth. In a way it reminds one of a picture of a globe, it looks like the texture of the object has very dark lines that sort of looks like countries shapes, but those few dark lines are the ones that really stick out at you, but if you look carefully at the texture of the grain as a whole it looks very smooth with some sort of wavy lines, look like a refraction on water. The object is very shiny, its a light colored wood and if the light is shined on it it reflects the light very well.

6-14 A shape of a block of wood which is that of a square with a moon sitting in the center of it, which is round.

7-27 Another cylinder end on so that you look at it as a circle. Length is a third of the diameter and placed up, this log, this cylinder. Well a side view of another cylinder except that the cylinder is wide and then quickly decreases in diameter until it is about 1/2 its original diameter and then it increases again to its original diameter, so the top is wide, narrow in the middle and wide again at the bottom. And then at the very bottom, the place where it rests on the other cylinder, it decreases slightly in diameter and it's a little less than half as tall as the bottom cylinder on which it rests. I should say it rests on end with a circular part on the bottom cylinder and it is probably about as long as the bottom cylinder is, but perhaps not quite.

9-21 This is an object outside. It is sitting on a hard rock base with a box support and then sticking out of that is a wooden object that starts out as sort of a beam going straight up out of the ground, but about 2/3 of the way up through the picture it curves around, droops over to the left and then comes forward, goes back up, droops over to the right and then goes back up, droops back a little bit and then goes up and finishes up as if it were the end of the beam that started on the bottom. This is a dark woodgrain texture. A beam is a rectangular beam, basically a square bottom and then it shoots up.

10-11 I'd say the primary shape is a prism, it's lying flat on one edge and it rises to a peak along the top, but the top edge is curved a little and at one end there is a triangular end to it, but that triangle does not extend all the way to the top edge of the prism, its sort of a flat triangle whereas the top of the prism is stretched up and rounded.

What shape is a prism?

It's a triangle that's extruded, pulled-out.

A.7.4 Group 3

1-14 We have that same square with a squiggly shape going through it, it looks like a snake going through the square. The shape would be a straight line that has been moved into curved shapes, and moves back and forth.

2-20 Consider if you will, to acquaint you with the base of this object, putting three cylindrical objects side by side. The object closest to you is the largest of the three, and the two cylinders next to it appear to be about the same size themselves and only a little bit smaller than the object closest to you. Now, on top of the cylinders appears to be a kind of terrain. And its as though you laid the terrain on top so it overlaps the cylinder just near the top as though you were putting a lid on a container except that this lid covers all three of them, its not separately on each one. Now, this terrain covering the first cylinder, taking a look at first the right half of it, has certain indentations and permeations in it. First of all the way it sits on this container is that on the right side it sits near the top of the container and as you go towards the left side it starts to bend down and cover more of the container in a semi-circular shape. Now looking at this and incorporation the terrain on top of the other two containers, consider the shape of an "M" and the first half of the "M" covers all of the first container and part of the second container, and the second half of the "M" covers most of the second container and all of the third container, and then the "M" comes back up just as an "M" would and has an indentation if you were to make an indentation, it has an indentation that reaches into the crack between the second and third container, and another indentation between the second and first container. As far as the top part is concerned, it looks to have three major bumps, mountains in the terrain, all of them at the bottom part of the "M" of the "M" analogy. It also has a pattern on it. The pattern is free form, its as though someone, looks kind of like the side of a mountain. Looks as if someone had just taken a paint brush or some sort of tool and free formed black lines and white and gray paint.

A mountain you would usually think of coming up, as being half of a diamond, but the mountain that I'm describing is as though it had been eroded and its kind of smooth, smooth dots so that it was more of a conical shape except its more of a sphere than a conical, in between a sphere and a conical.

An "M" shape, you would, think of taking a circle, squishing it so that you had equal sides, cutting that circle in half and moving the bottom half to meet the top half so that both ends of the circle were facing up.

3-18 Two wooden cylindrical objects, each bent so that it passes through a 90 degree change. One of them is bent more sharply than the other and is shorter than the other such that when the two of them are attached to another object, which they are attached to, the other object is a cylinder with two projections coming out of it. The projections are such that a cylindrical object can be plugged into the object. The two projections are such that the two cylindrical objects that are plugged in are parallel to each other. The projections are smoothly generated out of the cylinder. The cylinder has a cap on its top. The cap appears to have a rubber seal around it. There is a handle, a handle is an object designed to be turned by the hand, it is a shaft with four protrusions extending radially outward from the shaft. The protrusions are of a circular cross-section and their surfaces are smooth. The two cylindrical objects that are plugged into the larger object are curved to the left and have on the other end attached to them caps, which appear to be round cylindrical objects with a smaller diameter projection coming out of the end of them and the smaller diameter projection coming out of the end has been squared off and the end of the projection has been squared off and is rounded slightly.

P: What shape is the shaft?

That shaft is round where it enters the cap and where it meets the cap there is no discontinuity in shape, the shape is smooth as it comes up out of the cap and then it turns into a square shaft and the projections attached to the shaft where the shaft is square, just past that the square projection becomes circular again of a much smaller diameter than the square part of the shaft.

P: What shape is the cap?

The cap is round.

4-19 Here is a bulge, resting on a narrow base, a hemispherical bottom but the ends are splayed out. Now it is a receptacle but the top surface is jagged and extends fairly irregularly outward from a hemispherical bulb which it has for a base. The edges are jagged and irregular and appear to be slit and cut.

5-11 The primary shape is a hollowed out sphere that's slightly symmetrical on the vertical axis but its slightly longer and more pointed towards the bottom but then its flattened off at the very bottom so that it will stand up. The top is cut off so that it is hollow outside, or you can reach inside. An opening in the top about a third of the size.

6-36 Once again, a woodgrain box, in a square shape, although the front side seems to be a little bit imperfect, a little bit concave in. On the top of this square shaped box is a circle cut in the surface. The circle has been cut toward the front left part of the box. So you can see where the circle has been cut there is some black substance that fills the circle and it has depth and it appears as if it rises towards the center of this circle.

There is also a nice bright spotlight which is evident in the black circular stuff. Basically in the center of it and cascading down to the front. The box is set at possibly a 40 degree or 50 degree angle, whichever way you look at it. It is in shadows on the right front side, the left front side is lit, the left back side you cannot see and the right back side you can't see. The woodgrain on the right front side is parallel to the ground as well as the left front side. On the top the woodgrain on the front corner is diagonal on the box. On the left corner it is more parallel to the box and the woodgrain is wide, the lines are spread apart. On the back corner of the box it is kind of a blended effect, you can't see much woodgrain. On the right corner the woodgrain is once again parallel to the box but spread out.

7-26 This is shaped like a slightly uneven circle with one side flattened, extending backwards. It is like a cylinder on its side. The base, the side it is resting on is slightly flat. It has concentric rings inside it. On the uppermost part there is an object which looks like two ellipsoids placed on top of each other.

9-12 This is a statue on a pedestal. The pedestal has a box base and a very high thin box support mounted on top of the box space. It's a free form thing that looks a little bit of a side view of someone sitting cut from the middle of the torso down through the hip, imagine looking at the side view of someone sitting with their knees up, come down the hip curves back, your little indentation where the leg hip joint and up to a very short knee from a very rounded knee coming down vertically towards the foot, instead of a foot, it looks like there's another mirror image on the other side, your looking at the left side of the model, you kind of see the right leg. If you go down to where the feet would be instead the feet all become one big solid mass that's about the size of the ass. Then we go back up to the torso and the torso is rectangular cross section.

What shape is somebody's body?

Take a tube, a torso is like a tube, except this torso happens to be square across section, and mount it, take a tube and flatten it some, and took a sphere and stretched it so it's slightly fat and wrapped it 180 degrees around the cylinder and let it bulge out at the half-way point, that's what an ass is like, legs are cylinders attached to that, a 45 degree angle from the torso.

10-27 It is another wooden object with a rectangular base, twice as long as it is wide. It appears to have been made from 9 segments of wood, somehow joined. I say this because there are seams, or what appear to be seams in the wood, and differences in grain. On one end it has the beginning of a face coming up, but it only reaches about a 1/5 of the total height of the object. That's an isosceles triangle, much shorter than it is wide, because it is along the side and not, along the short side of the rectangle. From there the rest of the object is gentle sloping curves. It seems to slope inward everywhere from the base, then at the top only a small portion, small fraction of the size it is at the base is actually nearly as long but not nearly as wide and there appears to be some strange outcropping, a very thin plateau outcropping at the top, but only at one end and only about 1/3 of the base, no I would say about 1/5 of the long side of the base, and it does not appear to come too far out the other side. And the top of the object is not level with the base, it slopes. The higher side is where the isosceles triangle face begins to come up and the lower side is at the other end.

A.8 Spearman-Brown Reliability Figures for Descriptions and Reconstructions

Evaluation of descriptions, across all objects, across all questions:
R = .917

Evaluation of reconstructions, across all objects, across all questions: R = .949

Evaluation of descriptions across all objects and all questions: .917
Broken down by object across all questions:

Obj 1: .920	Obj 2: .909	Obj 3: .902	Obj 4: .910	Obj 5: .918	Obj 6: .928
Obj 7: .927	Obj 9: .925	Obj 10: .926			

Broken down by question across all objects:

Ques 1: .791	Ques 2: .950	Ques 3: .940	Ques 4: .754	Ques 5: .729	Ques 6: .746
Ques 7: .716	Ques 8: .887	Ques 9: .846	Ques 10: .820	Ques 11: .906	Ques 12: .862
Ques 13: .837	Ques 14: .861	Ques 15: .647	Ques 16: .745		

Evaluation of reconstructions across all objects and all questions: .949
Broken down by object across all questions:

OBJ: 0 .953	OBJ: 1 .954	OBJ: 2 .943	OBJ: 3 .907	OBJ: 4 .954	OBJ: 5 .956
OBJ: 6 .933	OBJ: 7 .946	OBJ: 9 .959	OBJ: 10 .970		

Broken down by question across all objects:

QUES: 1 .968	QUES: 2 .900	QUES: 3 .932	QUES: 4 .939	QUES: 5 .937	QUES: 6 .920
QUES: 7 .944	QUES: 8 .942	QUES: 9 .922	QUES: 10 .839		

A.9 Correlation Coefficients for Descriptions and Reconstructions

Evaluation of descriptions for each object across all questions:			
OBJ: 1	J1 vs J2&3: .789	J2 vs J1&3: .788	J3 vs J1&2: .805
OBJ: 2	J1 vs J2&3: .763	J2 vs J1&3: .802	J3 vs J1&2: .742
OBJ: 3	J1 vs J2&3: .765	J2 vs J1&3: .751	J3 vs J1&2: .747
OBJ: 5	J1 vs J2&3: .822	J2 vs J1&3: .794	J3 vs J1&2: .753
OBJ: 6	J1 vs J2&3: .807	J2 vs J1&3: .809	J3 vs J1&2: .820
OBJ: 7	J1 vs J2&3: .805	J2 vs J1&3: .830	J3 vs J1&2: .792
OBJ: 9	J1 vs J2&3: .794	J2 vs J1&3: .792	J3 vs J1&2: .825
OBJ: 10	J1 vs J2&3: .836	J2 vs J1&3: .848	J3 vs J1&2: .732
Evaluation of descriptions for each question across all objects:			
QUES: 1	J1 vs J2&3: .556	J2 vs J1&3: .476	J3 vs J1&2: .642
QUES: 2	J1 vs J2&3: .878	J2 vs J1&3: .827	J3 vs J1&2: .884
QUES: 3	J1 vs J2&3: .813	J2 vs J1&3: .870	J3 vs J1&2: .834
QUES: 4	J1 vs J2&3: .503	J2 vs J1&3: .474	J3 vs J1&2: .539
QUES: 5	J1 vs J2&3: .483	J2 vs J1&3: .416	J3 vs J1&2: .520
QUES: 6	J1 vs J2&3: .536	J2 vs J1&3: .485	J3 vs J1&2: .463
QUES: 7	J1 vs J2&3: .392	J2 vs J1&3: .466	J3 vs J1&2: .511
QUES: 8	J1 vs J2&3: .777	J2 vs J1&3: .742	J3 vs J1&2: .651
QUES: 9	J1 vs J2&3: .694	J2 vs J1&3: .678	J3 vs J1&2: .569
QUES: 10	J1 vs J2&3: .619	J2 vs J1&3: .633	J3 vs J1&2: .557
QUES: 11	J1 vs J2&3: .757	J2 vs J1&3: .774	J3 vs J1&2: .759
QUES: 12	J1 vs J2&3: .697	J2 vs J1&3: .667	J3 vs J1&2: .661
QUES: 13	J1 vs J2&3: .639	J2 vs J1&3: .605	J3 vs J1&2: .651
QUES: 14	J1 vs J2&3: .702	J2 vs J1&3: .710	J3 vs J1&2: .610
QUES: 15	J1 vs J2&3: .392	J2 vs J1&3: .384	J3 vs J1&2: .362
QUES: 16	J1 vs J2&3: .536	J2 vs J1&3: .459	J3 vs J1&2: .484
Evaluations of reconstructions for each object across all questions:			
OBJ: 0	J1 vs J2&3: .857	J2 vs J1&3: .889	J3 vs J1&2: .867

OBJ: 1	J1 vs J2&3: .869	J2 vs J1&3: .878	J3 vs J1&2: .877
OBJ: 2	J1 vs J2&3: .878	J2 vs J1&3: .822	J3 vs J1&2: .840
OBJ: 3	J1 vs J2&3: .750	J2 vs J1&3: .770	J3 vs J1&2: .777
OBJ: 4	J1 vs J2&3: .849	J2 vs J1&3: .867	J3 vs J1&2: .903
OBJ: 5	J1 vs J2&3: .897	J2 vs J1&3: .827	J3 vs J1&2: .913
OBJ: 6	J1 vs J2&3: .809	J2 vs J1&3: .848	J3 vs J1&2: .812
OBJ: 7	J1 vs J2&3: .865	J2 vs J1&3: .863	J3 vs J1&2: .834
OBJ: 9	J1 vs J2&3: .872	J2 vs J1&3: .893	J3 vs J1&2: .895
OBJ: 10	J1 vs J2&3: .916	J2 vs J1&3: .908	J3 vs J1&2: .917

Evaluation of reconstructions for each question across all objects:

QUES: 1	J1 vs J2&3: .882	J2 vs J1&3: .911	J3 vs J1&2: .935
QUES: 2	J1 vs J2&3: .732	J2 vs J1&3: .741	J3 vs J1&2: .780
QUES: 3	J1 vs J2&3: .843	J2 vs J1&3: .855	J3 vs J1&2: .766
QUES: 4	J1 vs J2&3: .824	J2 vs J1&3: .827	J3 vs J1&2: .859
QUES: 5	J1 vs J2&3: .818	J2 vs J1&3: .811	J3 vs J1&2: .869
QUES: 6	J1 vs J2&3: .767	J2 vs J1&3: .793	J3 vs J1&2: .818
QUES: 7	J1 vs J2&3: .861	J2 vs J1&3: .825	J3 vs J1&2: .859
QUES: 8	J1 vs J2&3: .851	J2 vs J1&3: .825	J3 vs J1&2: .854
QUES: 9	J1 vs J2&3: .808	J2 vs J1&3: .808	J3 vs J1&2: .777
QUES: 10	J1 vs J2&3: .575	J2 vs J1&3: .675	J3 vs J1&2: .652

A.10 Agreement Rates for Descriptionsand Reconstructions

A.10.1 Agreement Rates of Description Evaluations

For objects: 1 2 3 4 5 6 7 9 10
For questions: 3 4 5 6 7 8 9 10 11 12 13 14 15
all-agree: 1004
two-agree: 1891 and 1689 next door; 89%
none-agree: 381
agreement rate: 88%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 3
all-agree: 149
two-agree: 93 and 92 next door; 99%
none-agree: 10
agreement rate: 96%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 4
all-agree: 62
two-agree: 162 and 154 next door; 95%
none-agree: 28
agreement rate: 89%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 5
all-agree: 106
two-agree: 127 and 119 next door; 94%
none-agree: 19
agreement rate: 92%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 6
all-agree: 54
two-agree: 167 and 147 next door; 88%
none-agree: 31
agreement rate: 88%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 7
all-agree: 76
two-agree: 163 and 158 next door; 97%
none-agree: 13
agreement rate: 95%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 8
all-agree: 182
two-agree: 66 and 63 next door; 95%
none-agree: 4
agreement rate: 98%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 9
all-agree: 51
two-agree: 162 and 132 next door; 81%
none-agree: 39
agreement rate: 85%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 10
all-agree: 55
two-agree: 164 and 137 next door; 84%
none-agree: 33
agreement rate: 87%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 11
all-agree: 83
two-agree: 150 and 139 next door; 93%
none-agree: 19
agreement rate: 92%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 12
all-agree: 62
two-agree: 161 and 152 next door; 94%
none-agree: 29
agreement rate: 88%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 13
all-agree: 44
two-agree: 161 and 135 next door; 84%
none-agree: 47
agreement rate: 81%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 14
all-agree: 53
two-agree: 159 and 139 next door; 87%
none-agree: 40
agreement rate: 84%

For objects: 1 2 3 4 5 6 7 9 10
For questions: 15
all-agree: 27
two-agree: 156 and 122 next door; 78%
none-agree: 69
agreement rate: 73%

For objects: 1
For questions: 3 4 5 6 7 8 9 10 11 12 13 14 15
all-agree: 107
two-agree: 212 and 187 next door; 88%
none-agree: 45
agreement rate: 88%

For objects: 2
For questions: 3 4 5 6 7 8 9 10 11 12 13 14 15
all-agree: 98
two-agree: 213 and 184 next door; 86%
none-agree: 53
agreement rate: 85%

For objects: 3
For questions: 3 4 5 6 7 8 9 10 11 12 13 14 15
all-agree: 103
two-agree: 216 and 194 next door; 90%
none-agree: 45
agreement rate: 88%

For objects: 4
For questions: 3 4 5 6 7 8 9 10 11 12 13 14 15
all-agree: 104
two-agree: 218 and 187 next door; 86%
none-agree: 42
agreement rate: 88%

For objects: 5
For questions: 3 4 5 6 7 8 9 10 11 12 13 14 15
all-agree: 103
two-agree: 208 and 192 next door; 92%
none-agree: 53
agreement rate: 85%

For objects: 6
For questions: 3 4 5 6 7 8 9 10 11 12 13 14 15
all-agree: 121
two-agree: 205 and 187 next door; 91%
none-agree: 38
agreement rate: 90%

For objects: 7
For questions: 3 4 5 6 7 8 9 10 11 12 13 14 15
all-agree: 129
two-agree: 195 and 179 next door; 92%
none-agree: 40
agreement rate: 89%

For objects: 9
For questions: 3 4 5 6 7 8 9 10 11 12 13 14 15
all-agree: 121
two-agree: 211 and 193 next door; 91%
none-agree: 32
agreement rate: 91%

For objects: 10
For questions: 3 4 5 6 7 8 9 10 11 12 13 14 15
all-agree: 118
two-agree: 213 and 186 next door; 87%
none-agree: 33
agreement rate: 91%

A.10.2 Agreement Rates of Reconstruction Evaluations

For objects: 0 1 2 3 4 5 6 7 9 10
For questions: 2 3 4 5 6 7 8 9 10
all-agree: 1103
two-agree: 1448 and 1252 next door; 86%
none-agree: 329
agreement rate: 89%

For objects: 0 1 2 3 4 5 6 7 9 10
For questions: 2
all-agree: 76
two-agree: 198 and 180 next door; 91%
none-agree: 46
agreement rate: 86%

For objects: 0 1 2 3 4 5 6 7 9 10
For questions: 3
all-agree: 220
two-agree: 88 and 74 next door; 84%
none-agree: 12
agreement rate: 96%

For objects: 0 1 2 3 4 5 6 7 9 10
For questions: 4
all-agree: 130
two-agree: 158 and 137 next door; 87%
none-agree: 32
agreement rate: 90%

For objects: 0 1 2 3 4 5 6 7 9 10
For questions: 5
all-agree: 137
two-agree: 155 and 140 next door; 90%
none-agree: 28
agreement rate: 91%

For objects: 0 1 2 3 4 5 6 7 9 10
For questions: 6
all-agree: 84
two-agree: 200 and 180 next door; 90%
none-agree: 36
agreement rate: 89%

For objects: 0 1 2 3 4 5 6 7 9 10
For questions: 7
all-agree: 154
two-agree: 124 and 96 next door; 77%
none-agree: 42
agreement rate: 87%

For objects: 0 1 2 3 4 5 6 7 9 10
For questions: 8
all-agree: 152
two-agree: 125 and 97 next door; 78%
none-agree: 43
agreement rate: 87%

For objects: 0 1 2 3 4 5 6 7 9 10
For questions: 9
all-agree: 87
two-agree: 193 and 167 next door; 87%
none-agree: 40
agreement rate: 88%

For objects: 0 1 2 3 4 5 6 7 9 10
For questions: 10
all-agree: 63
two-agree: 207 and 181 next door; 87%
none-agree: 50
agreement rate: 84%

For objects: 0
For questions: 1 2 3 4 5 6 7 8 9 10
all-agree: 146
two-agree: 146 and 133 next door; 91%
none-agree: 28
agreement rate: 91%

For objects: 1
For questions: 1 2 3 4 5 6 7 8 9 10
all-agree: 143
two-agree: 146 and 127 next door; 87%
none-agree: 31
agreement rate: 90%

For objects: 2
For questions: 1 2 3 4 5 6 7 8 9 10
all-agree: 107
two-agree: 180 and 165 next door; 92%
none-agree: 33
agreement rate: 90%

For objects: 3
For questions: 1 2 3 4 5 6 7 8 9 10
all-agree: 87
two-agree: 198 and 174 next door; 88%
none-agree: 35
agreement rate: 89%

For objects: 4
For questions: 1 2 3 4 5 6 7 8 9 10
all-agree: 152
two-agree: 141 and 117 next door; 83%
none-agree: 27
agreement rate: 92%

For objects: 5
For questions: 1 2 3 4 5 6 7 8 9 10
all-agree: 172
two-agree: 123 and 93 next door; 76%
none-agree: 25
agreement rate: 92%

For objects: 6
For questions: 1 2 3 4 5 6 7 8 9 10
all-agree: 111
two-agree: 170 and 146 next door; 86%
none-agree: 39
agreement rate: 88%

For objects: 7
For questions: 1 2 3 4 5 6 7 8 9 10
all-agree: 135
two-agree: 140 and 117 next door; 84%
none-agree: 45
agreement rate: 86%

For objects: 9
For questions: 1 2 3 4 5 6 7 8 9 10
all-agree: 155
two-agree: 131 and 118 next door; 90%
none-agree: 34
agreement rate: 89%

For objects: 10
For questions: 1 2 3 4 5 6 7 8 9 10
all-agree: 186
two-agree: 102 and 91 next door; 89%
none-agree: 32
agreement rate: 90%

A.11 Description Graphs

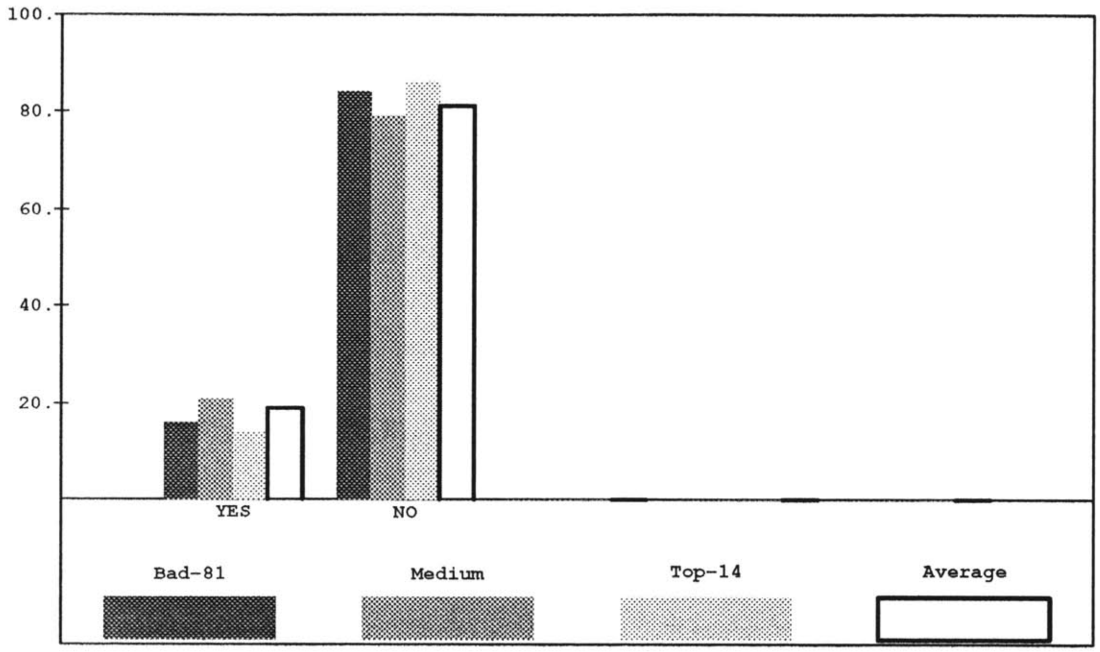

Figure A-1: Question #1 Did this description start with a global overview or introduction?

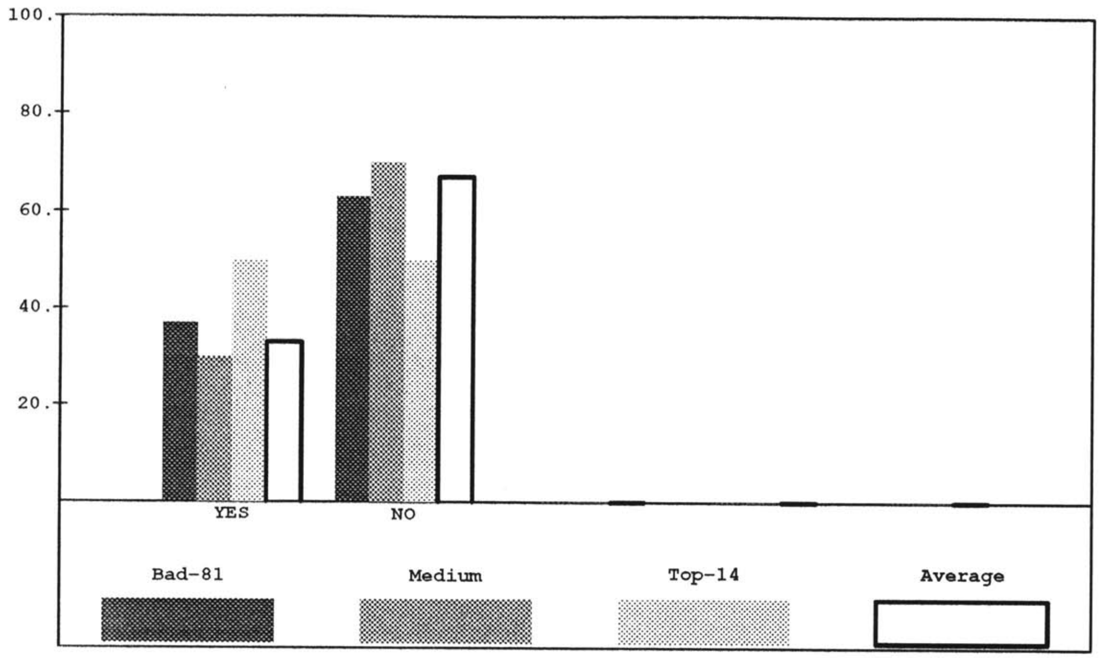

Figure A-2: Question #2 At any time was appearance or texture of the surface specified?

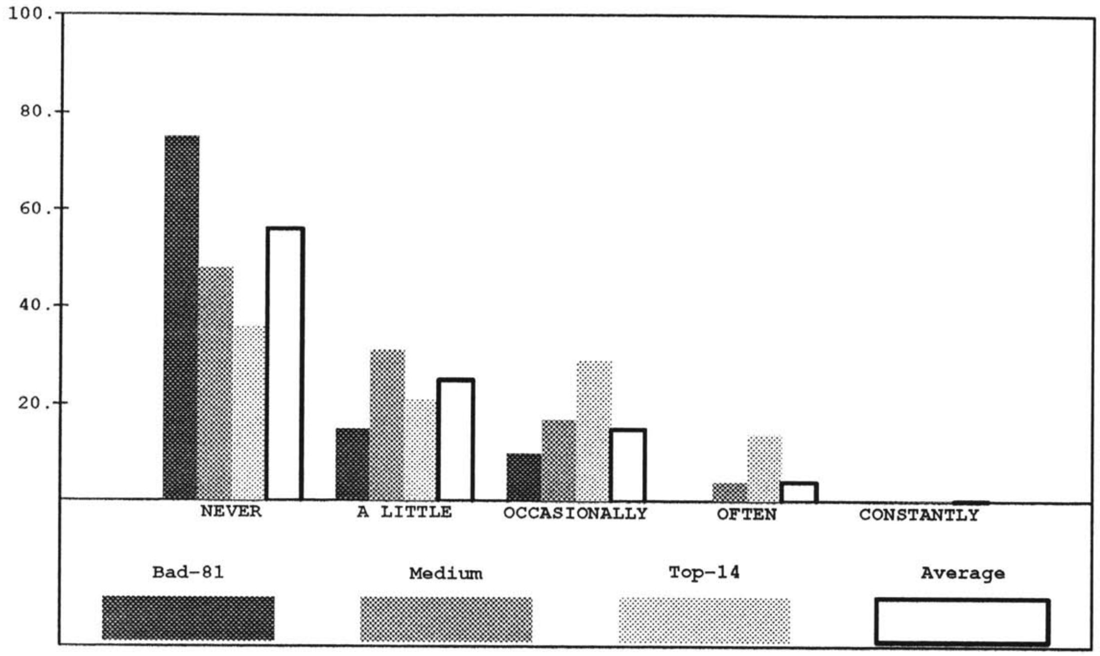

Figure A-3: Question #3 Was scale specified?

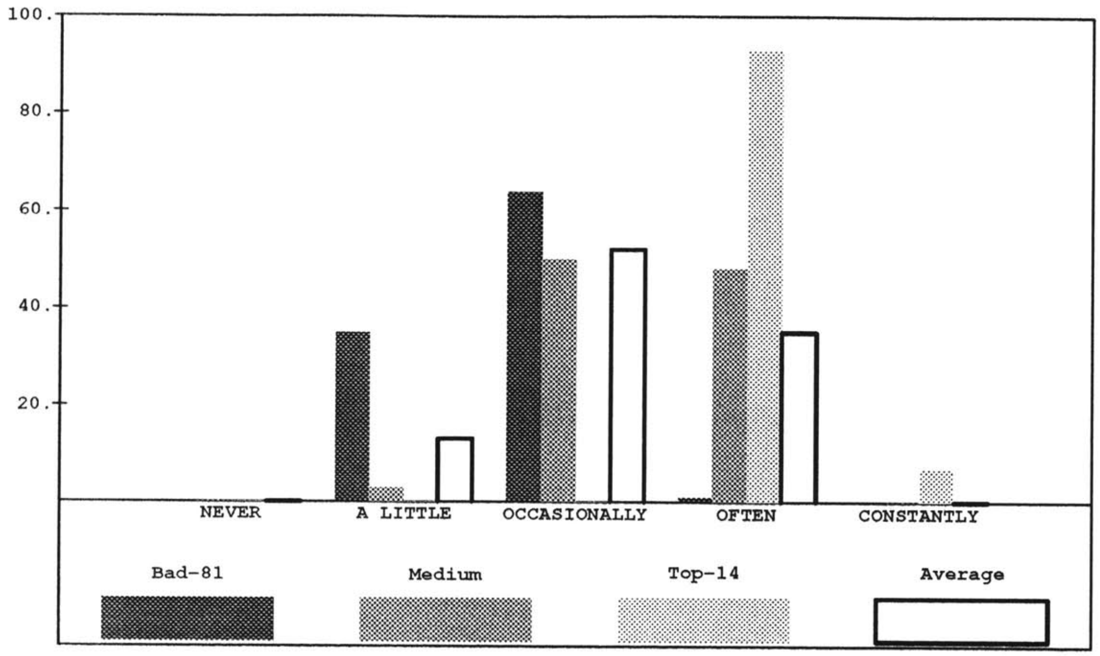

Figure A-4: Question #4 Was the vocabulary used to specify a shape accurate?

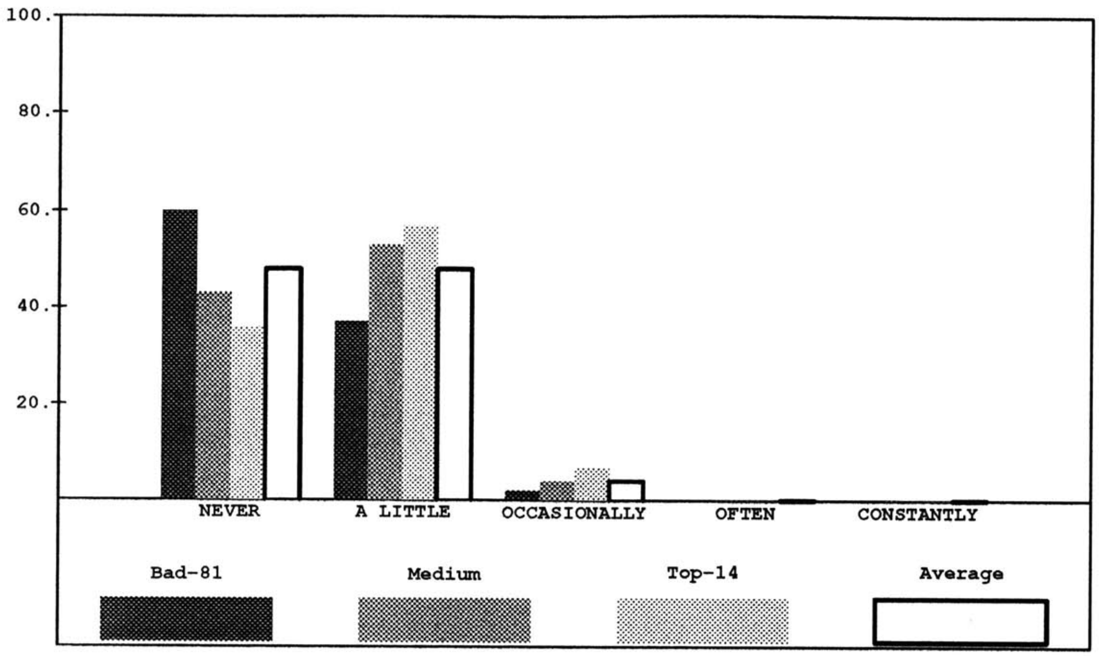

Figure A-5: Question #5 Was the description repetitious?

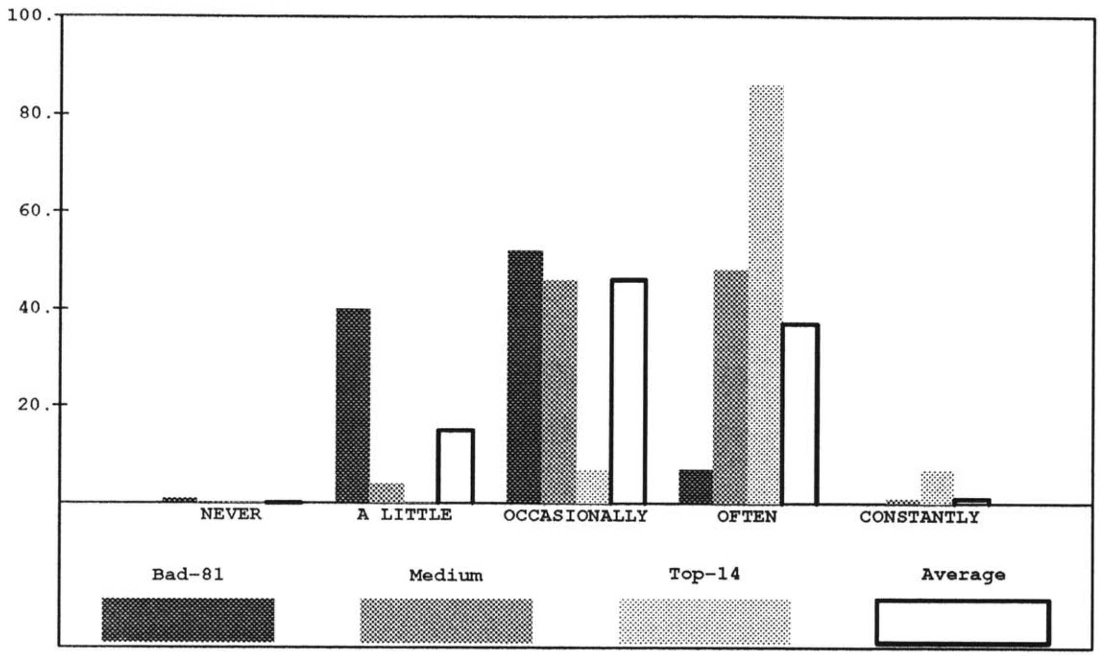

Figure A-6: Question #6 Was the positioning and placement of each part clear and understandable?

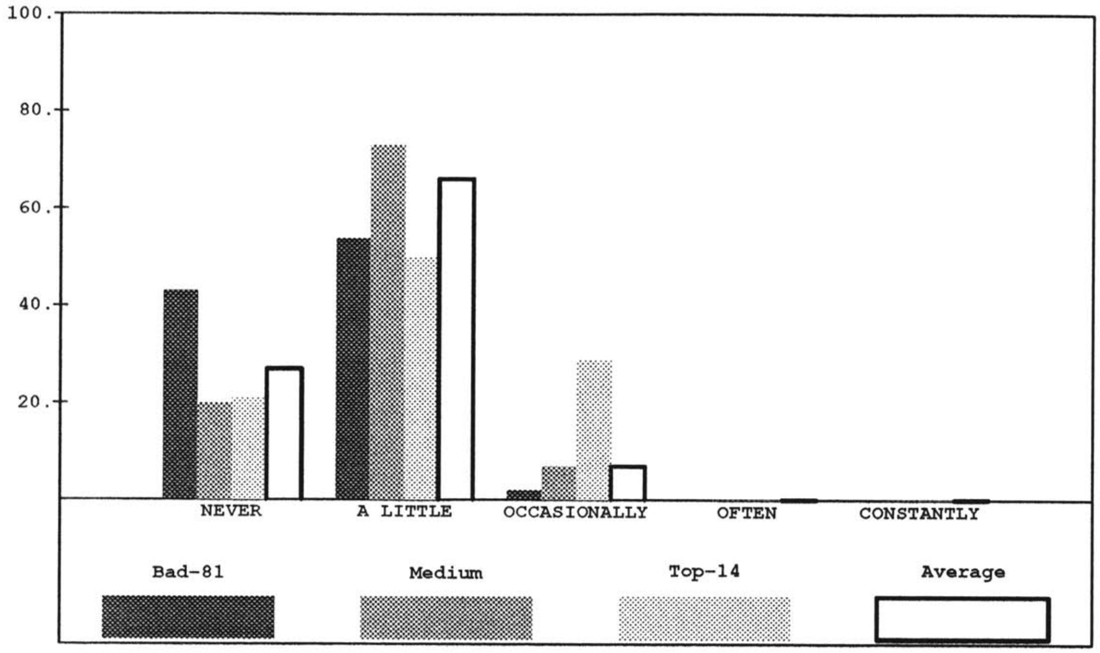

Figure A-7: Question #7 Did the describer use constraints?

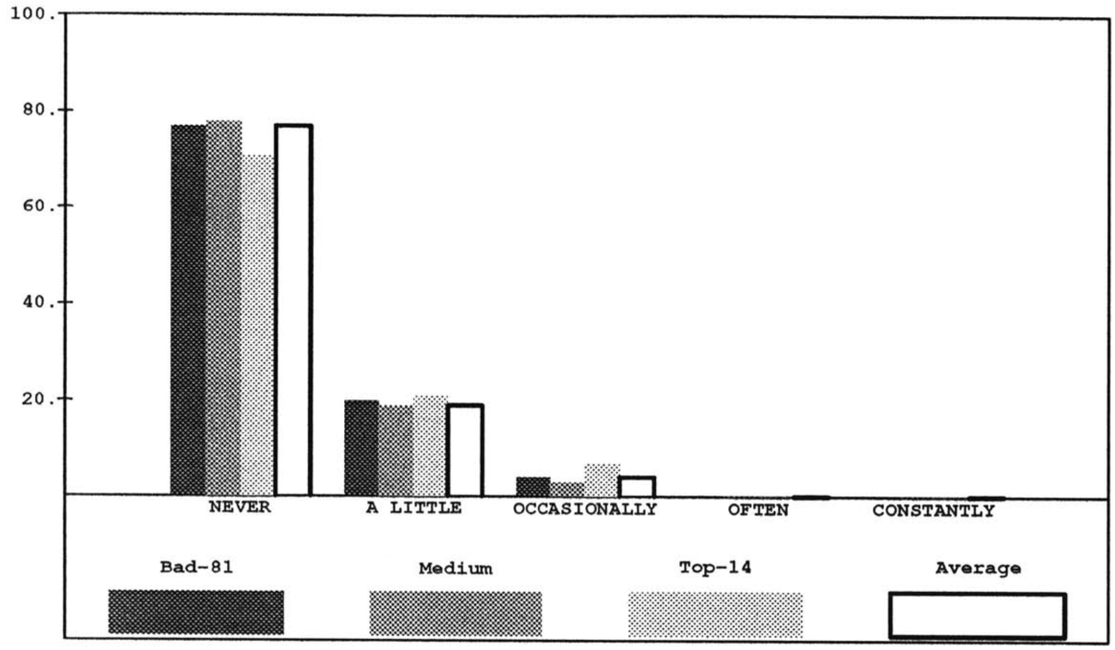

Figure A-8: Question #8 Did the describer refer to functionality?

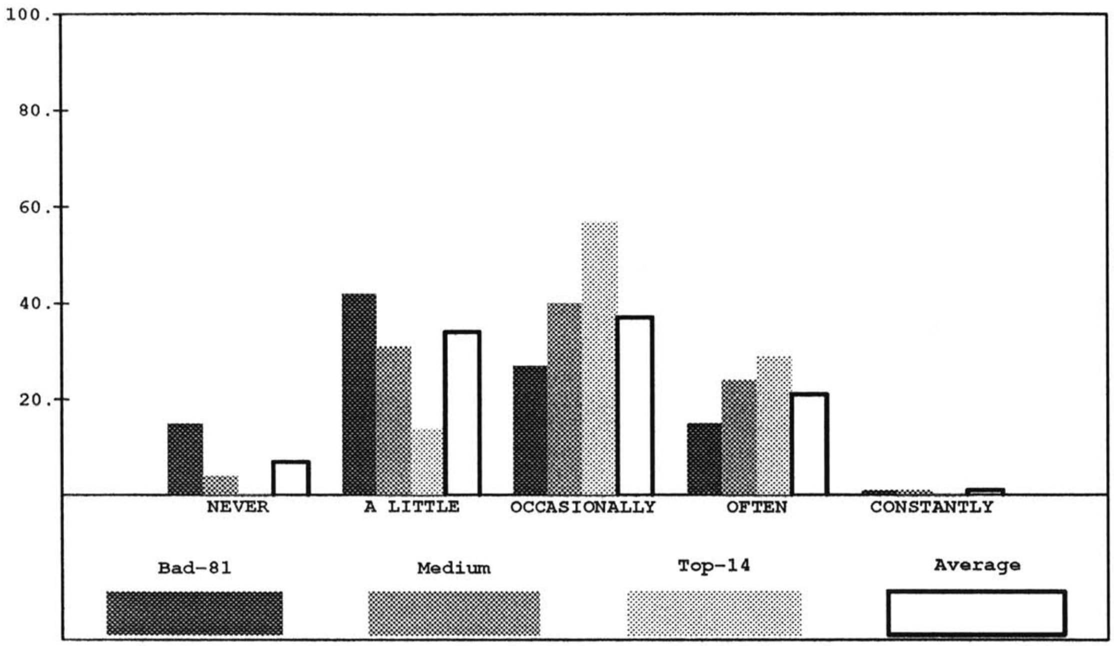

Figure A-9: Question #9 Did the describer use constructive techniques?

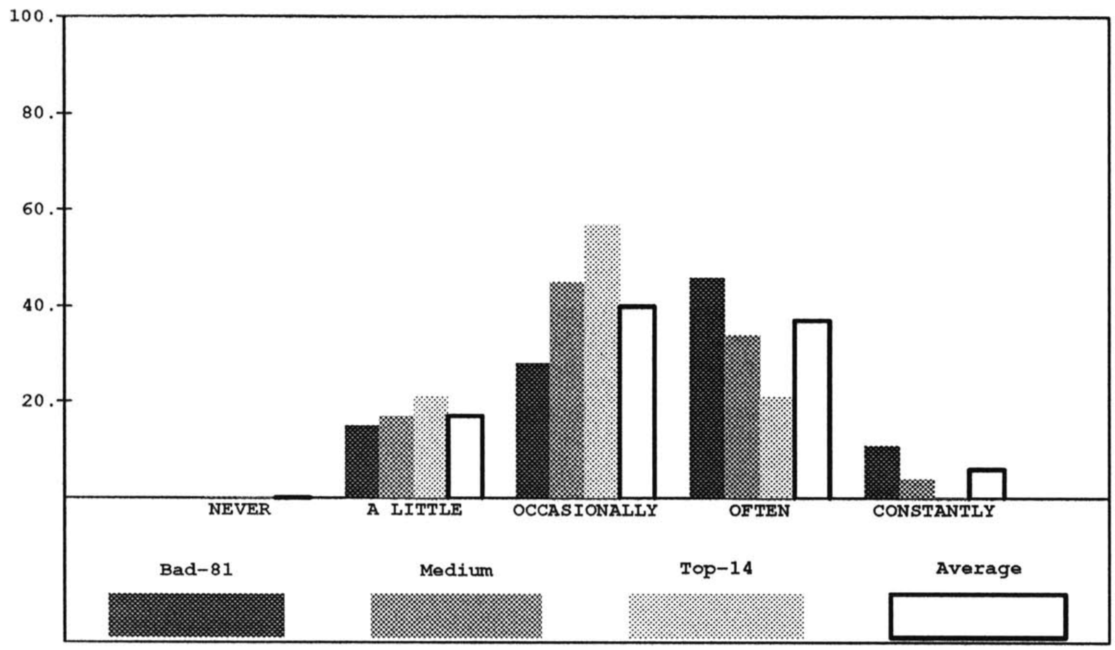

Figure A-10: Question #10 Did the describer use static techniques?

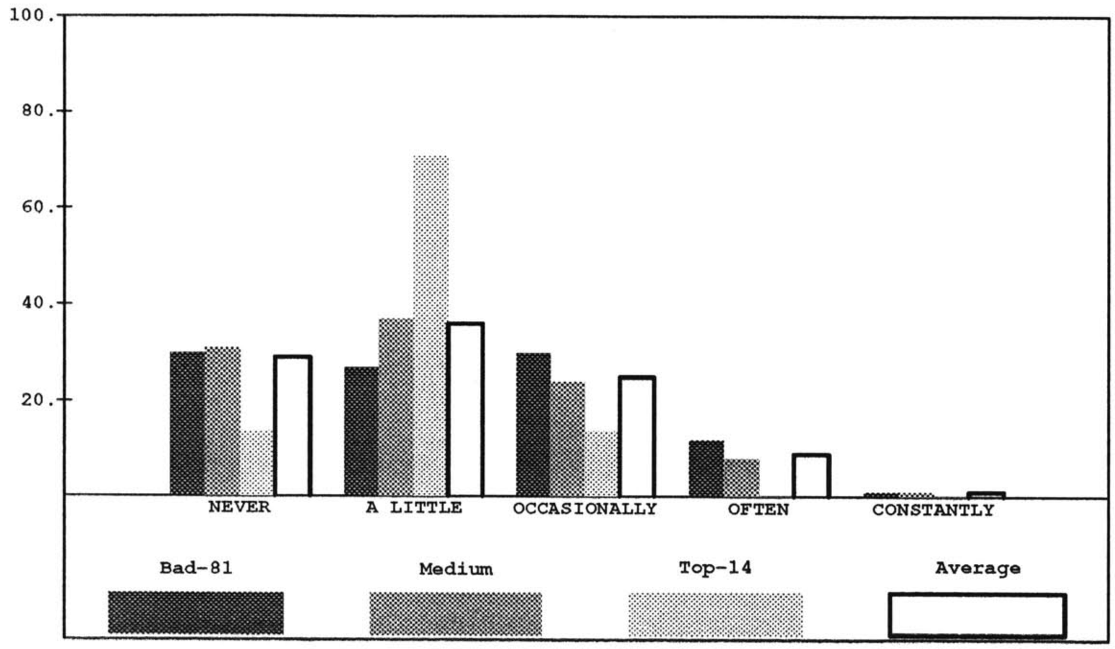

Figure A-11: Question #11 Did the describer use analogies?

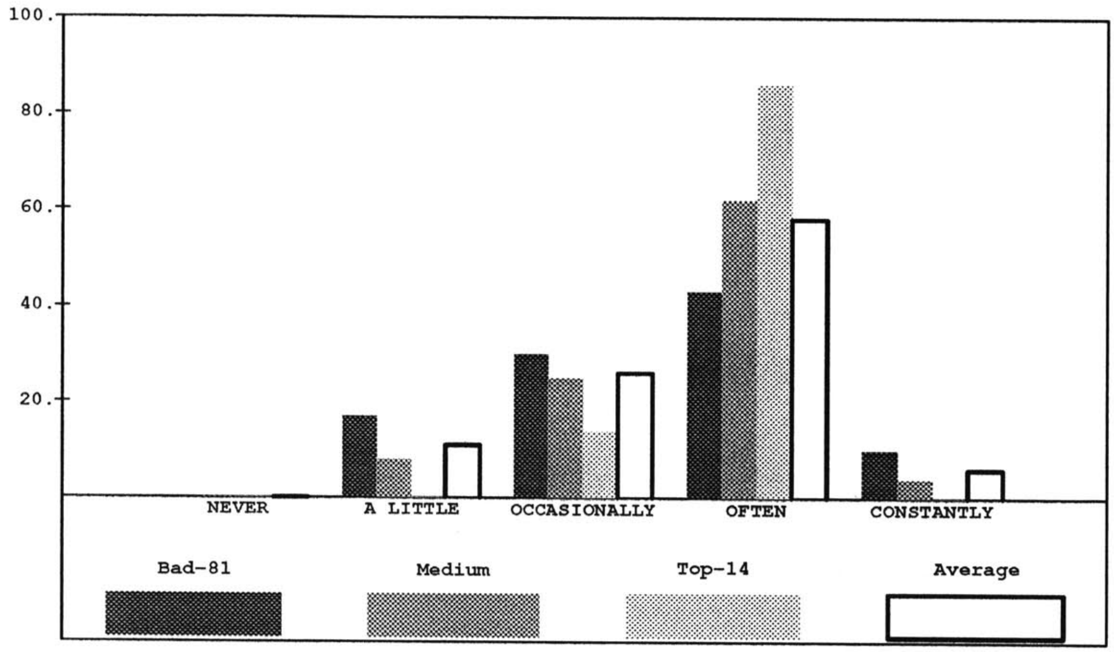

Figure A-12: Question #12 Did the describer use geometric terms?

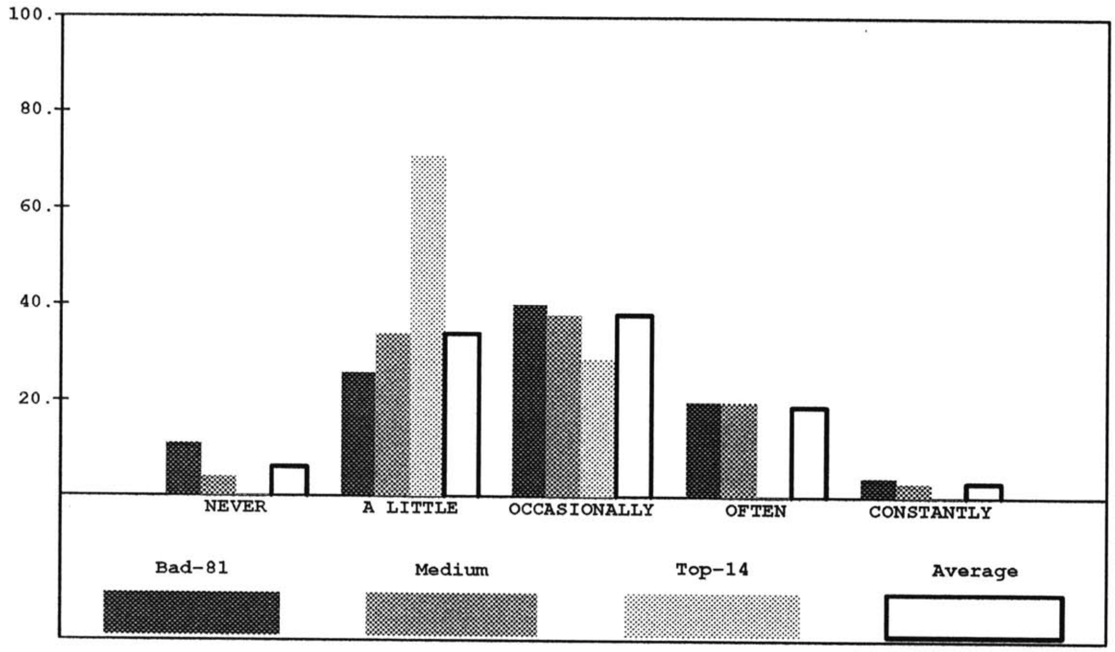

Figure A-13: Question #13 Did the describer use 2D terms?

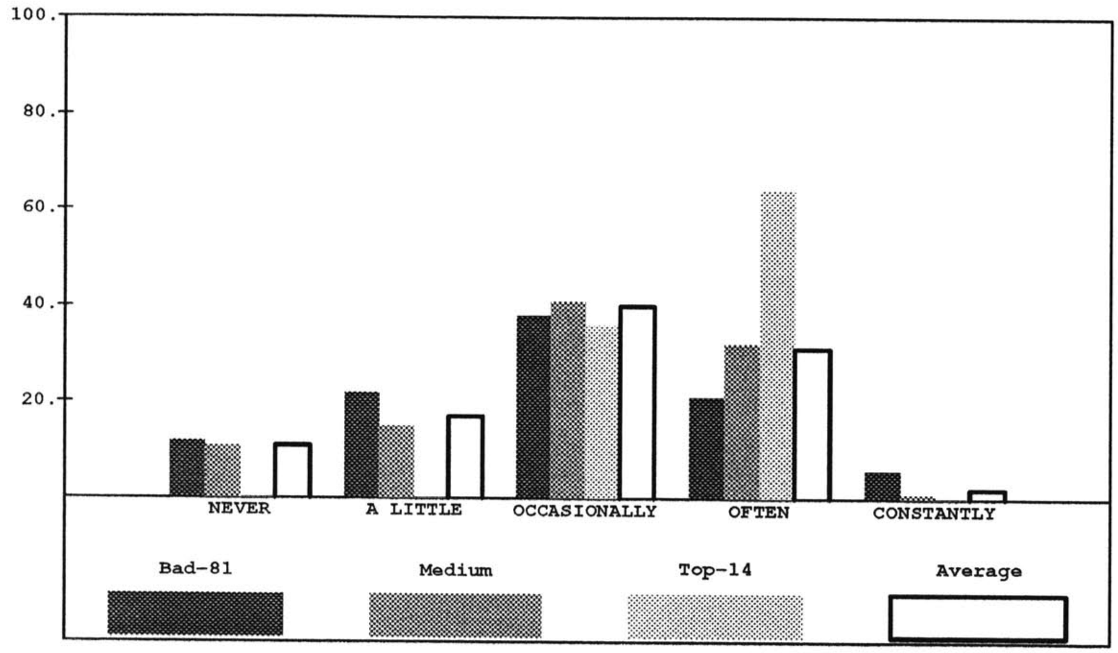

Figure A-14: Question #14 Did the describer use 3D terms?

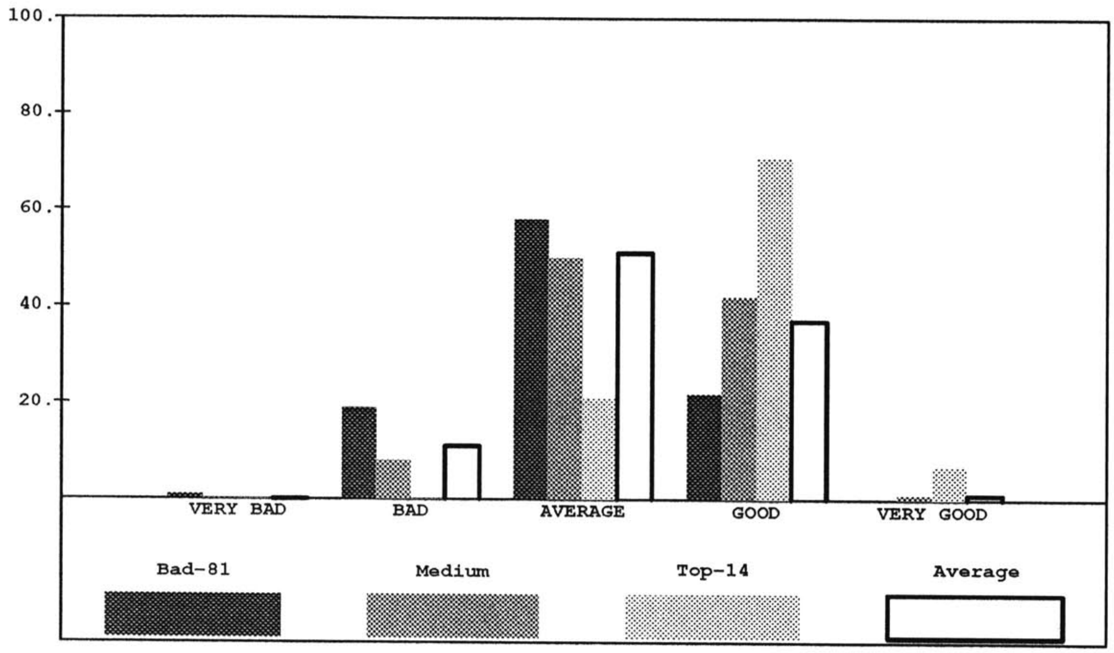

Figure A-15: Question #15 Rate the organization of the description.

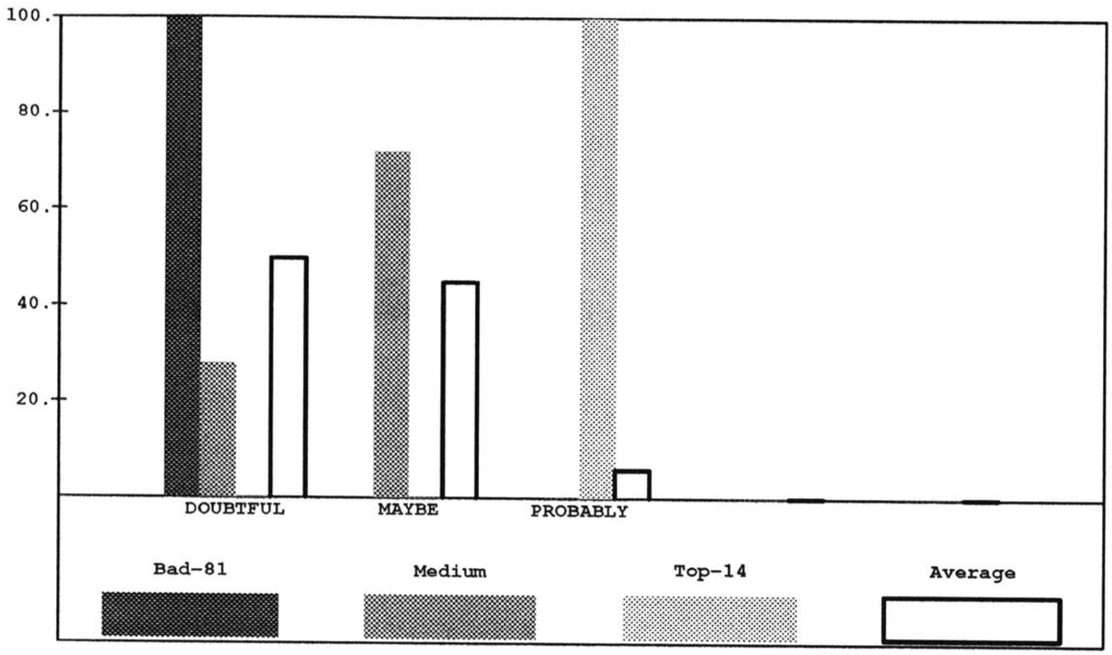

Figure A-16: Question #16 Do you think someone could draw an accurate reconstruction of this object from this description?

A.12 Description Graphs for Each Object

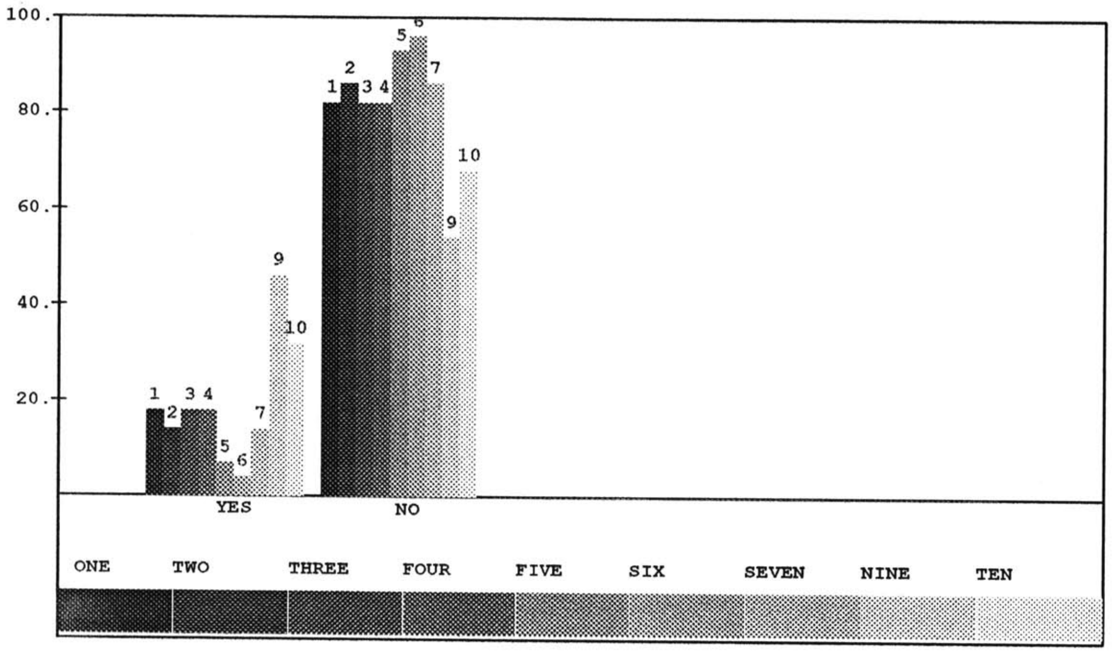

Figure A-17: Question #1 Did this description start with a global overview or introduction?

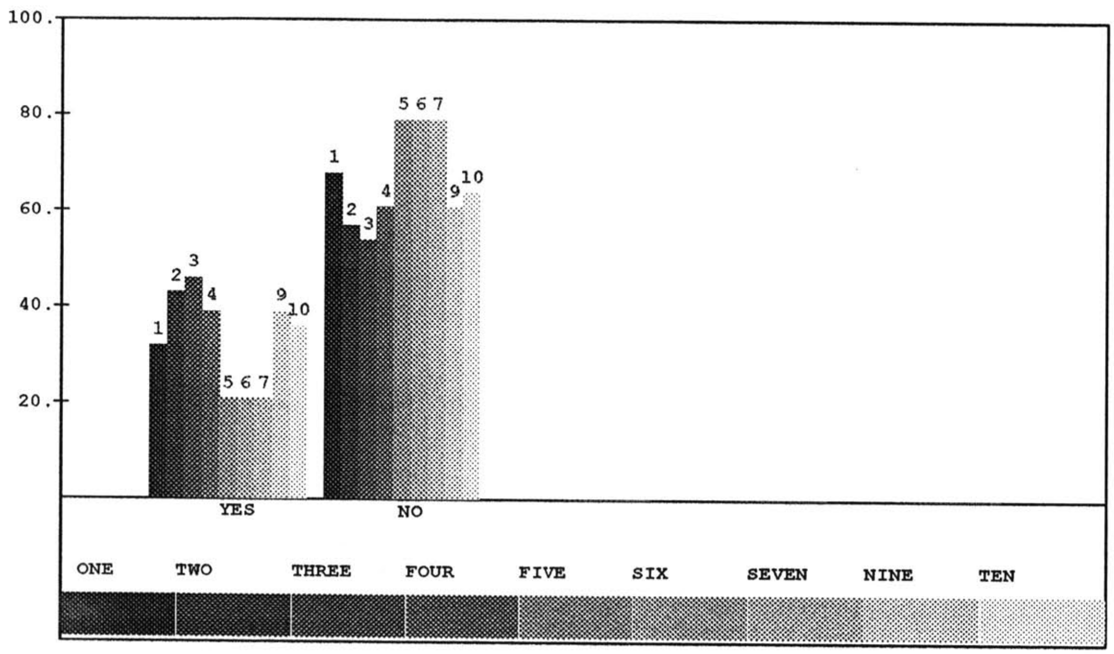

Figure A-18: Question #2 At any time was appearance or texture of the surface specified?

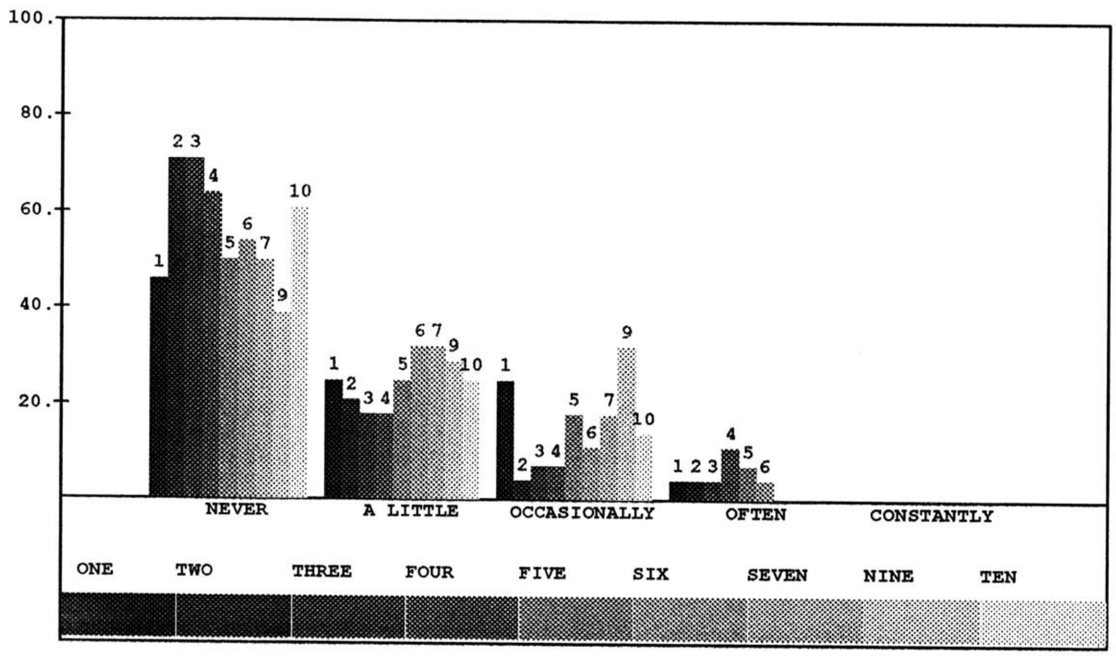

Figure A-19: Question #3 Was scale specified?

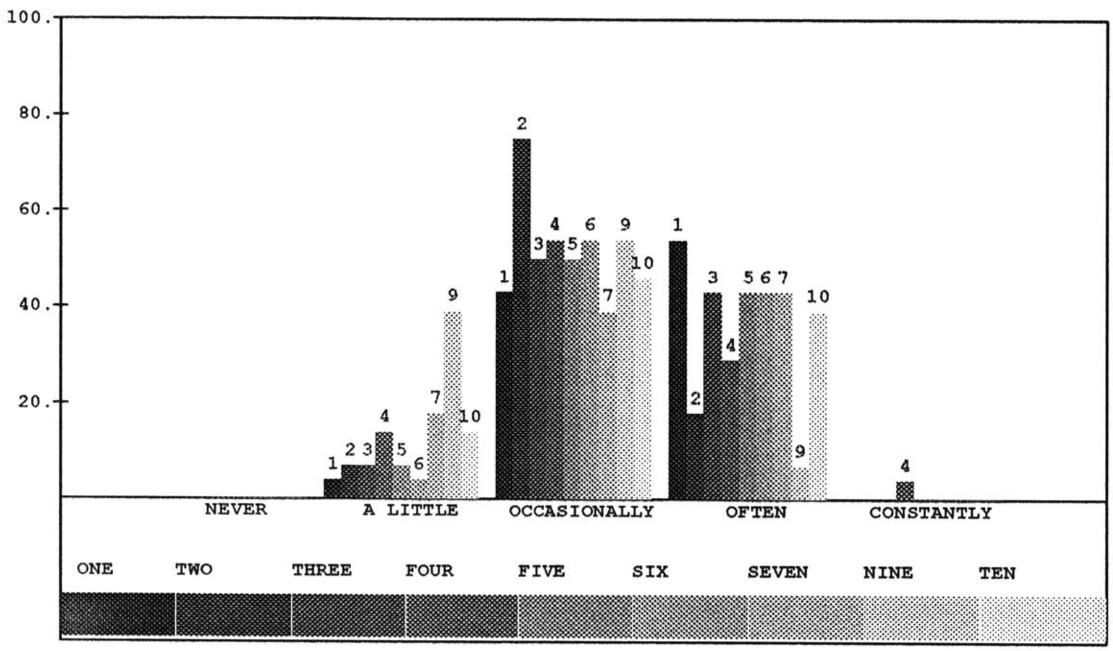

Figure A-20: Question #4 Was the vocabulary used to specify a shape accurate?

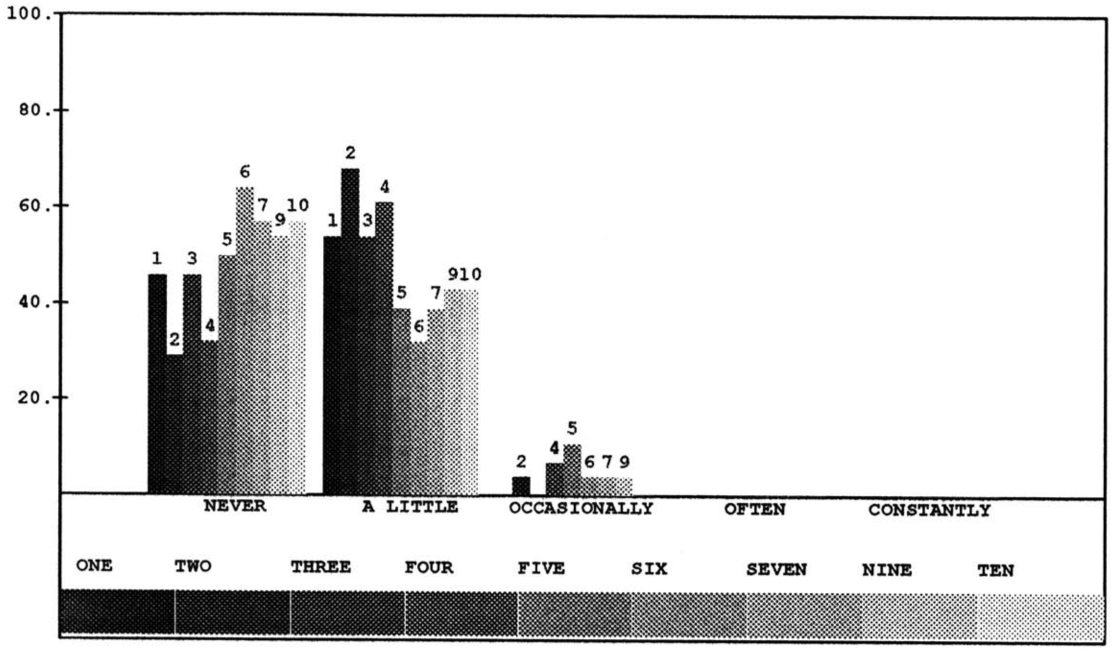

Figure A-21: Question #5 Was the description repetitious?

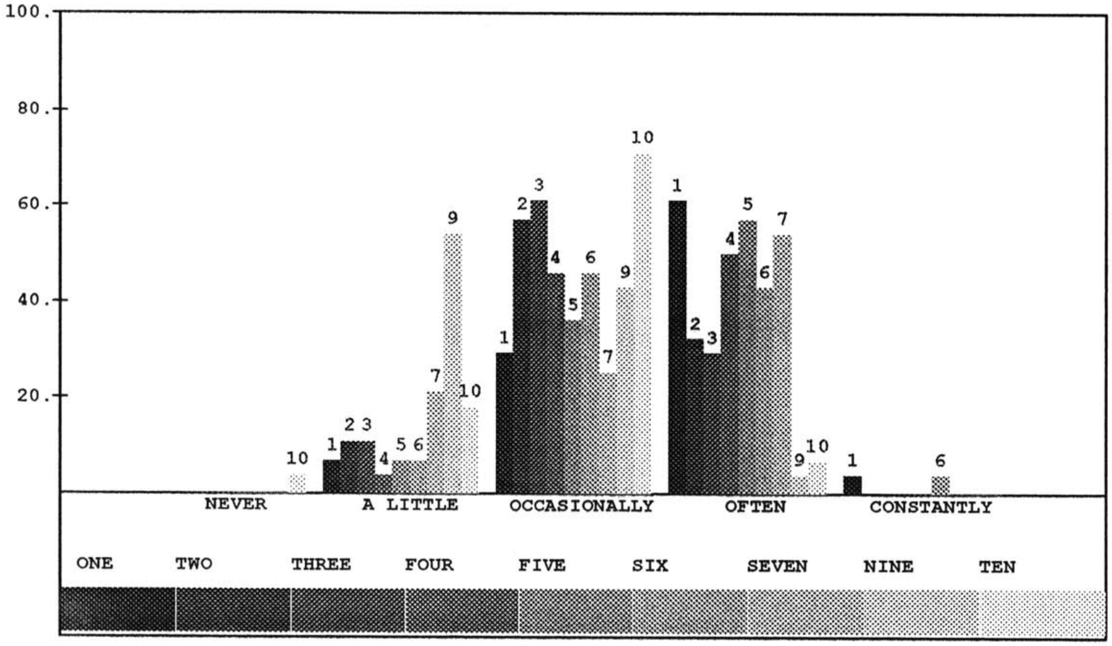

Figure A-22: Question #6 Was the positioning and placement of each part clear and understandable?

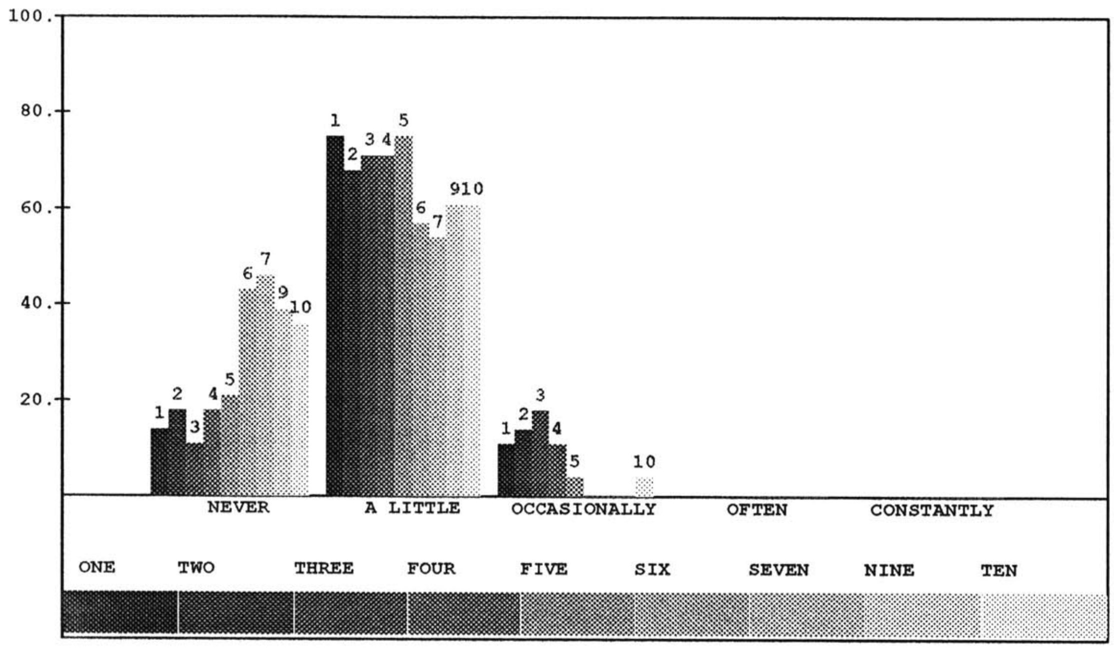

Figure A-23: Question #7 Did the describer use constraints?

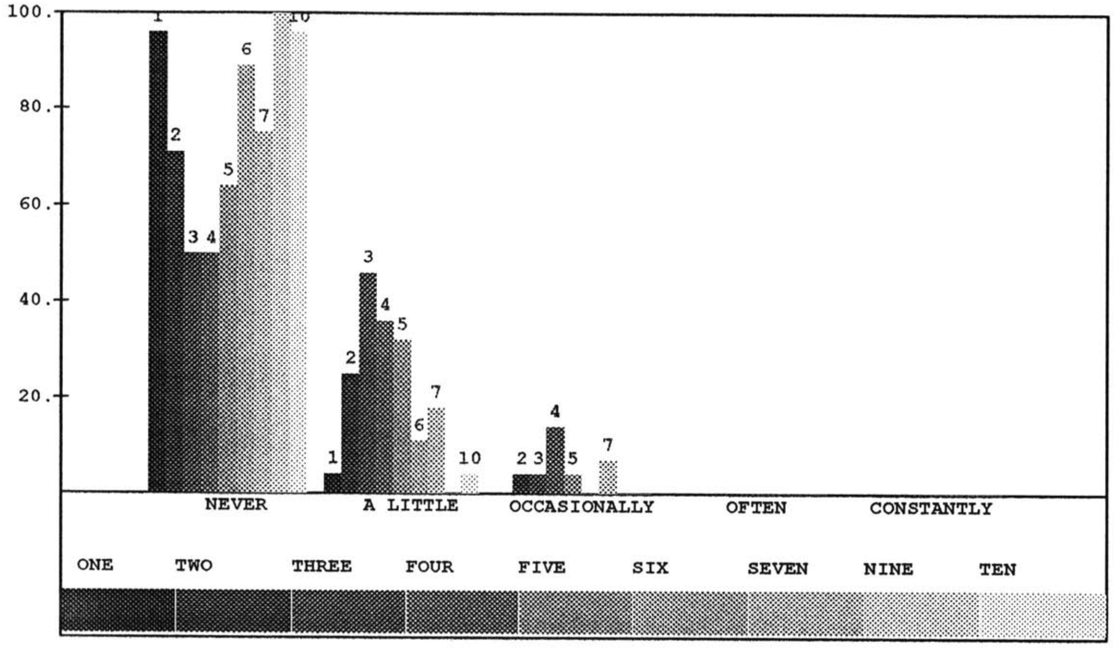

Figure A-24: Question #8 Did the describer refer to functionality?

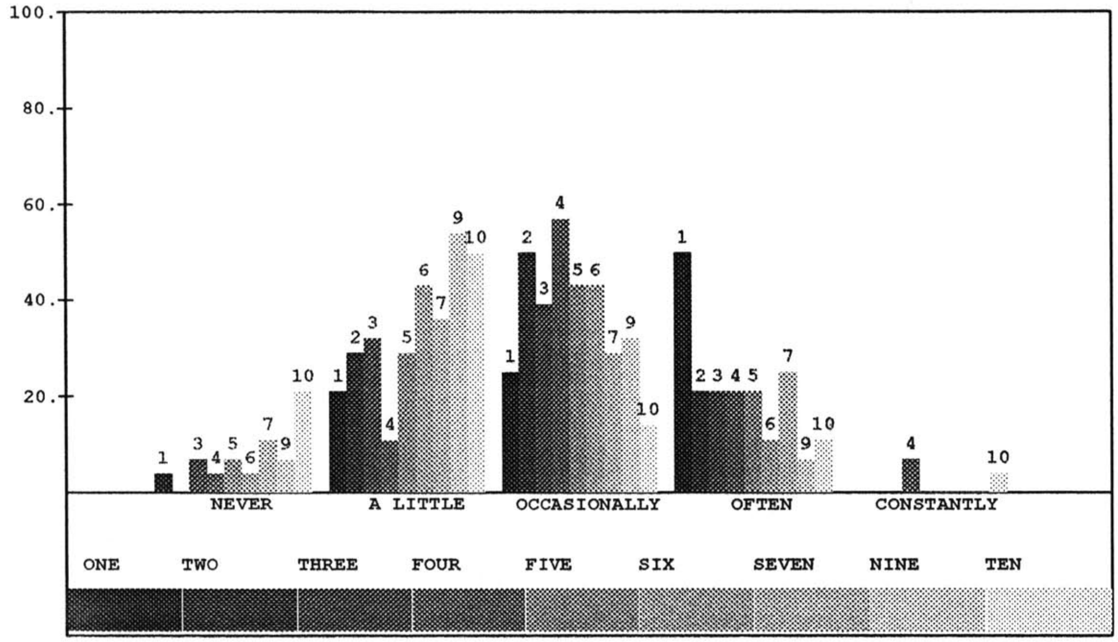

Figure A-25: Question #9 Did the describer use constructive techniques?

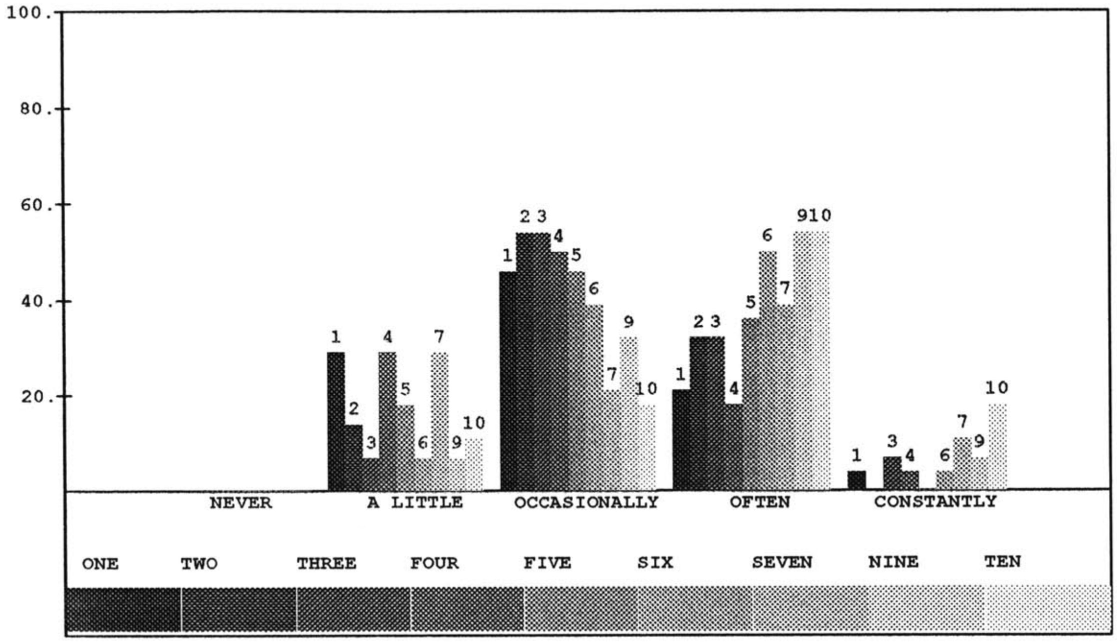

Figure A-26: Question #10 Did the describer use static techniques?

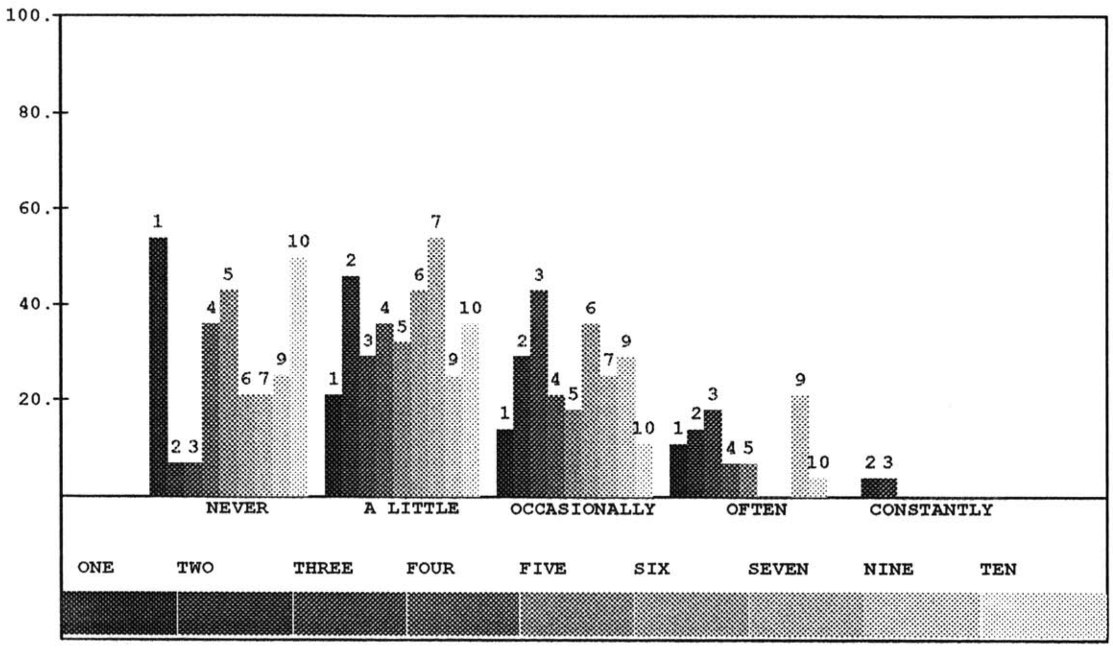

Figure A-27: Question #11 Did the describer use analogies?

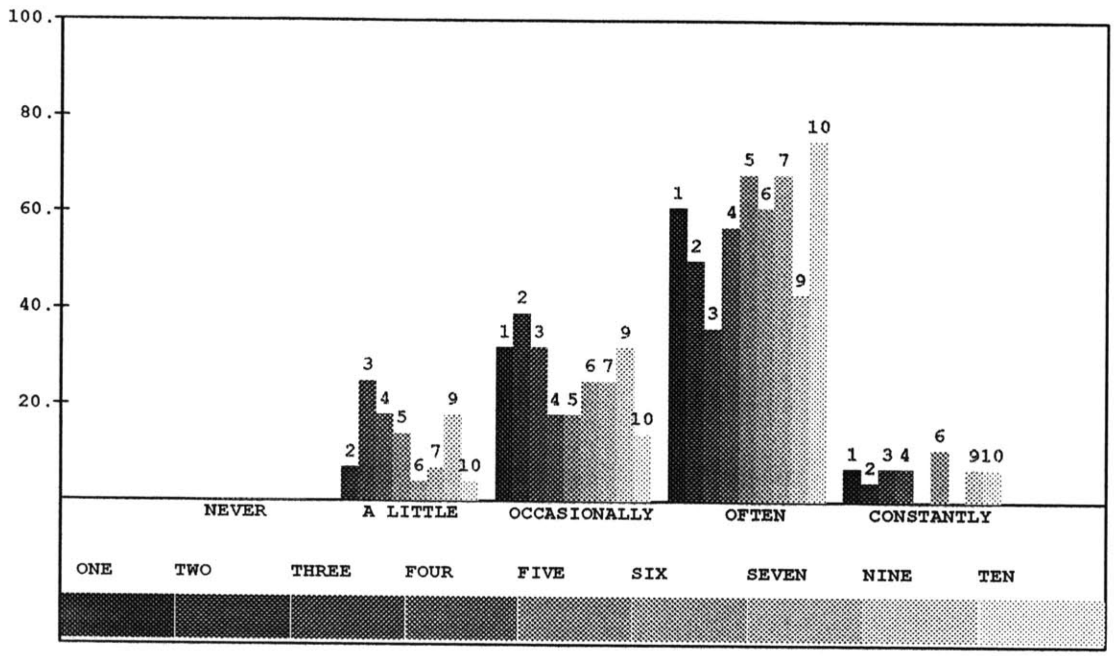

Figure A-28: Question #12 Did the describer use geometric terms?

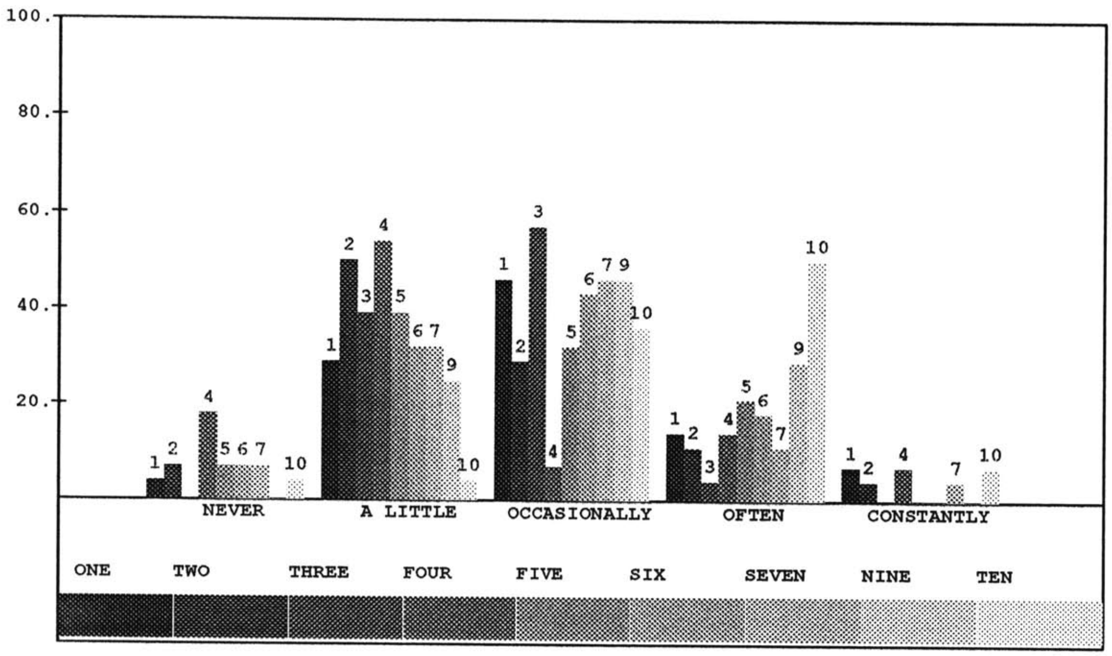

Figure A-29: Question #13 Did the describer use 2D terms?

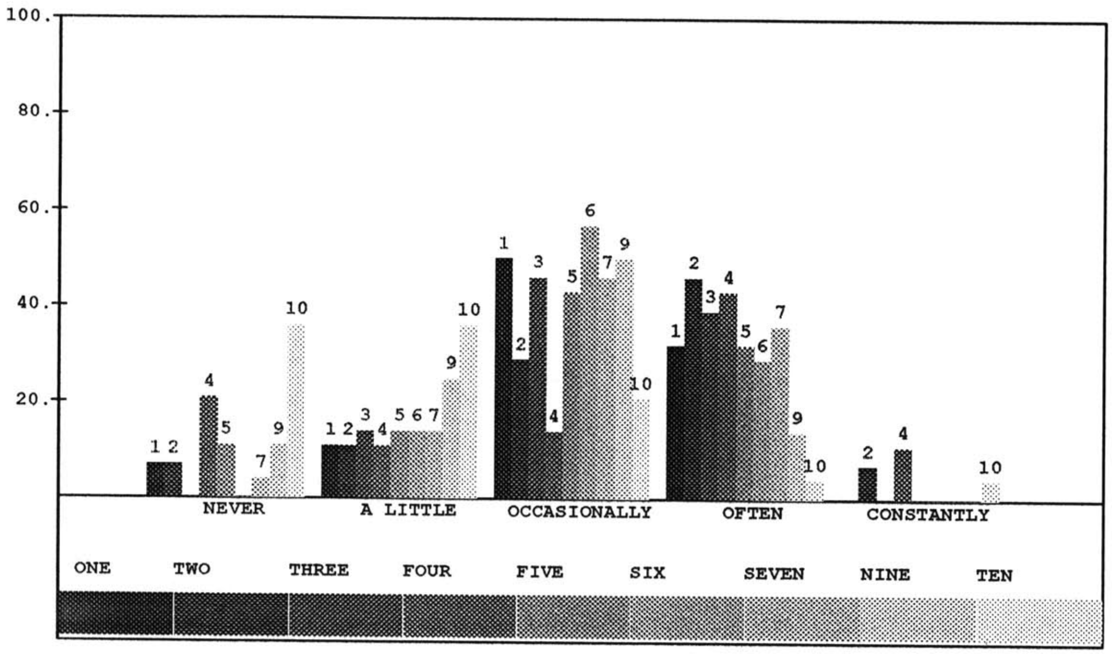

Figure A-30: Question #14 Did the describer use 3D terms?

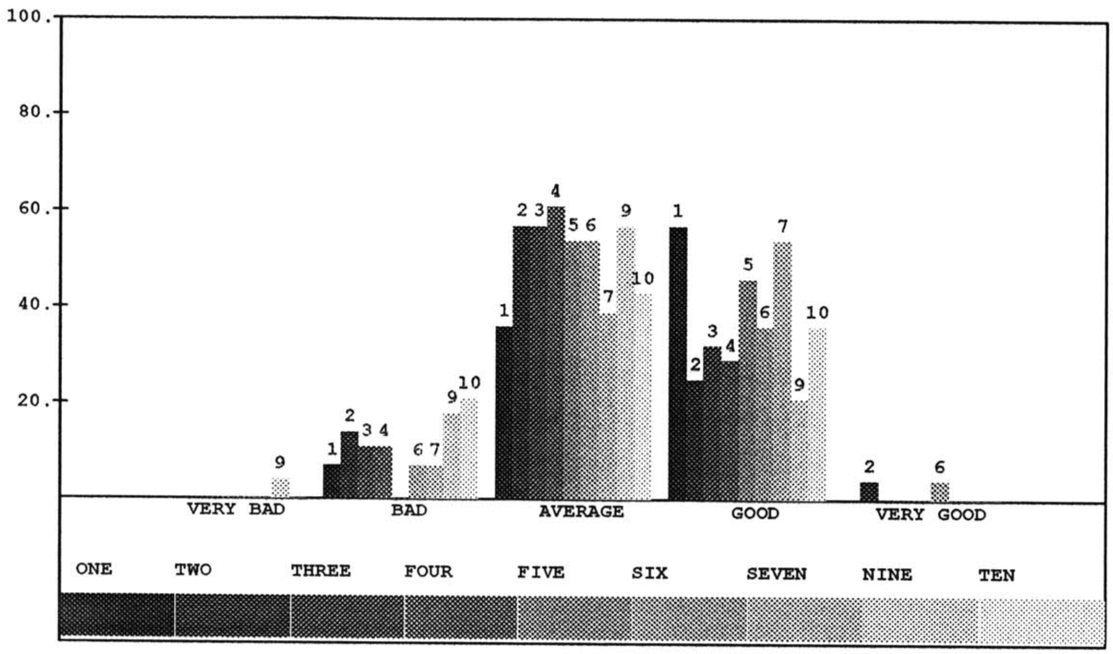

Figure A-31: Question #15 Rate the organization of the description.

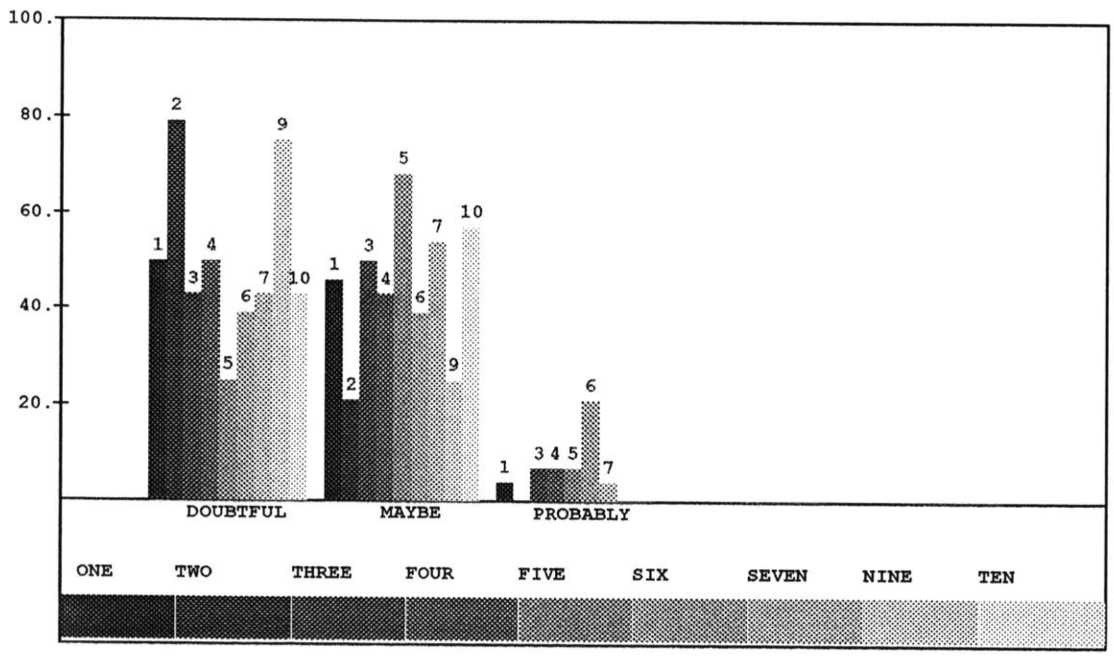

Figure A-32: Question #16 Do you think someone could draw an accurate reconstruction of this object from this description?

A.13 Reconstruction Graphs

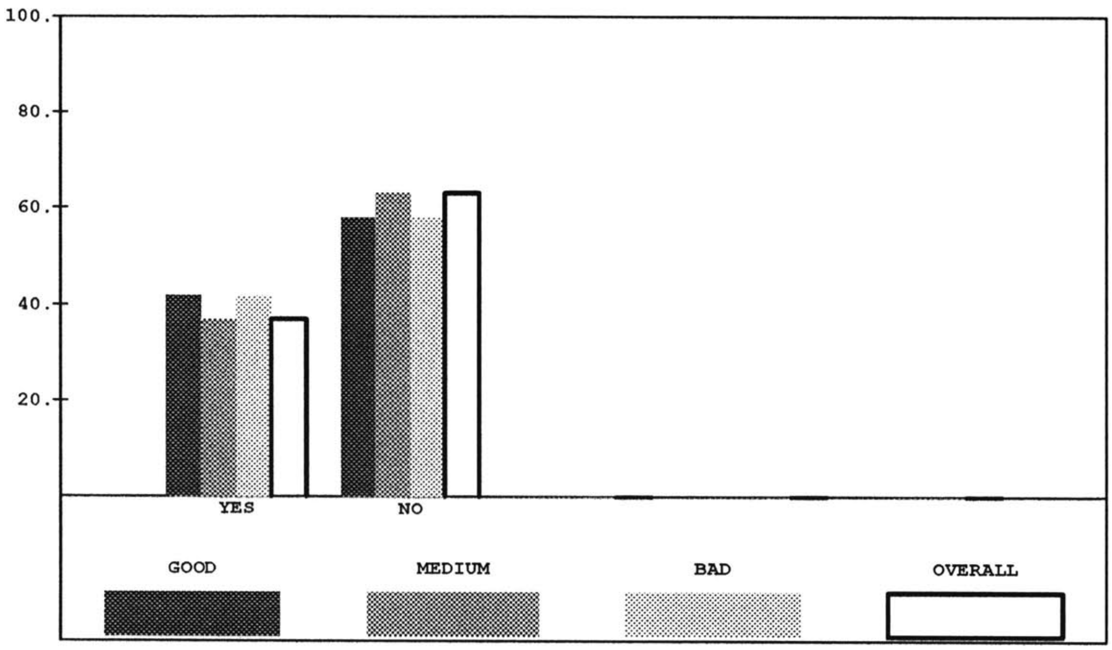

Figure A-33: Question #1 At any time was appearance or texture of the surface specified?

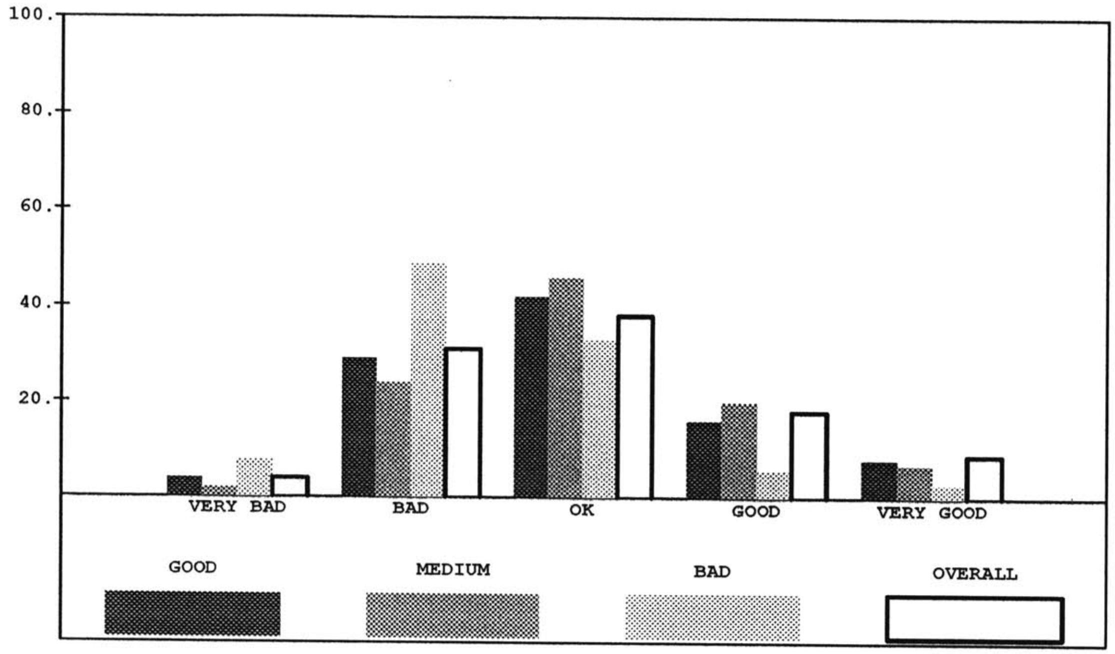

Figure A-34: Question #2 How accurate was the use of scale?

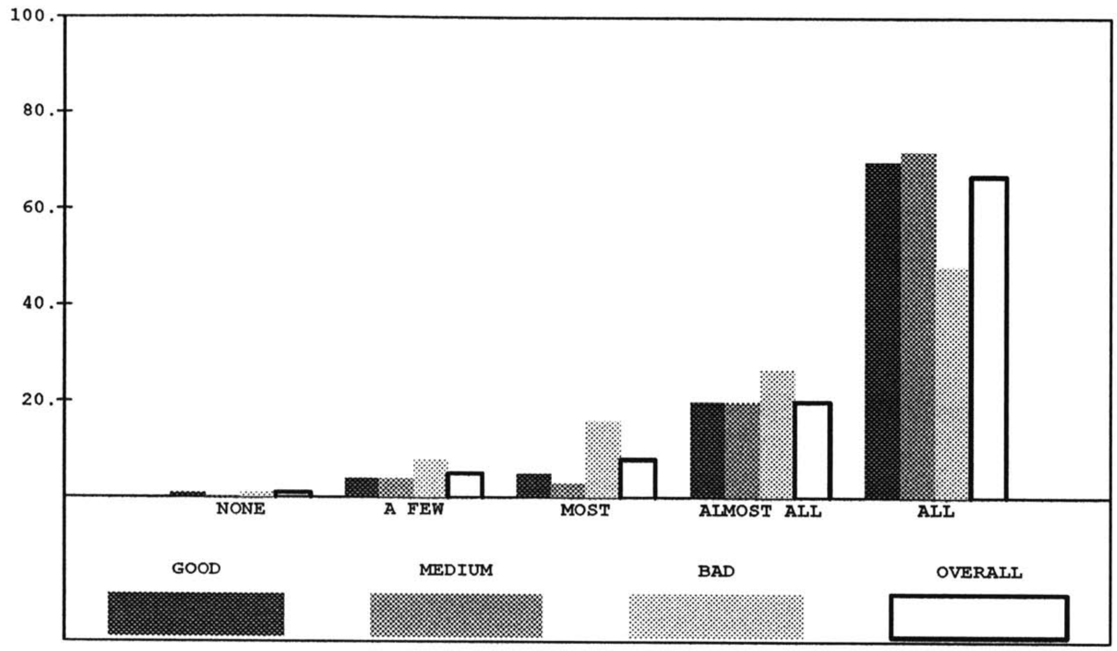

Figure A-35: Question #3 Are all the parts present?

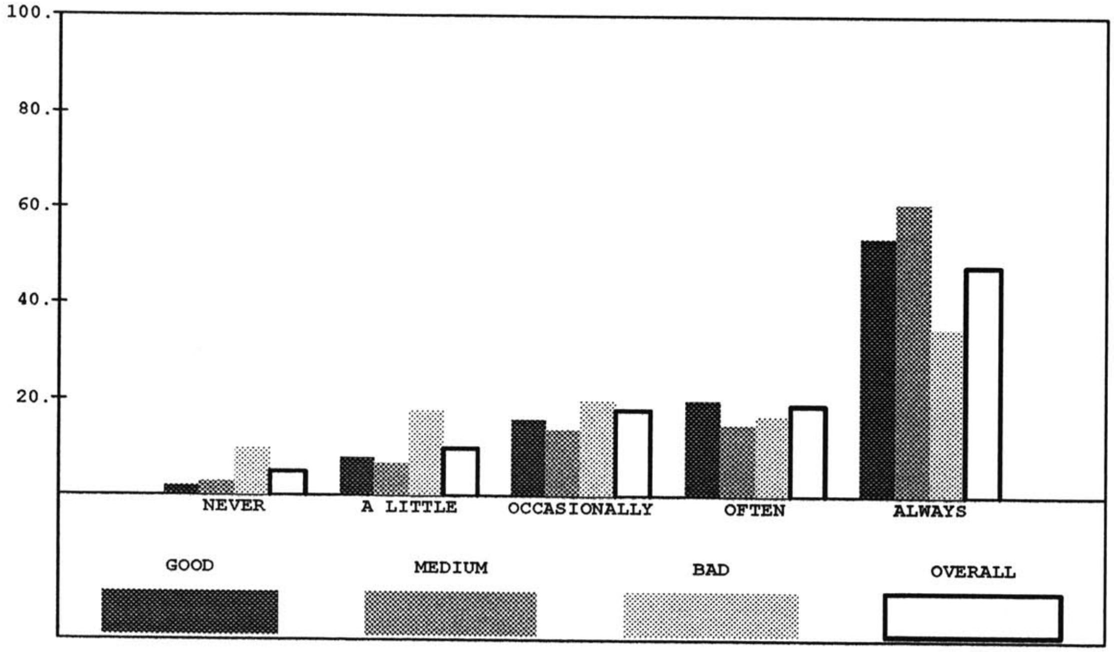

Figure A-36: Question #4 Was the positioning and placement of each part accurate?

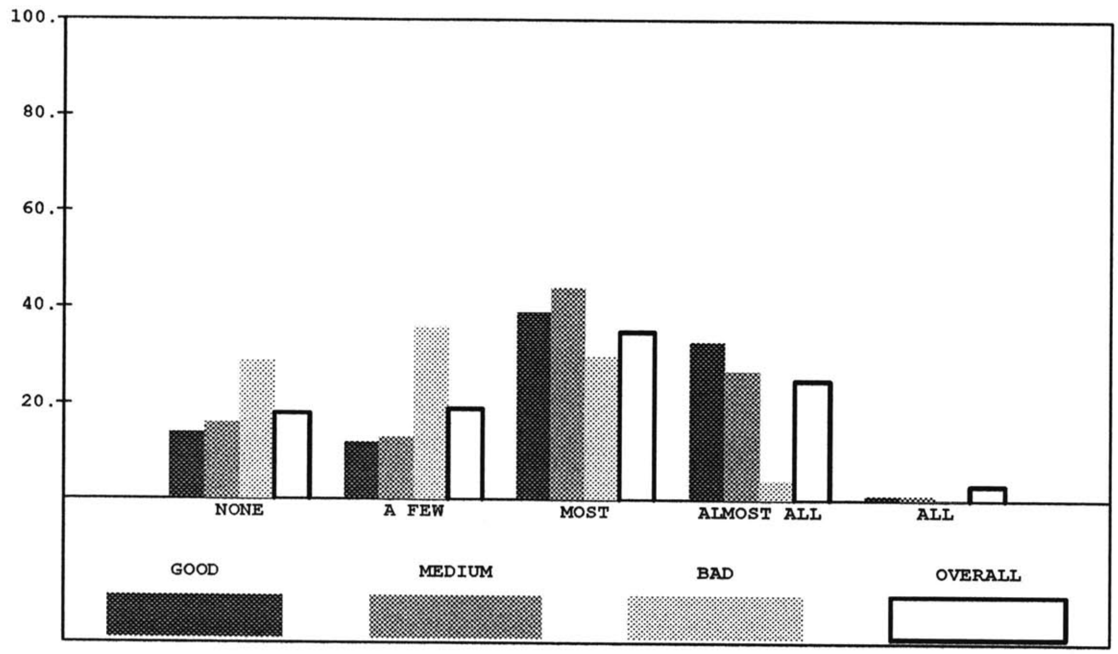

Figure A-37: Question #5 How many parts have the correct shape?

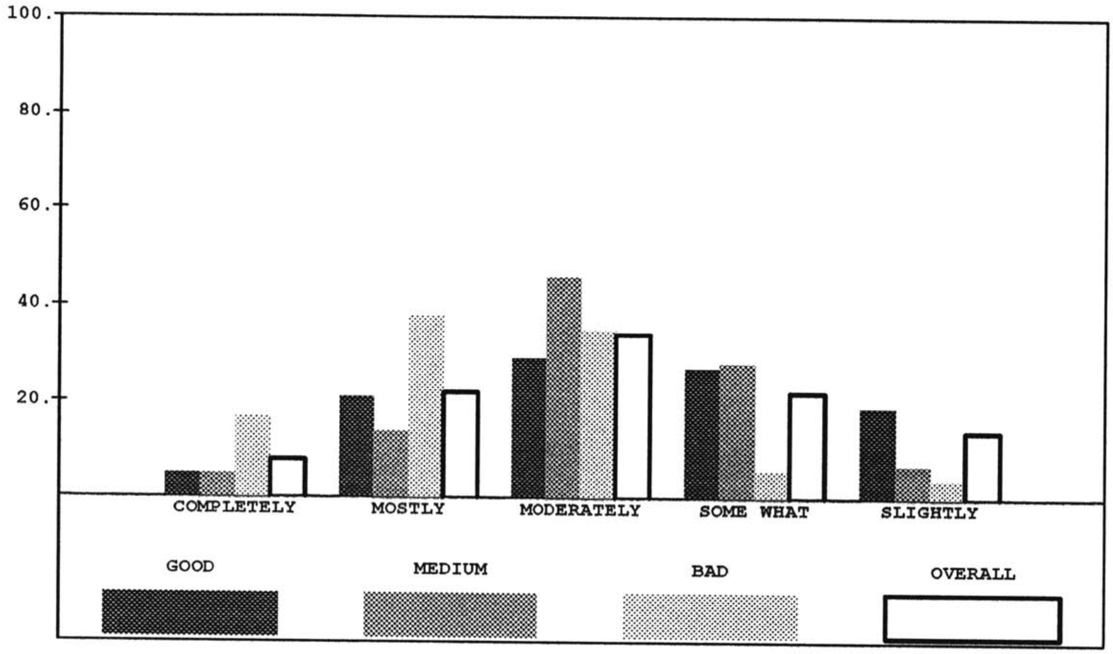

Figure A-38: Question #6 How inaccurate are the incorrectly shaped parts?

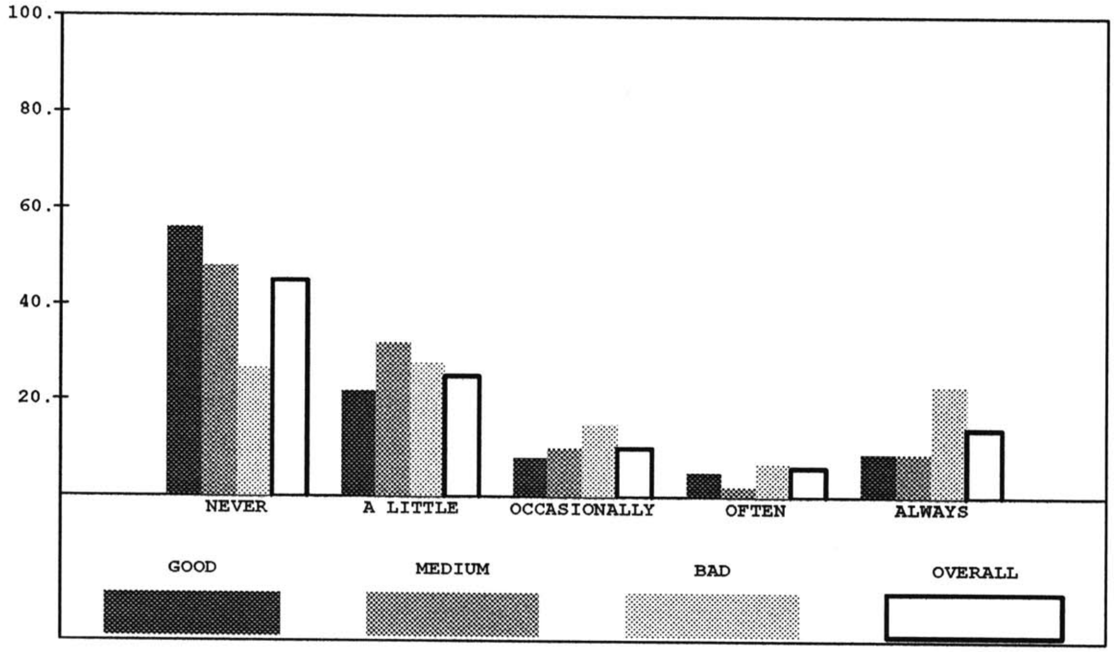

Figure A-39: Question #7 Did the reconstructor use 2D elements?

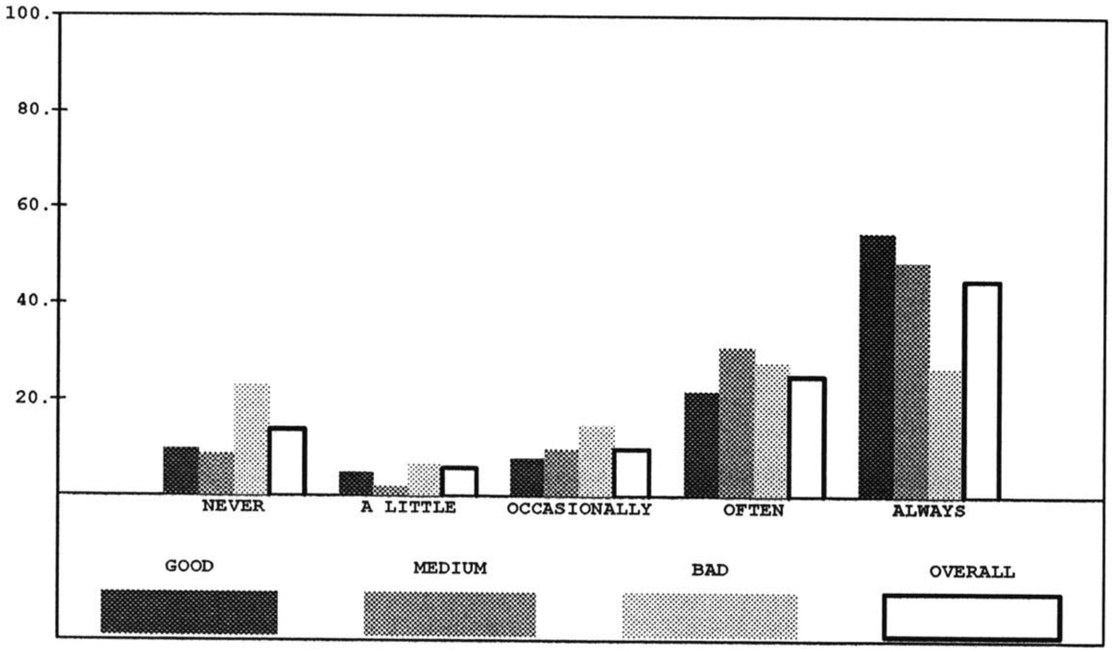

Figure A-40: Question #8 Did the reconstructor use 3D elements?

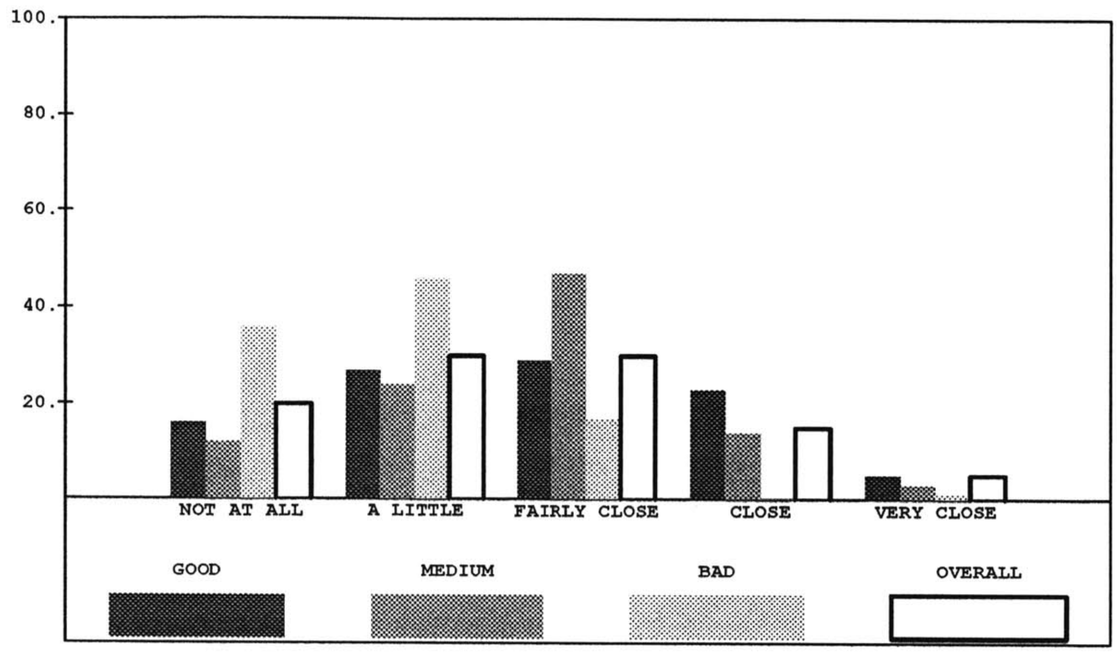

Figure A-41: Question #9 How much does this reconstruction resemble the object?

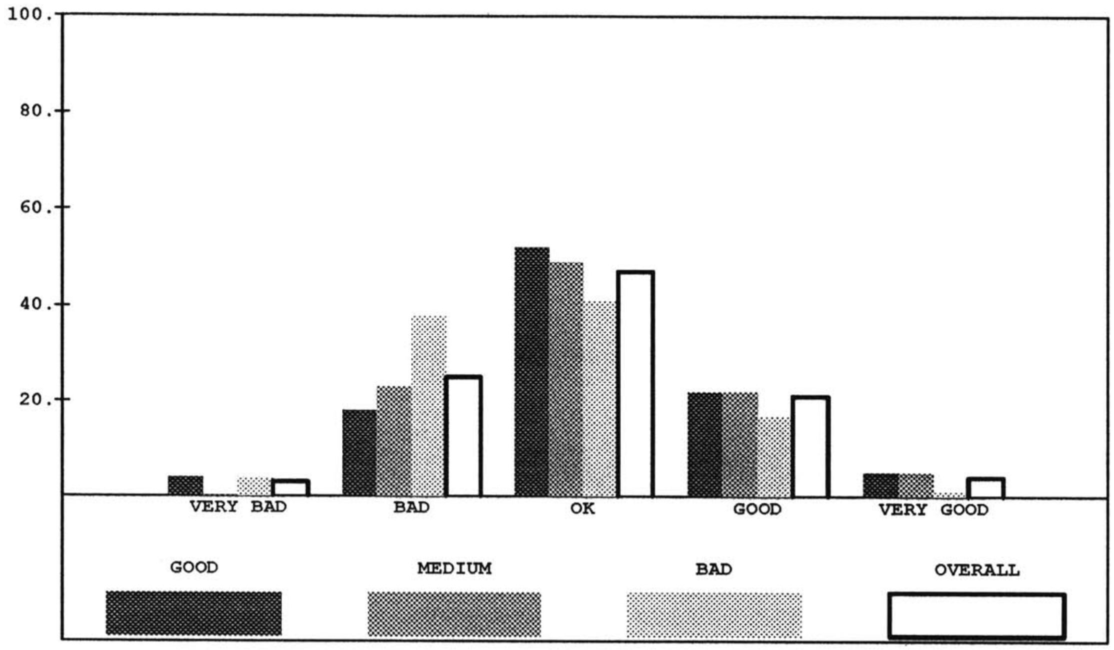

Figure A-42: Question #10 In your opinion, how good was the reconstructor's drawing ability?

A.14 Reconstruction Graphs for Each Object

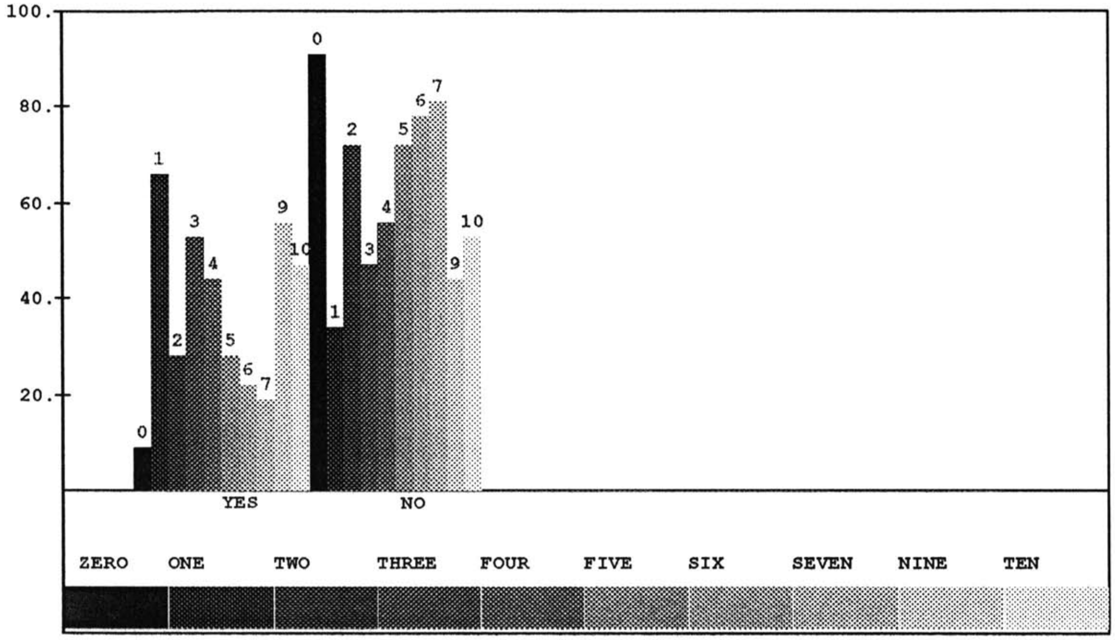

Figure A-43: Question #1 At any time was appearance or texture of the surface specified?

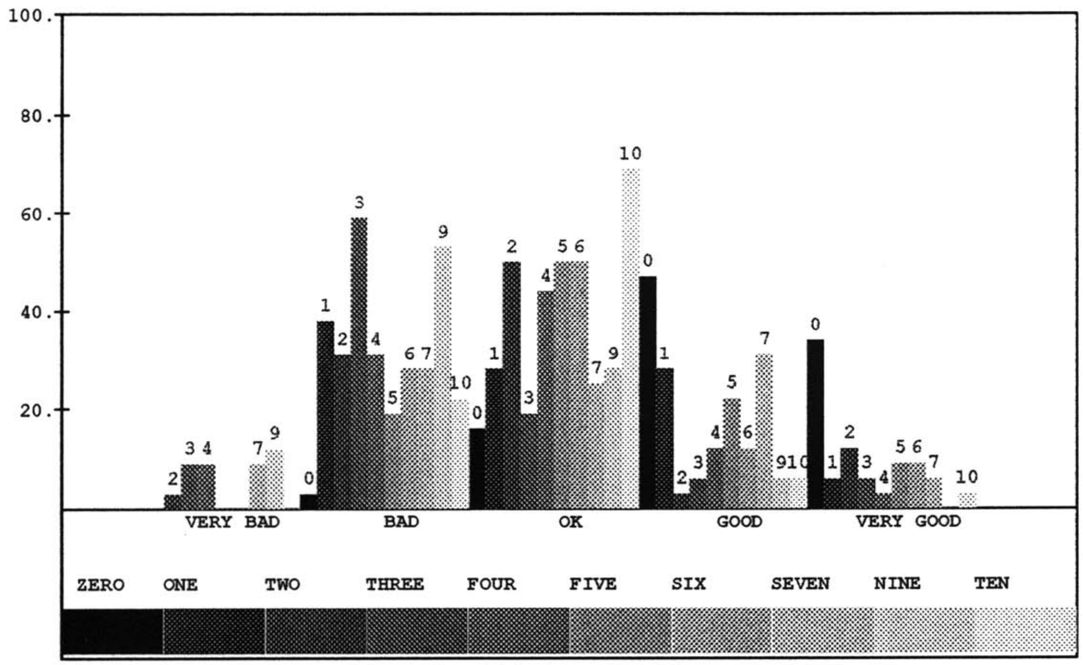

Figure A-44: Question #2 How accurate was the use of scale?

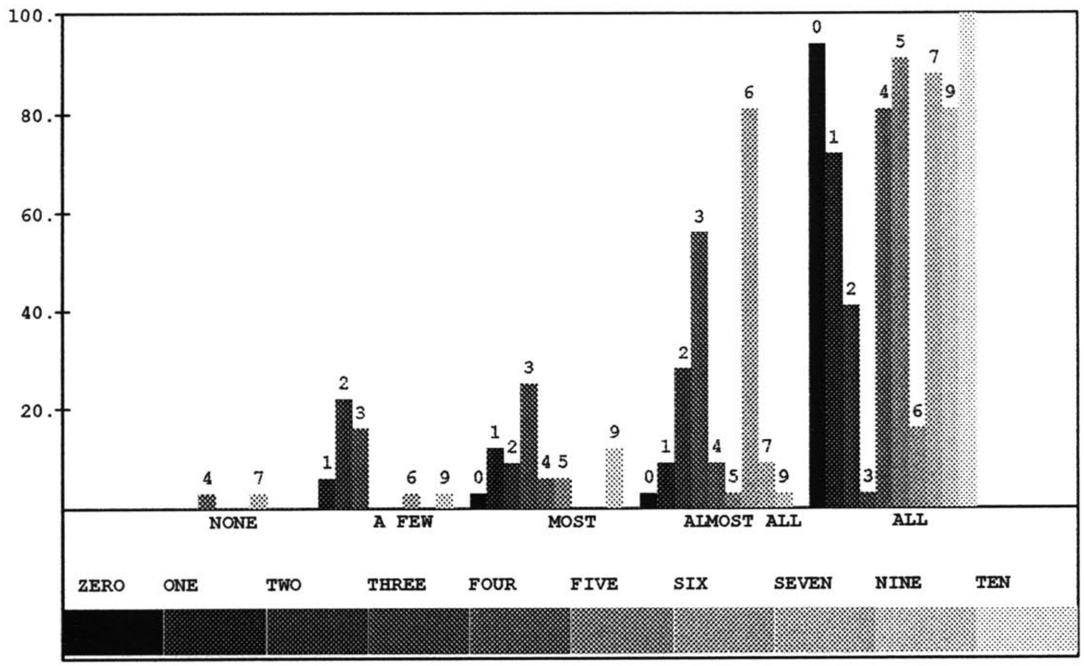

Figure A-45: Question #3 Are all the parts present?

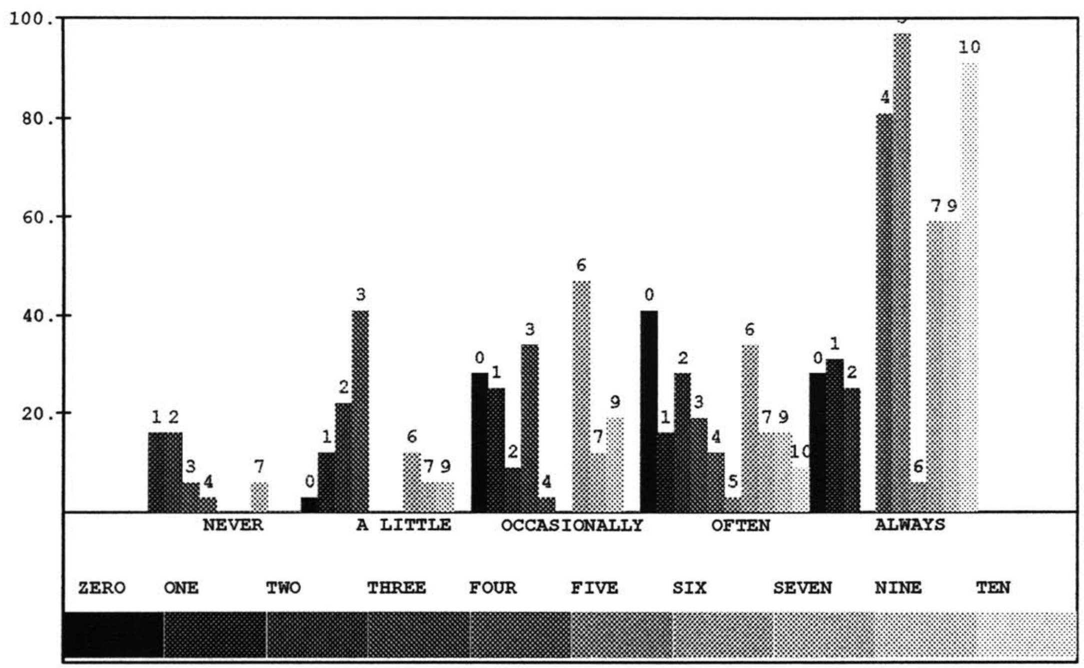

Figure A-46: Question #4 Was the positioning and placement of each part accurate?

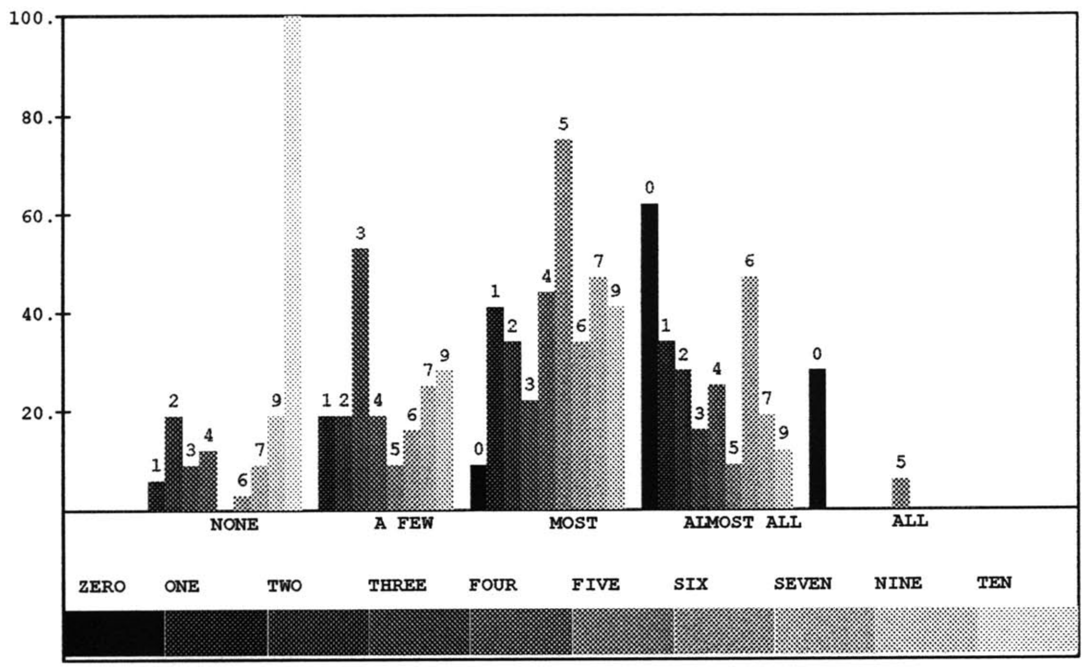

Figure A-47: Question #5 How many parts have the correct shape?

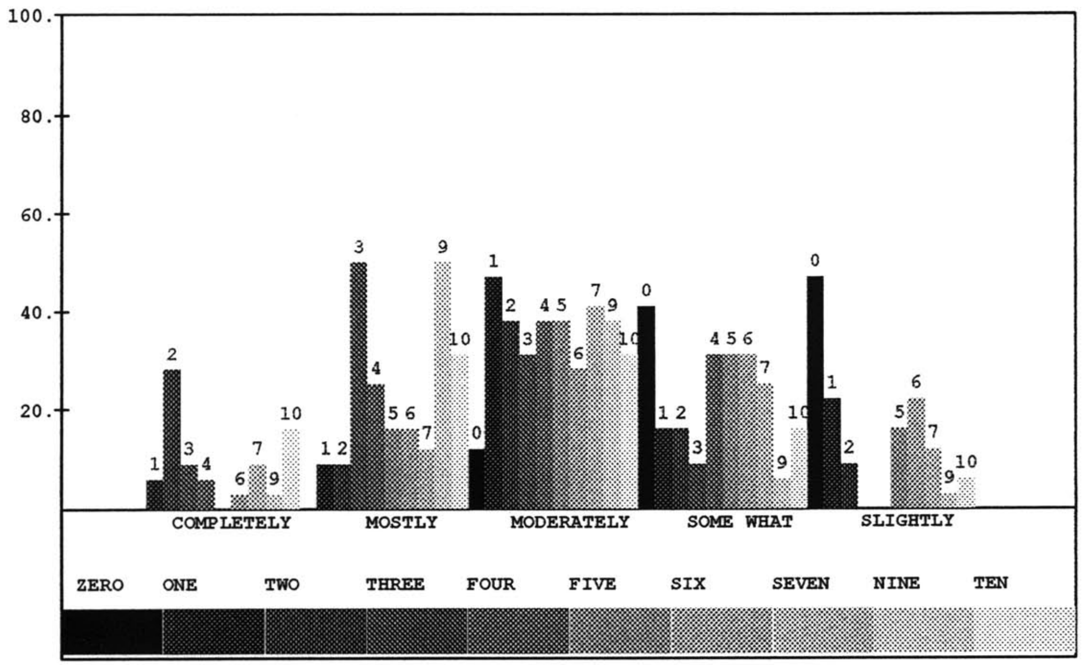

Figure A-48: Question #6 How inaccurate are the incorrectly shaped parts?

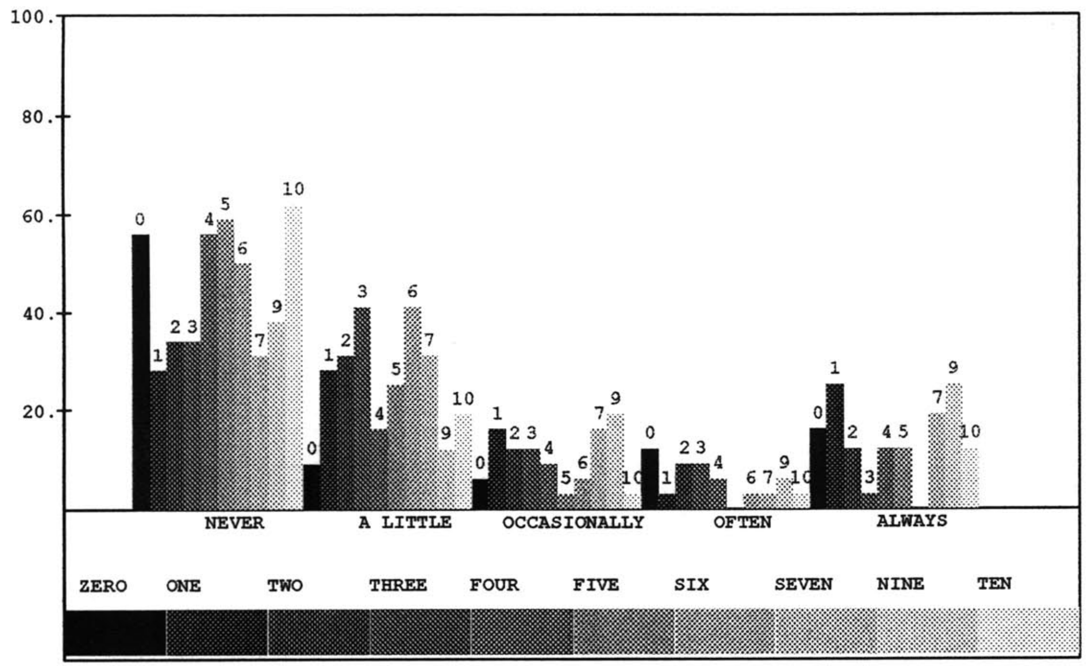

Figure A-49: Question #7 Did the reconstructor use 2D elements?

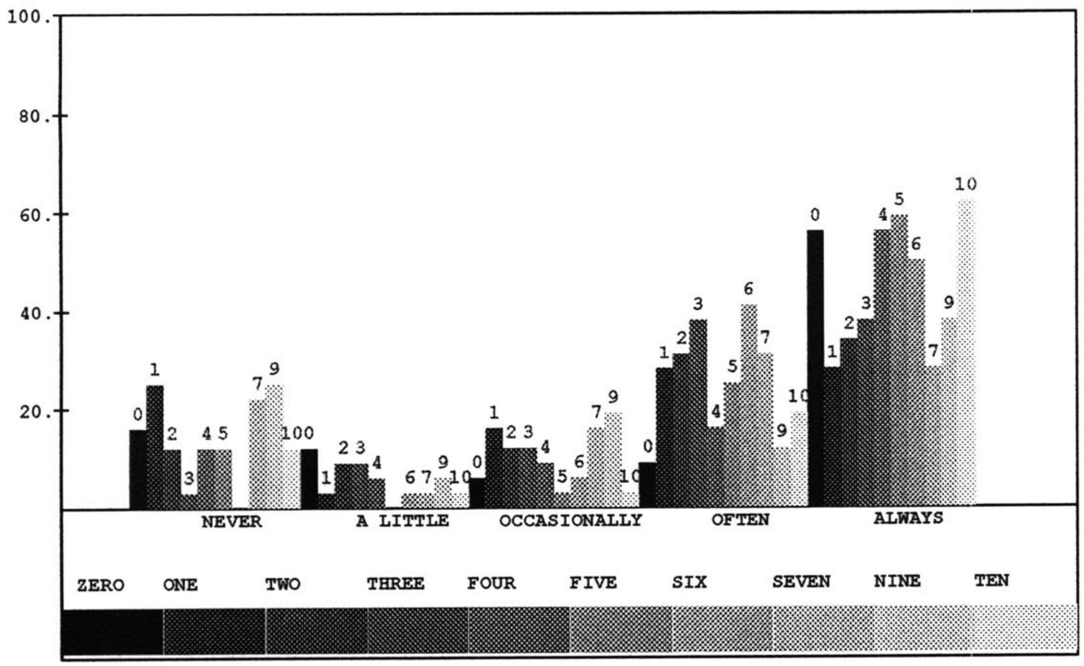

Figure A-50: Question #8 Did the reconstructor use 3D elements?

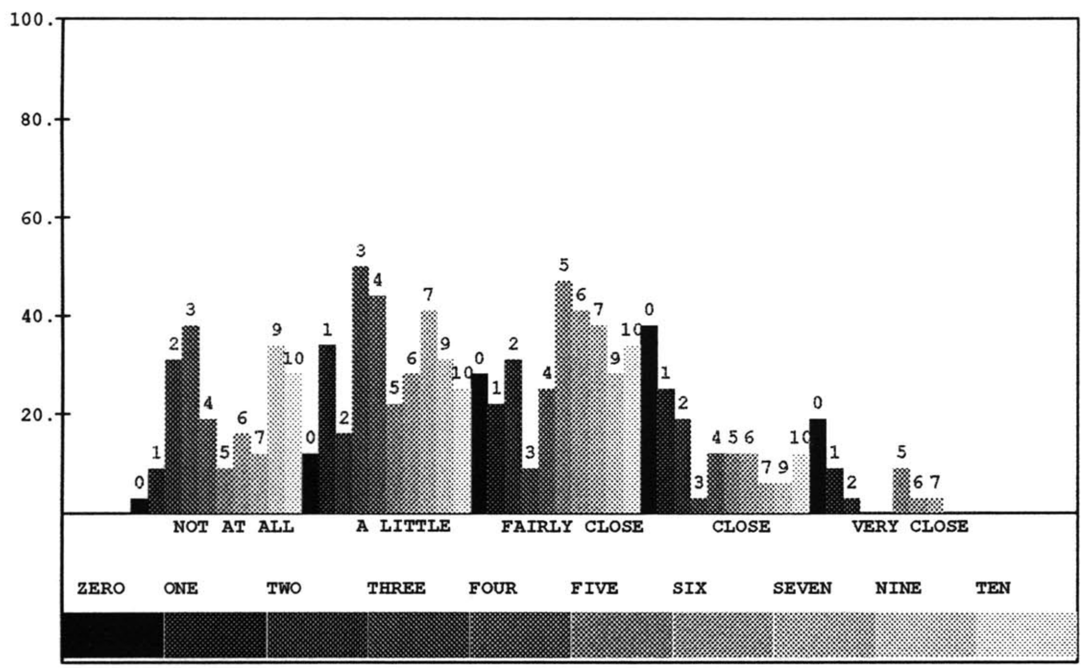

Figure A-51: Question #9 How much does this reconstruction resemble the object?

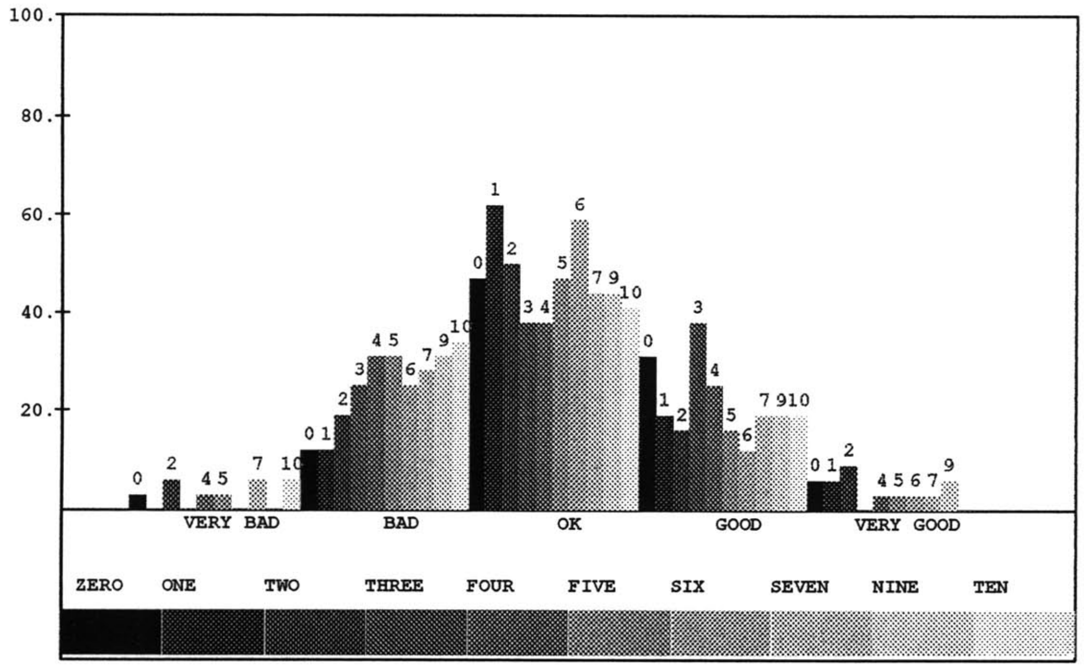

Figure A-52: Question #10 In your opinion, how good was the reconstructor's drawing ability?

A.15 Description Correlation Matrices

A.15.1 Overall Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	.077	-.088	.003	-.029	.032	-.135	-.008	-.081	.092	.005	-.064	-.114	.107	.049	-.057
2	.077	1.000	.016	.009	.141	.113	-.058	.053	-.035	.056	.077	-.088	.125	-.145	.017	.045
3	-.088	.016	1.000	.276	.123	.261	.225	-.141	.088	-.062	-.071	.139	.108	-.057	.113	.327
4	.003	.009	.276	1.000	.127	.722	.393	.030	.230	-.188	-.148	.241	-.170	.296	.383	.756
5	-.029	.141	.123	.127	1.000	.126	.277	.342	.218	-.179	.282	-.183	.044	-.008	-.447	.081
6	.032	.113	.261	.722	.126	1.000	.326	.076	.349	-.306	-.197	.234	-.141	.259	.420	.675
7	-.135	-.058	.225	.393	.277	.326	1.000	.082	.406	-.356	-.004	.139	.044	.107	.006	.313
8	-.008	.053	-.141	.030	.342	.076	.082	1.000	.183	-.172	.393	-.386	-.105	.023	-.182	-.030
9	-.081	-.035	.088	.230	.218	.349	.406	.183	1.000	-.966	.065	-.051	-.135	.177	.058	.228
10	.092	.056	-.062	-.188	-.179	-.306	-.356	-.172	-.966	1.000	-.072	.080	.149	-.174	-.042	-.193
11	.005	.077	-.071	-.148	.282	-.197	-.004	.393	.065	-.072	1.000	-.823	-.058	-.066	-.323	-.131
12	-.064	-.088	.139	.241	-.183	.234	.139	-.386	-.051	.080	-.823	1.000	.025	.196	.309	.221
13	-.114	.125	.108	-.170	.044	-.141	.044	-.105	-.135	.149	-.058	.025	1.000	-.899	-.112	-.024
14	.107	-.145	-.057	.296	-.008	.259	.107	.023	.177	-.174	-.066	.196	-.899	1.000	.167	.121
15	.049	.017	.113	.383	-.447	.420	.006	-.182	.058	-.042	-.323	.309	-.112	.167	1.000	.378
16	-.057	.045	.327	.756	.081	.675	.313	-.030	.228	-.193	-.131	.221	-.024	.121	.378	1.000

A.15.2 Bad 81 Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	.128	-.042	.184	.015	.031	-.124	.017	-.133	.135	.019	-.031	-.147	.155	-.016	.075
2	.128	1.000	.215	.046	.188	.113	-.044	.088	-.138	.154	.100	-.097	-.009	-.036	.028	.044
3	-.042	.215	1.000	.192	-.035	.251	.230	-.154	.066	-.057	-.130	.183	.061	-.015	.056	.028
4	.184	.046	.192	1.000	.029	.592	.204	.096	-.023	.022	-.120	.227	-.331	.412	.256	.069
5	.015	.188	-.035	.029	1.000	.041	.269	.460	.240	-.216	.366	-.245	-.062	.040	-.517	.037
6	.031	.113	.251	.592	.041	1.000	.264	.051	.195	-.182	-.262	.286	-.231	.370	.309	.059
7	-.124	-.044	.230	.204	.269	.264	1.000	.067	.230	-.212	-.003	.065	.248	-.133	-.077	.049
8	.017	.088	-.154	.096	.460	.051	.067	1.000	.135	-.118	.508	-.489	-.058	-.081	-.155	.033
9	-.133	-.138	.066	-.023	.240	.195	.230	.135	1.000	-.978	.104	-.100	-.069	.074	-.029	.035
10	.135	.154	-.057	.022	-.216	-.182	-.212	-.118	-.978	1.000	-.106	.112	.065	-.071	.040	.053
11	.019	.100	-.130	-.120	.366	-.262	-.003	.508	.104	-.106	1.000	-.881	-.060	-.181	-.317	.029
12	-.031	-.097	.183	.227	-.245	.286	.065	-.489	-.100	.112	-.881	1.000	-.045	.317	.276	.052
13	-.147	-.009	.061	-.331	-.062	-.231	.248	-.058	-.069	.065	-.060	-.045	1.000	-.893	-.038	.036
14	.155	-.036	-.015	.412	.040	.370	-.133	-.081	.074	-.071	-.181	.317	-.893	1.000	.090	.035
15	-.016	.028	.056	.256	-.517	.309	-.077	-.155	-.029	.040	-.317	.276	-.038	.090	1.000	.058
16	.075	.044	.028	.069	.037	.059	.049	.033	.035	.053	.029	.052	.036	.035	.058	1.000

A.15.3 Medium Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	.092	-.053	.045	.001	.122	-.106	.037	-.026	.034	-.012	-.081	-.103	.111	.105	-.034
2	.092	1.000	-.037	-.045	.112	.130	-.074	.068	-.005	.039	.077	-.090	.185	-.192	.008	.075
3	-.053	-.037	1.000	.083	.079	.057	.134	-.175	.024	-.006	-.030	.062	.171	-.168	.067	.208
4	.045	-.045	.083	1.000	.004	.458	.310	-.080	.176	-.116	-.115	.133	-.147	.251	.272	.593
5	.001	.112	.079	.004	1.000	.031	.181	.288	.146	-.096	.282	-.226	.101	-.071	-.535	-.114
6	.122	.130	.057	.458	.031	1.000	.169	.103	.326	-.279	-.151	.096	-.138	.195	.352	.449
7	-.106	-.074	.134	.310	.181	.169	1.000	.029	.408	-.349	.051	.110	-.044	.192	-.068	.188
8	.037	.068	-.175	-.080	.288	.103	.029	1.000	.194	-.172	.361	-.358	-.139	.076	-.234	-.125
9	-.026	-.005	.024	.176	.146	.326	.408	.194	1.000	-.956	.088	-.093	-.167	.212	.026	.108
10	.034	.039	-.006	-.116	-.096	-.279	-.349	-.172	-.956	1.000	-.087	.123	.200	-.216	-.015	-.082
11	-.012	.077	-.030	-.115	.282	-.151	.051	.361	.088	-.087	1.000	-.785	-.060	.026	-.308	-.148
12	-.081	-.090	.062	.133	-.226	.096	.110	-.358	-.093	.123	-.785	1.000	.090	.079	.269	.182
13	-.103	.185	.171	-.147	.101	-.138	-.044	-.139	-.167	.200	-.060	.090	1.000	-.907	-.143	.031
14	.111	-.192	-.168	.251	-.071	.195	.192	.076	.212	-.216	.026	.079	-.907	1.000	.178	.040
15	.105	.008	.067	.272	-.535	.352	-.068	-.234	.026	-.015	-.308	.269	-.143	.178	1.000	.299
16	-.034	.075	.208	.593	-.114	.449	.188	-.125	.108	-.082	-.148	.182	.031	.040	.299	1.000

A.15.4 Top 14 Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	-.040	-.283	-.163	-.204	.400	-.124	-.439	-.060	.448	.126	.333	.296	-.083	.300	.285
2	-.040	1.000	-.225	.059	.155	.154	-.109	-.130	.259	-.160	.100	.092	.270	-.193	.258	.267
3	-.283	-.225	1.000	.253	.458	.186	.170	-.002	-.054	.242	.207	.111	-.069	.505	-.340	.142
4	-.163	.059	.253	1.000	.299	.543	.465	.644	.422	-.001	.114	.446	.279	.525	.392	.510
5	-.204	.155	.458	.299	1.000	.081	.674	.345	.406	-.240	.220	.204	.271	.234	-.347	.007
6	.400	.154	.186	.543	.081	1.000	.130	.062	.384	.127	.501	.147	.170	.281	.239	.504
7	-.124	-.109	.170	.465	.674	.130	1.000	.624	.738	-.472	-.058	.312	.164	.321	-.186	-.083
8	-.439	-.130	-.002	.644	.345	.062	.624	1.000	.383	-.394	.095	-.084	.304	.039	-.043	-.104
9	-.060	.259	-.054	.422	.406	.384	.738	.383	1.000	-.727	-.014	.151	-.128	.309	-.157	.030
10	.448	-.160	.242	-.001	-.240	.127	-.472	-.394	-.727	1.000	.127	.374	.401	.052	.498	.428
11	.126	.100	.207	.114	.220	.501	-.058	.095	-.014	.127	1.000	-.400	.146	.014	-.159	.365
12	.333	.092	.111	.446	.204	.147	.312	-.084	.151	.374	-.400	1.000	.277	.465	.555	.458
13	.296	.270	-.069	.279	.271	.170	.164	.304	-.128	.401	.146	.277	1.000	-.385	.441	.112
14	-.083	-.193	.505	.525	.234	.281	.321	.039	.309	.052	.014	.465	-.385	1.000	.009	.632
15	.300	.258	-.340	.392	-.347	.239	-.186	-.043	-.157	.498	-.159	.555	.441	.009	1.000	.458
16	.285	.267	.142	.510	.007	.504	-.083	-.104	.030	.428	.365	.458	.112	.632	.458	1.000

A.16 Description Correlation Matrices For Each Object

A.16.1 Object One Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	.073	.084	.138	.035	.164	-.174	.101	.001	.153	-.283	-.097	.025	.033	.280	-.043
2	.073	1.000	.038	.130	.203	.044	-.202	.333	-.118	.261	.196	-.282	.146	-.131	-.098	.039
3	.084	.038	1.000	.358	.082	.472	.296	-.072	.125	.052	-.074	.275	-.270	.337	-.055	.407
4	.138	.130	.358	1.000	.211	.689	.474	.257	.134	.143	-.155	.295	-.350	.513	.110	.752
5	.035	.203	.082	.211	1.000	-.051	.266	.101	.134	-.023	.287	-.234	-.119	.132	-.410	.259
6	.164	.044	.472	.689	-.051	1.000	.436	.104	.493	-.264	-.433	.481	-.097	.260	.221	.729
7	-.174	-.202	.296	.474	.266	.436	1.000	-.083	.349	-.247	.047	.492	-.213	.328	-.060	.642
8	.101	.333	-.072	.257	.101	.104	-.083	1.000	.122	.083	.211	-.066	-.121	.158	.237	-.030
9	.001	-.118	.125	.134	.134	.493	.349	.122	1.000	-.890	.064	.025	.059	.016	.223	.328
10	.153	.261	.052	.143	-.023	-.264	-.247	.083	-.890	1.000	-.109	.123	-.083	.100	-.086	-.129
11	-.283	.196	-.074	-.155	.287	-.433	.047	.211	.064	-.109	1.000	-.581	-.001	-.030	-.109	-.119
12	-.097	-.282	.275	.295	-.234	.481	.492	-.066	.025	.123	-.581	1.000	-.040	.211	.166	.343
13	.025	.146	-.270	-.350	-.119	-.097	-.213	-.121	.059	-.083	-.001	-.040	1.000	-.919	.061	-.294
14	.033	-.131	.337	.513	.132	.260	.328	.158	.016	.100	-.030	.211	-.919	1.000	.010	.418
15	.280	-.098	-.055	.110	-.410	.221	-.060	.237	.223	-.086	-.109	.166	.061	.010	1.000	.064
16	-.043	.039	.407	.752	.259	.729	.642	-.030	.328	-.129	-.119	.343	-.294	.418	.064	1.000

A.16.2 Object Two Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	.318	-.132	.087	.071	.205	-.205	.116	-.163	.238	-.026	.068	-.186	.119	-.094	.221
2	.318	1.000	.129	.134	.249	.291	.029	.066	-.137	.212	.192	-.093	-.195	.203	-.024	.077
3	-.132	.129	1.000	.355	.127	.342	.421	-.156	.406	-.433	.133	.022	.002	.095	.314	.299
4	.087	.134	.355	1.000	.037	.742	.326	-.249	.459	-.421	.067	.251	-.349	.553	.496	.558
5	.071	.249	.127	.037	1.000	.024	.127	.390	-.135	.192	.272	-.027	.153	-.111	-.237	.018
6	.205	.291	.342	.742	.024	1.000	.262	-.121	.241	-.217	.047	.220	-.420	.609	.473	.514
7	-.205	.029	.421	.326	.127	.262	1.000	-.186	.562	-.457	.041	.156	.455	-.210	.293	.486
8	.116	.066	-.156	-.249	.390	-.121	-.186	1.000	-.139	.234	.571	-.510	.024	-.187	-.024	-.055
9	-.163	-.137	.406	.459	-.135	.241	.562	-.139	1.000	-.913	.008	.091	.342	-.134	.331	.493
10	.238	.212	-.433	-.421	.192	-.217	-.457	.234	-.913	1.000	.105	-.111	-.260	.126	-.269	-.453
11	-.026	.192	.133	.067	.272	.047	.041	.571	.008	.105	1.000	-.816	-.221	-.067	.074	.061
12	.068	-.093	.022	.251	-.027	.220	.156	-.510	.091	-.111	-.816	1.000	.194	.190	-.038	.177
13	-.186	-.195	.002	-.349	.153	-.420	.455	.024	.342	-.260	-.221	.194	1.000	-.853	-.198	.071
14	.119	.203	.095	.553	-.111	.609	-.210	-.187	-.134	.126	-.067	.190	-.853	1.000	.372	.069
15	-.094	-.024	.314	.496	-.237	.473	.293	-.024	.331	-.269	.074	-.038	-.198	.372	1.000	.382
16	.221	.077	.299	.558	.018	.514	.486	-.055	.493	-.453	.061	.177	.071	.069	.382	1.000

A.16.3 Object Three Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	-.099	-.071	-.201	.261	-.174	.170	.270	.240	-.165	.620	-.580	.292	-.399	-.473	-.394
2	-.099	1.000	-.095	-.167	.047	-.074	-.278	.104	-.017	-.020	.059	-.074	-.101	.183	.128	-.062
3	-.071	-.095	1.000	.356	.381	.208	.442	-.217	.132	-.064	-.062	.175	.140	.025	.124	.421
4	-.201	-.167	.356	1.000	.117	.798	.350	.027	.350	-.264	-.083	.296	.220	.068	.428	.851
5	.261	.047	.381	.117	1.000	.008	.451	.201	.577	-.499	.268	-.140	.003	.122	-.442	-.024
6	-.174	-.074	.208	.798	.008	1.000	.315	-.037	.168	-.031	-.155	.357	.351	-.004	.651	.803
7	.170	-.278	.442	.350	.451	.315	1.000	.001	.501	-.364	-.053	.236	.082	.104	.003	.308
8	.270	.104	-.217	.027	.201	-.037	.001	1.000	.281	-.333	.641	-.530	-.085	-.196	-.236	-.134
9	.240	-.017	.132	.350	.577	.168	.501	.281	1.000	-.904	.347	-.205	.045	-.012	-.273	.217
10	-.165	-.020	-.064	-.264	-.499	-.031	-.364	-.333	-.904	1.000	-.343	.296	-.017	.125	.344	-.174
11	.620	.059	-.062	-.083	.268	-.155	-.053	.641	.347	-.343	1.000	-.904	.036	-.310	-.537	-.357
12	-.580	-.074	.175	.296	-.140	.357	.236	-.530	-.205	.296	-.904	1.000	-.039	.481	.629	.488
13	.292	-.101	.140	.220	.003	.351	.082	-.085	.045	-.017	.036	-.039	1.000	-.729	.144	.267
14	-.399	.183	.025	.068	.122	-.004	.104	-.196	-.012	.125	-.310	.481	-.729	1.000	.120	.028
15	-.473	.128	.124	.428	-.442	.651	.003	-.236	-.273	.344	-.537	.629	.144	.120	1.000	.677
16	-.394	-.062	.421	.851	-.024	.803	.308	-.134	.217	-.174	-.357	.488	.267	.028	.677	1.000

A.16.4 Object Four Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	.287	-.185	-.391	.159	-.292	-.344	.044	-.361	.378	.071	-.034	.005	-.046	-.082	-.439
2	.287	1.000	-.123	-.019	.074	.085	.018	.151	-.133	.196	-.021	-.021	.315	-.251	.287	-.139
3	-.185	-.123	1.000	.351	.054	.302	.194	-.073	-.005	.141	-.153	.002	.490	-.413	-.006	.481
4	-.391	-.019	.351	1.000	.090	.700	.496	.011	.048	.053	-.253	.239	-.043	.205	.466	.753
5	.159	.074	.054	.090	1.000	.164	.062	.414	-.067	.063	.384	-.074	.314	-.170	-.578	.040
6	-.292	.085	.302	.700	.164	1.000	.441	.103	.031	.144	-.179	.175	.152	.031	.359	.750
7	-.344	.018	.194	.496	.062	.441	1.000	.229	.359	-.206	-.066	.171	.173	.042	.160	.471
8	.044	.151	-.073	.011	.414	.103	.229	1.000	.089	-.080	.716	-.393	.040	-.126	-.214	-.036
9	-.361	-.133	-.005	.048	-.067	.031	.359	.089	1.000	-.905	.165	-.050	-.072	.098	-.138	.267
10	.378	.196	.141	.053	.063	.144	-.206	-.080	-.905	1.000	-.239	.239	.205	-.117	.235	-.145
11	.071	-.021	-.153	-.253	.384	-.179	-.066	.716	.165	-.239	1.000	-.680	-.014	-.197	-.442	-.121
12	-.034	-.021	.002	.239	-.074	.175	.171	-.393	-.050	.239	-.680	1.000	-.083	.515	.250	.076
13	.005	.315	.490	-.043	.314	.152	.173	.040	-.072	.205	-.014	-.083	1.000	-.821	-.139	.119
14	-.046	-.251	-.413	.205	-.170	.031	.042	-.126	.098	-.117	-.197	.515	-.821	1.000	.192	.053
15	-.082	.287	-.006	.466	-.578	.359	.160	-.214	-.138	.235	-.442	.250	-.139	.192	1.000	.291
16	-.439	-.139	.481	.753	.040	.750	.471	-.036	.267	-.145	-.121	.076	.119	.053	.291	1.000

A.16.5 Object Five Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	-.181	.087	.117	-.179	.068	-.230	-.090	-.161	.215	.075	.060	-.015	.131	.143	-.028
2	-.181	1.000	.040	.351	.344	.227	.191	.055	.073	.049	-.017	.254	.197	-.143	.079	.411
3	.087	.040	1.000	.168	.284	.172	.303	-.118	.033	-.021	.009	.345	.276	-.078	-.005	.194
4	.117	.351	.168	1.000	.232	.649	.451	.050	.266	-.132	-.310	.547	-.133	.319	.337	.871
5	-.179	.344	.284	.232	1.000	.188	.423	.296	.152	-.068	.300	.028	.304	-.201	-.452	.142
6	.068	.227	.172	.649	.188	1.000	.513	-.129	.428	-.321	-.374	.636	-.183	.431	.326	.766
7	-.230	.191	.303	.451	.423	.513	1.000	-.040	.409	-.310	-.054	.418	.186	.084	-.084	.451
8	-.090	.055	-.118	.050	.296	-.129	-.040	1.000	.223	-.181	.258	-.208	-.086	.043	-.163	-.041
9	-.161	.073	.033	.266	.152	.428	.409	.223	1.000	-.936	-.172	.419	-.462	.678	.287	.478
10	.215	.049	-.021	-.132	-.068	-.321	-.310	-.181	-.936	1.000	.182	-.295	.521	-.634	-.275	-.366
11	.075	-.017	.009	-.310	.300	-.374	-.054	.258	-.172	.182	1.000	-.692	.258	-.259	-.466	-.502
12	.060	.254	.345	.547	.028	.636	.418	-.208	.419	-.295	-.692	1.000	-.074	.344	.300	.711
13	-.015	.197	.276	-.133	.304	-.183	.186	-.086	-.462	.521	.258	-.074	1.000	-.884	-.292	-.213
14	.131	-.143	-.078	.319	-.201	.431	.084	.043	.678	-.634	-.259	.344	-.884	1.000	.326	.427
15	.143	.079	-.005	.337	-.452	.326	-.084	-.163	.287	-.275	-.466	.300	-.292	.326	1.000	.481
16	-.028	.411	.194	.871	.142	.766	.451	-.041	.478	-.366	-.502	.711	-.213	.427	.481	1.000

A.16.6 Object Six Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	.049	.232	.177	-.120	.243	.095	-.550	-.083	.120	-.118	.290	.054	.185	.422	.249
2	.049	1.000	.046	.030	.148	.146	.201	.047	.083	.058	.213	-.191	.162	-.248	-.041	-.023
3	.232	.046	1.000	.225	.042	.321	-.014	-.214	-.120	.118	-.024	.129	.040	-.029	.305	.306
4	.177	.030	.225	1.000	.210	.702	.433	.069	.240	-.088	-.043	.288	-.190	.284	.311	.715
5	-.120	.148	.042	.210	1.000	.168	.240	.300	.164	.003	.347	-.296	.208	-.213	-.524	.221
6	.243	.146	.321	.702	.168	1.000	.196	-.052	.054	.054	.042	.214	-.076	.161	.410	.732
7	.095	.201	-.014	.433	.240	.196	1.000	.049	.400	-.283	-.045	.130	-.105	.199	.142	.461
8	-.550	.047	-.214	.069	.300	-.052	.049	1.000	.066	.115	.069	-.030	.131	-.122	-.273	-.127
9	-.083	.083	-.120	.240	.164	.054	.400	.066	1.000	-.883	.348	-.301	-.082	-.075	-.219	.267
10	.120	.058	.118	-.088	.003	.054	-.283	.115	-.883	1.000	-.204	.329	.269	-.004	.241	-.188
11	-.118	.213	-.024	-.043	.347	.042	-.045	.069	.348	-.204	1.000	-.856	.296	-.495	-.352	.223
12	.290	-.191	.129	.288	-.296	.214	.130	-.030	-.301	.329	-.856	1.000	-.234	.589	.508	.027
13	.054	.162	.040	-.190	.208	-.076	-.105	.131	-.082	.269	.296	-.234	1.000	-.826	-.182	-.093
14	.185	-.248	-.029	.284	-.213	.161	.199	-.122	-.075	-.004	-.495	.589	-.826	1.000	.341	.110
15	.422	-.041	.305	.311	-.524	.410	.142	-.273	-.219	.241	-.352	.508	-.182	.341	1.000	.396
16	.249	-.023	.306	.715	.221	.732	.461	-.127	.267	-.188	.223	.027	-.093	.110	.396	1.000

A.16.7 Object Seven Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	-.014	-.035	-.102	-.049	-.323	-.376	-.376	-.174	.274	-.178	.236	-.063	-.008	.351	-.124
2	-.014	1.000	-.267	-.164	.472	.048	.195	.250	.231	-.149	.359	-.245	.152	-.139	-.187	.007
3	-.035	-.267	1.000	.378	.080	.199	.390	-.059	-.025	.028	.130	.019	-.156	.272	-.066	.409
4	-.102	-.164	.378	1.000	.132	.665	.419	.016	-.028	.020	.016	.233	-.278	.437	.198	.774
5	-.049	.472	.080	.132	1.000	.167	.120	.466	.452	-.405	.430	-.378	-.126	.131	-.585	.223
6	-.323	.048	.199	.665	.167	1.000	.257	.170	.253	-.271	.003	.204	-.200	.333	.245	.711
7	-.376	.195	.390	.419	.120	.257	1.000	.039	.217	-.166	.080	.144	.022	.184	-.074	.371
8	-.376	.250	-.059	.016	.466	.170	.039	1.000	.241	-.263	.394	-.456	.282	-.241	-.476	.026
9	-.174	.231	-.025	-.028	.452	.253	.217	.241	1.000	-.954	.122	-.046	-.273	.323	-.255	-.012
10	.274	-.149	.028	.020	-.405	-.271	-.166	-.263	-.954	1.000	-.104	.122	.294	-.286	.315	.024
11	-.178	.359	.130	.016	.430	.003	.080	.394	.122	-.104	1.000	-.793	.169	-.142	-.540	.171
12	.236	-.245	.019	.233	-.378	.204	.144	-.456	-.046	.122	-.793	1.000	-.197	.320	.614	.039
13	-.063	.152	-.156	-.278	-.126	-.200	.022	.282	-.273	.294	.169	-.197	1.000	-.928	-.115	-.141
14	-.008	-.139	.272	.437	.131	.333	.184	-.241	.323	-.286	-.142	.320	-.928	1.000	.161	.296
15	.351	-.187	-.066	.198	-.585	.245	-.074	-.476	-.255	.315	-.540	.614	-.115	.161	1.000	.142
16	-.124	.007	.409	.774	.223	.711	.371	.026	-.012	.024	.171	.039	-.141	.296	.142	1.000

A.16.8 Object Nine Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	.041	-.079	.024	.030	.003	.077	.122	.210	-.193	.006	.021	-.077	.208	-.117	-.197
2	.041	1.000	.330	.032	.126	.260	.051	.078	.125	-.046	.184	-.162	.087	-.104	.020	-.052
3	-.079	.330	1.000	.485	.108	.649	.253	-.003	.207	-.144	-.048	.177	-.247	.288	.216	.416
4	.024	.032	.485	1.000	.196	.747	.404	.115	.329	-.239	.312	-.197	-.385	.538	.298	.803
5	.030	.126	.108	.196	1.000	.371	.326	.329	.139	-.035	.336	-.189	.051	.061	-.428	.310
6	.003	.260	.649	.747	.371	1.000	.469	.136	.498	-.402	.188	-.072	-.191	.329	.291	.638
7	.077	.051	.253	.404	.326	.469	1.000	.079	.382	-.317	.017	.095	-.031	.271	-.006	.219
8	.122	.078	-.003	.115	.329	.136	.079	1.000	.166	-.028	.262	-.129	-.089	.192	-.315	.215
9	.210	.125	.207	.329	.139	.498	.382	.166	1.000	-.946	.295	-.292	-.046	.088	.253	.256
10	-.193	-.046	-.144	-.239	-.035	-.402	-.317	-.028	-.946	1.000	-.241	.313	.105	-.062	-.231	-.188
11	.006	.184	-.048	.312	.336	.188	.017	.262	.295	-.241	1.000	-.920	-.041	-.057	-.080	.467
12	.021	-.162	.177	-.197	-.189	-.072	.095	-.129	-.292	.313	-.920	1.000	.039	.168	.102	-.373
13	-.077	.087	-.247	-.385	.051	-.191	-.031	-.089	-.046	.105	-.041	.039	1.000	-.850	-.225	-.257
14	.208	-.104	.288	.538	.061	.329	.271	.192	.088	-.062	-.057	.168	-.850	1.000	.202	.362
15	-.117	.020	.216	.298	-.428	.291	-.006	-.315	.253	-.231	-.080	.102	-.225	.202	1.000	.255
16	-.197	-.052	.416	.803	.310	.638	.219	.215	.256	-.188	.467	-.373	-.257	.362	.255	1.000

A.16.9 Object Ten Description Evaluation Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	1.000	.110	-.215	-.093	-.315	-.229	-.061	.019	-.389	.433	.093	-.110	-.233	.263	.015	-.146
2	.110	1.000	.024	-.080	.138	.081	.132	.219	-.157	.150	.381	-.307	.450	-.497	-.123	-.001
3	-.215	.024	1.000	.338	.190	.279	.195	-.069	.282	-.251	-.201	.267	.494	-.421	.345	.460
4	-.093	-.080	.338	1.000	.207	.804	.411	-.237	.282	-.202	-.580	.674	.387	-.200	.660	.800
5	-.315	.138	.190	.207	1.000	.200	.287	.440	.252	-.240	-.115	.082	.076	-.006	-.275	.230
6	-.229	.081	.279	.804	.200	1.000	.308	-.052	.371	-.292	-.414	.548	.464	-.333	.672	.792
7	-.061	.132	.195	.411	.287	.308	1.000	-.180	.348	-.339	-.449	.454	.249	-.054	-.060	.289
8	.019	.219	-.069	-.237	.440	-.052	-.180	1.000	.017	.014	.391	-.219	-.064	.048	-.278	-.210
9	-.389	-.157	.282	.282	.252	.371	.348	.017	1.000	-.958	-.209	.288	.178	-.055	.148	.420
10	.433	.150	-.251	-.202	-.240	-.292	-.339	.014	-.958	1.000	.195	-.199	-.107	.060	-.040	-.358
11	.093	.381	-.201	-.580	-.115	-.414	-.449	.391	-.209	.195	1.000	-.870	-.004	-.115	-.390	-.338
12	-.110	-.307	.267	.674	.082	.548	.454	-.219	.288	-.199	-.870	1.000	.182	.030	.528	.429
13	-.233	.450	.494	.387	.076	.464	.249	-.064	.178	-.107	-.004	.182	1.000	-.916	.337	.525
14	.263	-.497	-.421	-.200	-.006	-.333	-.054	.048	-.055	.060	-.115	.030	-.916	1.000	-.230	-.396
15	.015	-.123	.345	.660	-.275	.672	-.060	-.278	.148	-.040	-.390	.528	.337	-.230	1.000	.579
16	-.146	-.001	.460	.800	.230	.792	.289	-.210	.420	-.358	-.338	.429	.525	-.396	.579	1.000

A.17 Reconstruction Correlation Matrices

A.17.1 Overall Reconstruction Correlation Matrix

This matrix does not include data from Object 0.

	1	2	3	4	5	6	7	8	9	10
1	1.000	.175	.178	.148	.228	.156	-.204	.218	.178	.289
2	.175	1.000	.419	.509	.555	.680	-.270	.286	.777	.459
3	.178	.419	1.000	.770	.323	.486	-.283	.315	.486	.233
4	.148	.509	.770	1.000	.278	.475	-.239	.256	.530	.198
5	.228	.555	.323	.278	1.000	.715	-.218	.230	.696	.391
6	.156	.680	.486	.475	.715	1.000	-.309	.322	.889	.420
7	-.204	-.270	-.283	-.239	-.218	-.309	1.000	-.983	-.281	-.434
8	.218	.286	.315	.256	.230	.322	-.983	1.000	.290	.454
9	.178	.777	.486	.530	.696	.889	-.281	.290	1.000	.426
10	.289	.459	.233	.198	.391	.420	-.434	.454	.426	1.000

A.17.2 Reconstruction Correlation Matrix for Object 0

	1	2	3	4	5	6	7	8	9	10
1	1.000	.365	.221	.290	.356	.228	-.004	.033	.304	.368
2	.365	1.000	.687	.621	.675	.634	.056	-.033	.659	.609
3	.221	.687	1.000	.383	.581	.512	-.300	.351	.486	.518
4	.290	.621	.383	1.000	.564	.542	.152	-.131	.865	.416
5	.356	.675	.581	.564	1.000	.858	-.359	.390	.751	.703
6	.228	.634	.512	.542	.858	1.000	-.297	.323	.742	.645
7	-.004	.056	-.300	.152	-.359	-.297	1.000	-.992	-.153	-.319
8	.033	-.033	.351	-.131	.390	.323	-.992	1.000	.168	.334
9	.304	.659	.486	.865	.751	.742	-.153	.168	1.000	.601
10	.368	.609	.518	.416	.703	.645	-.319	.334	.601	1.000

A.17.3 Reconstruction Correlation Matrix for Object 1

	1	2	3	4	5	6	7	8	9	10
1	1.000	.105	.140	.136	.218	.173	-.091	.103	.174	.224
2	.105	1.000	.609	.851	.724	.821	-.361	.374	.891	.553
3	.140	.609	1.000	.753	.764	.731	-.406	.428	.724	.333
4	.136	.851	.753	1.000	.836	.860	-.425	.435	.929	.494
5	.218	.724	.764	.836	1.000	.928	-.286	.300	.891	.506
6	.173	.821	.731	.860	.928	1.000	-.309	.322	.934	.601
7	-.091	-.361	-.406	-.425	-.286	-.309	1.000	-.992	-.401	-.322
8	.103	.374	.428	.435	.300	.322	-.992	1.000	.411	.343
9	.174	.891	.724	.929	.891	.934	-.401	.411	1.000	.562
10	.224	.553	.333	.494	.506	.601	-.322	.343	.562	1.000

A.17.4 Reconstruction Correlation Matrix for Object 2

	1	2	3	4	5	6	7	8	9	10
1	1.000	.472	.467	.525	.445	.449	-.248	.273	.509	.333
2	.472	1.000	.793	.800	.894	.898	-.553	.564	.921	.615
3	.467	.793	1.000	.897	.913	.888	-.546	.552	.856	.341
4	.525	.800	.897	1.000	.912	.892	-.574	.575	.913	.522
5	.445	.894	.913	.912	1.000	.945	-.636	.642	.924	.559
6	.449	.898	.888	.892	.945	1.000	-.496	.493	.941	.565
7	-.248	-.553	-.546	-.574	-.636	-.496	1.000	-.988	-.518	-.561
8	.273	.564	.552	.575	.642	.493	-.988	1.000	.520	.571
9	.509	.921	.856	.913	.924	.941	-.518	.520	1.000	.573
10	.333	.615	.341	.522	.559	.565	-.561	.571	.573	1.000

A.17.5 Reconstruction Correlation Matrix for Object 3

	1	2	3	4	5	6	7	8	9	10
1	1.000	.130	.210	.242	.178	.323	-.174	.229	.196	.555
2	.130	1.000	.331	.730	.750	.699	-.062	.060	.862	.414
3	.210	.331	1.000	.569	.490	.431	-.147	.170	.595	.376
4	.242	.730	.569	1.000	.637	.759	-.153	.159	.778	.314
5	.178	.750	.490	.637	1.000	.599	-.276	.270	.783	.515
6	.323	.699	.431	.759	.599	1.000	-.286	.293	.716	.449
7	-.174	-.062	-.147	-.153	-.276	-.286	1.000	-.953	-.085	-.261
8	.229	.060	.170	.159	.270	.293	-.953	1.000	.100	.250
9	.196	.862	.595	.778	.783	.716	-.085	.100	1.000	.485
10	.555	.414	.376	.314	.515	.449	-.261	.250	.485	1.000

A.17.6 Reconstruction Correlation Matrix for Object 4

	1	2	3	4	5	6	7	8	9	10
1	1.000	.402	.313	.339	.463	.405	-.675	.687	.423	.393
2	.402	1.000	.206	.396	.624	.655	-.444	.456	.652	.581
3	.313	.206	1.000	.936	.545	.492	-.470	.495	.449	.448
4	.339	.396	.936	1.000	.651	.619	-.515	.540	.540	.498
5	.463	.624	.545	.651	1.000	.892	-.472	.484	.877	.522
6	.405	.655	.492	.619	.892	1.000	-.479	.492	.947	.608
7	-.675	-.444	-.470	-.515	-.472	-.479	1.000	-.990	-.464	-.620
8	.687	.456	.495	.540	.484	.492	-.990	1.000	.475	.633
9	.423	.652	.449	.540	.877	.947	-.464	.475	1.000	.616
10	.393	.581	.448	.498	.522	.608	-.620	.633	.616	1.000

A.17.7 Reconstruction Correlation Matrix for Object 5

	1	2	3	4	5	6	7	8	9	10
1	1.000	.152	-.148	-.025	.108	.060	-.086	.105	.077	.151
2	.152	1.000	.073	.025	.766	.769	-.232	.250	.806	.626
3	-.148	.073	1.000	.519	.147	.245	-.741	.784	.237	.280
4	-.025	.025	.519	1.000	.105	.132	-.142	.258	.101	.052
5	.108	.766	.147	.105	1.000	.778	-.277	.299	.811	.681
6	.060	.769	.245	.132	.778	1.000	-.377	.395	.935	.617
7	-.086	-.232	-.741	-.142	-.277	-.377	1.000	-.988	-.361	-.525
8	.105	.250	.784	.258	.299	.395	-.988	1.000	.374	.542
9	.077	.806	.237	.101	.811	.935	-.361	.374	1.000	.644
10	.151	.626	.280	.052	.681	.617	-.525	.542	.644	1.000

A.17.8 Reconstruction Correlation Matrix for Object 6

	1	2	3	4	5	6	7	8	9	10
1	1.000	-.050	-.038	.015	.086	.043	.247	-.205	.102	.098
2	-.050	1.000	.207	.547	.587	.570	-.246	.272	.634	.422
3	-.038	.207	1.000	.337	.615	.481	-.068	.146	.444	-.050
4	.015	.547	.337	1.000	.676	.634	-.404	.435	.807	.283
5	.086	.587	.615	.676	1.000	.918	-.231	.262	.850	.191
6	.043	.570	.481	.634	.918	1.000	-.305	.329	.880	.220
7	.247	-.246	-.068	-.404	-.231	-.305	1.000	-.965	-.379	-.453
8	-.205	.272	.146	.435	.262	.329	-.965	1.000	.396	.485
9	.102	.634	.444	.807	.850	.880	-.379	.396	1.000	.215
10	.098	.422	-.050	.283	.191	.220	-.453	.485	.215	1.000

A.17.9 Reconstruction Correlation Matrix for Object 7

	1	2	3	4	5	6	7	8	9	10
1	1.000	-.079	.314	.047	-.303	-.446	.163	.031	-.389	.105
2	-.079	1.000	.494	.755	.697	.403	.300	-.121	.789	.212
3	.314	.494	1.000	.628	.521	.456	.189	.283	.429	.448
4	.047	.755	.628	1.000	.614	.515	.174	.067	.751	.406
5	-.303	.697	.521	.614	1.000	.725	.160	.047	.805	.291
6	-.446	.403	.456	.515	.725	1.000	.058	.120	.737	.293
7	.163	.300	.189	.174	.160	.058	1.000	-.876	.244	-.282
8	.031	-.121	.283	.067	.047	.120	-.876	1.000	-.090	.477
9	-.389	.789	.429	.751	.805	.737	.244	-.090	1.000	.257
10	.105	.212	.448	.406	.291	.293	-.282	.477	.257	1.000

A.17.10 Reconstruction Correlation Matrix for Object 9

	1	2	3	4	5	6	7	8	9	10
1	1.000	.361	.441	.275	.516	.470	-.518	.530	.412	.628
2	.361	1.000	.631	.698	.756	.750	-.421	.433	.749	.729
3	.441	.631	1.000	.769	.614	.576	-.471	.494	.524	.624
4	.275	.698	.769	1.000	.557	.525	-.190	.206	.556	.536
5	.516	.756	.614	.557	1.000	.864	-.496	.507	.898	.659
6	.470	.750	.576	.525	.864	1.000	-.450	.463	.942	.644
7	-.518	-.421	-.471	-.190	-.496	-.450	1.000	-.992	-.414	-.619
8	.530	.433	.494	.206	.507	.463	-.992	1.000	.422	.632
9	.412	.749	.524	.556	.898	.942	-.414	.422	1.000	.604
10	.628	.729	.624	.536	.659	.644	-.619	.632	.604	1.000

A.17.11 Reconstruction Correlation Matrix for Object 10

	1	2	3	4	5	6	7	8	9	10
1	1.000	-.158	.105	-.240	.105	-.166	.110	-.094	-.091	.401
2	-.158	1.000	.151	-.109	.151	.647	-.459	.478	.582	.494
3	.105	.151	1.000	.593	1.000	.082	.044	.097	.074	.106
4	-.240	-.109	.593	1.000	.593	-.084	.174	-.090	-.094	-.358
5	.105	.151	1.000	.593	1.000	.082	.044	.097	.074	.106
6	-.166	.647	.082	-.084	.082	1.000	-.239	.250	.941	.294
7	.110	-.459	.044	.174	.044	-.239	1.000	-.990	-.182	-.484
8	-.094	.478	.097	-.090	.097	.250	-.990	1.000	.192	.497
9	-.091	.582	.074	-.094	.074	.941	-.182	.192	1.000	.223
10	.401	.494	.106	-.358	.106	.294	-.484	.497	.223	1.000

A.18 Correlation of Description & Reconstruction Data

This matrix correlates data from the evaluations of the 27 descriptions submitted to the reconstructors and data from all the reconstructions. (df = 808)

	1	2	3	4	5	6	7	8	9	10
1	.091	.171	.211	-.072	-.056	.144	.042	.159	.200	.148
2	.660	.188	-.111	-.032	.013	-.115	-.103	.042	.018	.076
3	-.019	.224	.131	.209	.200	.270	-.246	.254	.239	.278
4	.001	.374	.228	.270	.371	.463	-.437	.539	.536	.498
5	.168	-.126	-.350	-.209	.104	-.182	.115	-.047	-.114	-.050
6	.111	.568	.261	.245	.652	.613	-.391	.418	.748	.570
7	.082	.275	.010	.040	.388	.241	-.158	.299	.364	.377
8	.165	-.031	.010	.142	.228	.040	-.135	.279	.028	.022
9	-.099	.185	.095	.019	.367	.233	.127	.087	.292	.232
10	.199	-.126	-.063	-.039	-.299	-.155	-.090	-.011	-.211	-.098
11	.372	-.273	-.287	-.385	.073	-.235	.157	.017	-.289	.164
12	-.156	.212	.123	.175	-.009	.216	-.102	.072	.279	.001
13	.130	.081	.049	-.145	-.210	-.085	.367	-.342	-.074	-.020
14	-.034	.051	-.013	.066	.335	.225	-.356	.452	.200	.247
15	-.019	.535	.377	.213	.396	.569	-.123	.150	.584	.440
16	.001	.403	.199	.239	.448	.565	-.477	.481	.571	.411

A.19 Object 0 Reconstructions

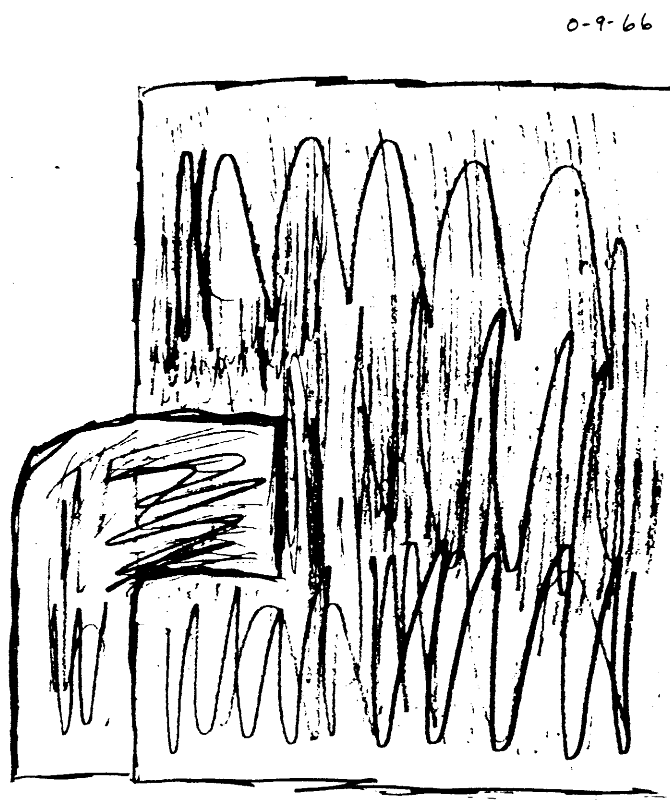

Figure A-53: Reconstruction 0-9-66 - Resemblance Score of 4

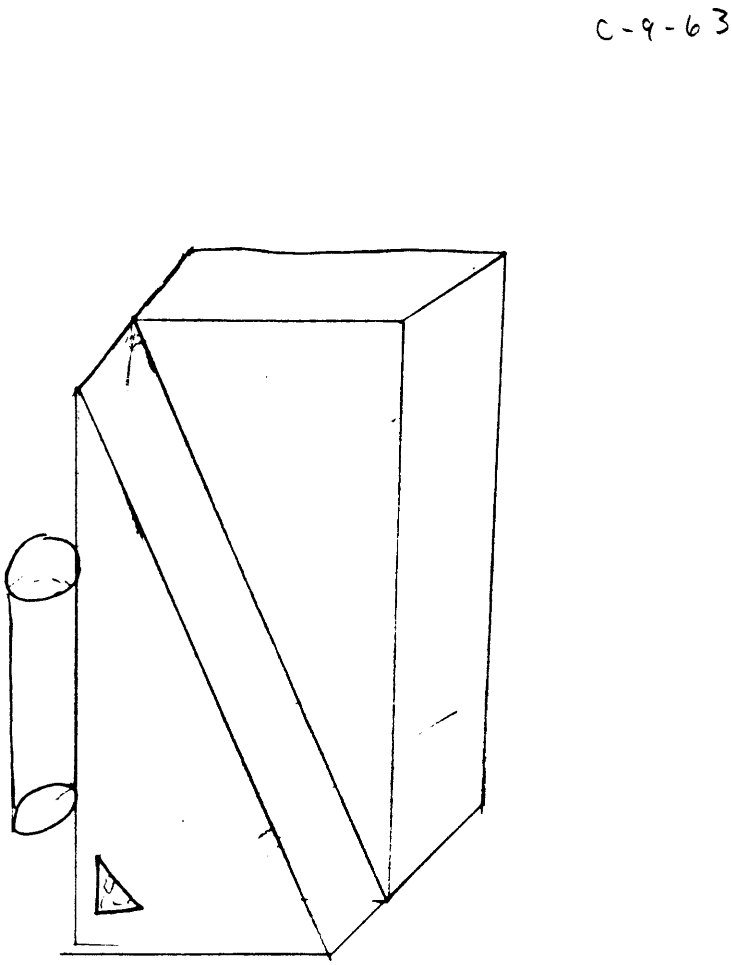

Figure A-54: Reconstruction 0-9-63 - Resemblance Score of 7

0-9-82

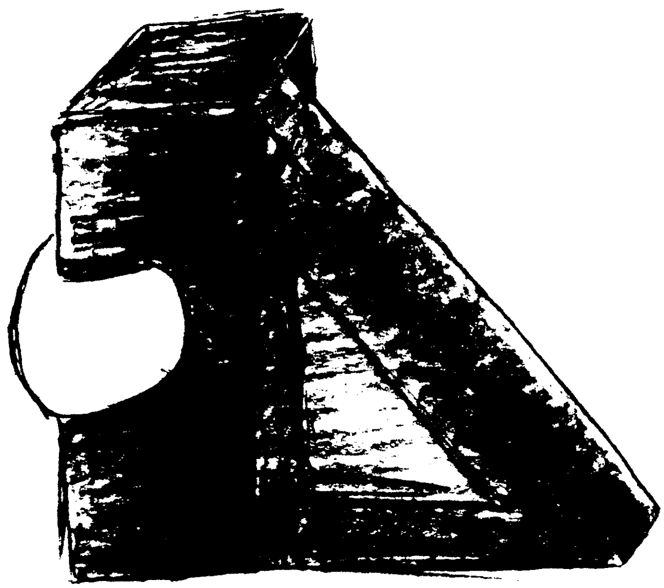

Figure A-55: Reconstruction 0-9-82 - Resemblance Score of 9

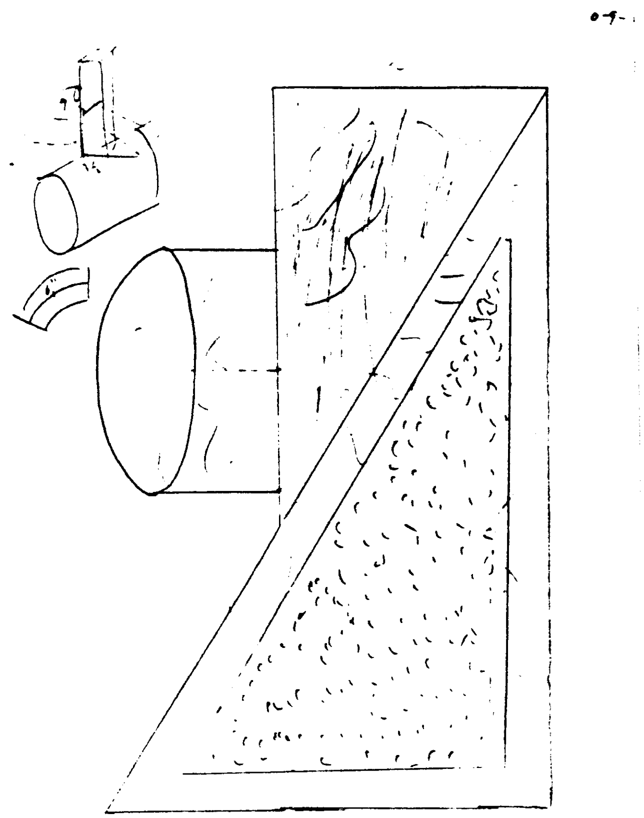

Figure A-56: Reconstruction 0-9-60 - Resemblance Score of 11

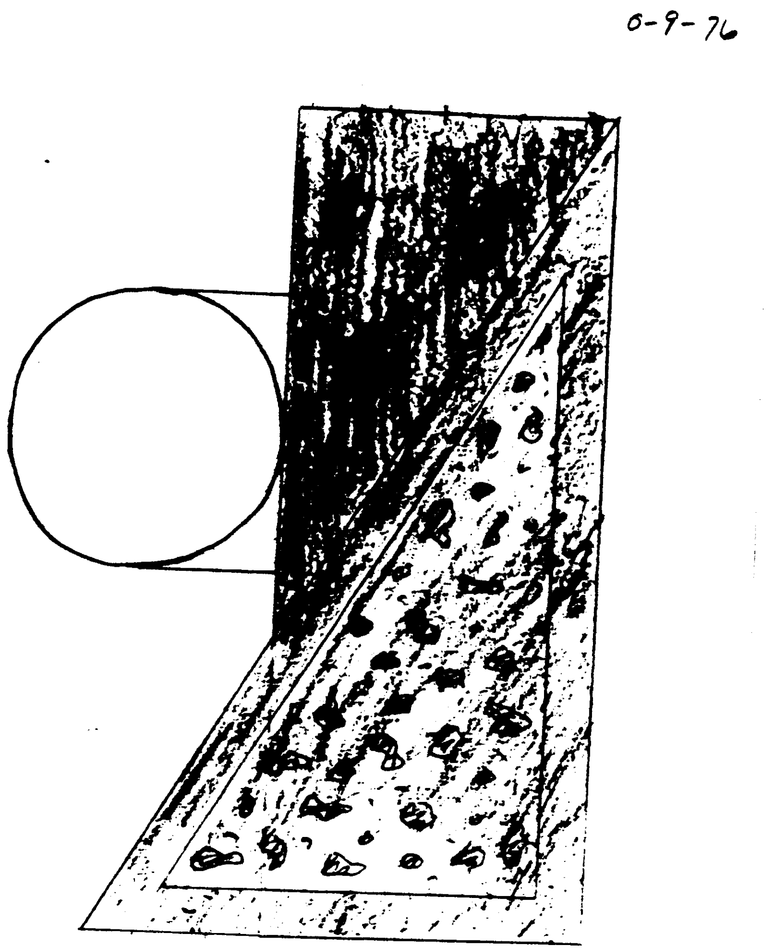

Figure A-57: Reconstruction 0-9-76 - Resemblance Score of 12

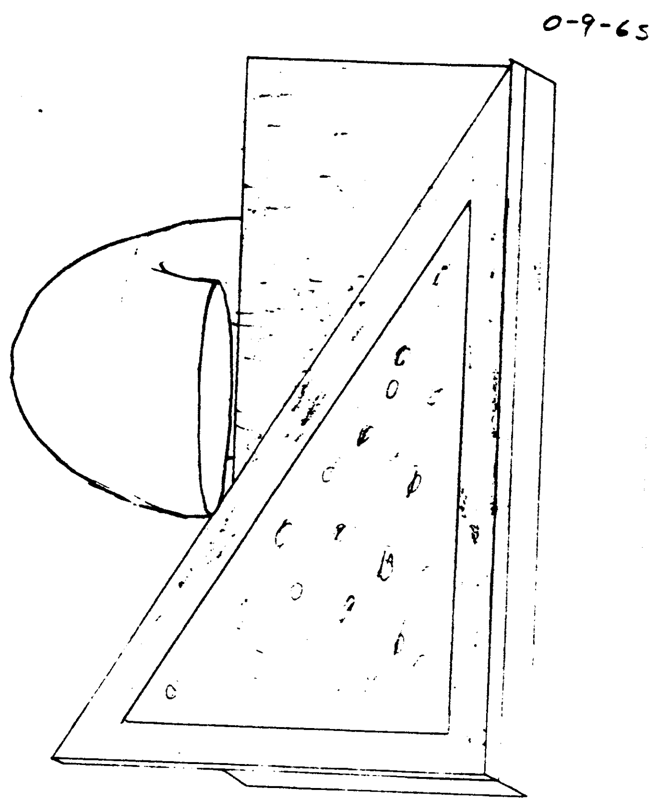

Figure A-58: Reconstruction 0-9-65 - Resemblance Score of 15

A.20 Objects

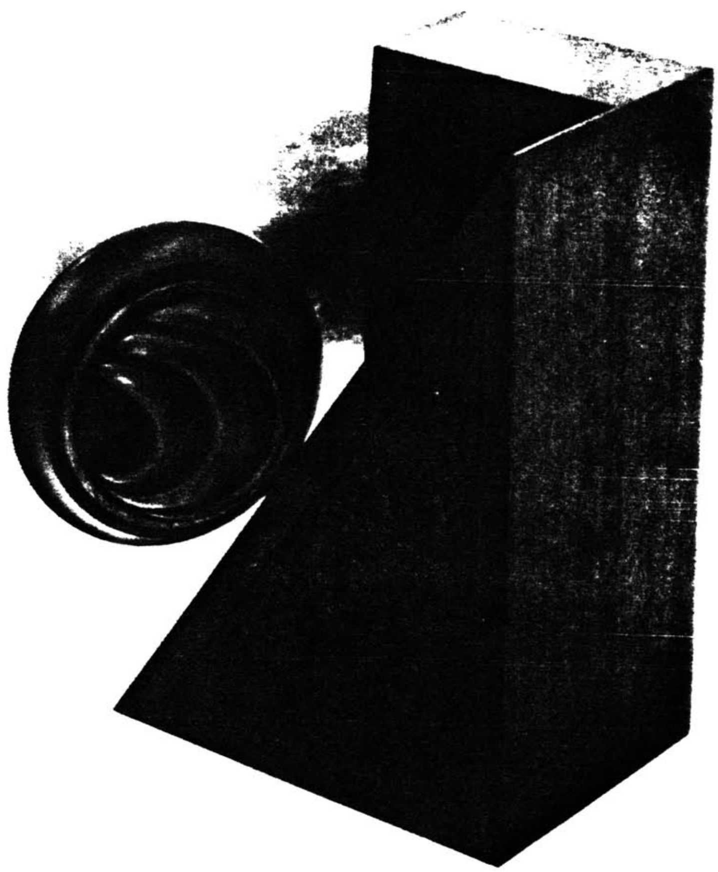

Figure A-59: Object 0 -- McCallister Box_Untitled by Michael N. Graham

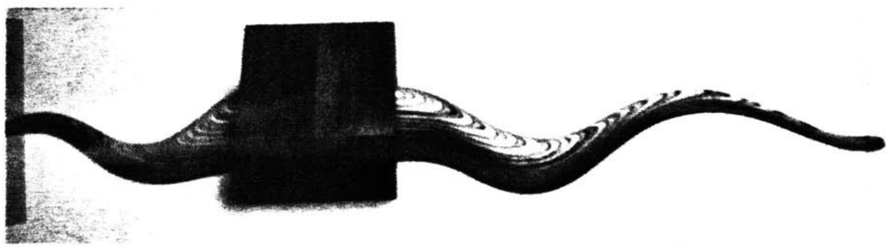

Figure A-60: Object 1 -- Parma Box by Dean Santner

Figure A-61: Object 2 -- Cloud Box by Mark Lindquist

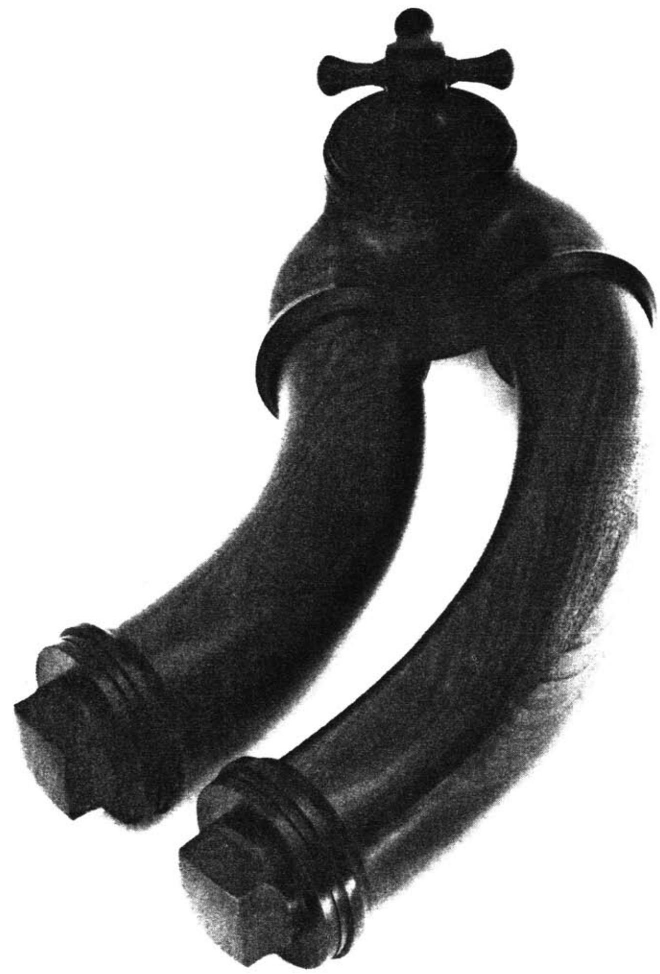

Figure A-62: Object 3 -- McCallister Box, Gate Valve Pipe Form by Michael N. Graham

Figure A-63: Object 4 -- Lotus Bowl by Hap Sakwa

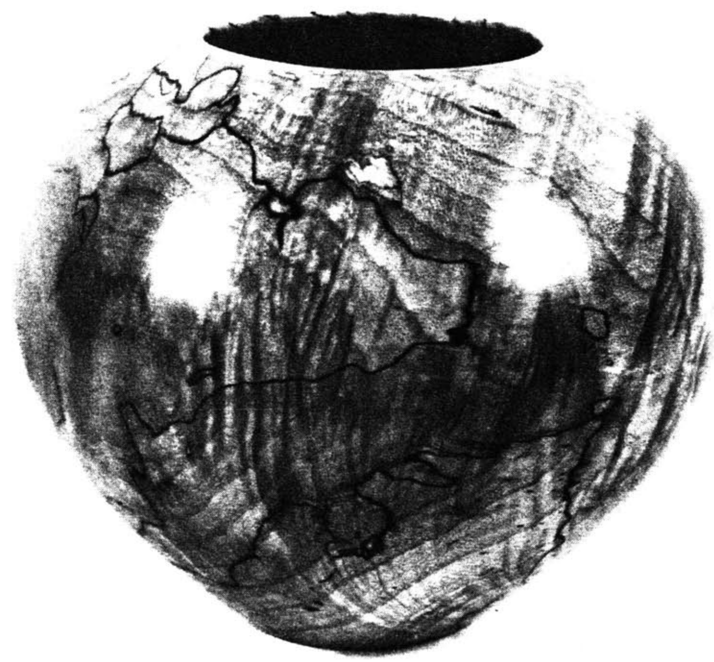

Figure A-64: Object 5 -- Egg Form Bowl by William Patrick

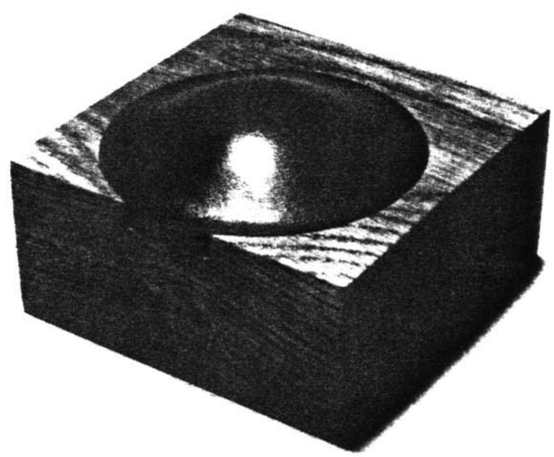

Figure A-65: Object 6 -- Box by Chuck Masters

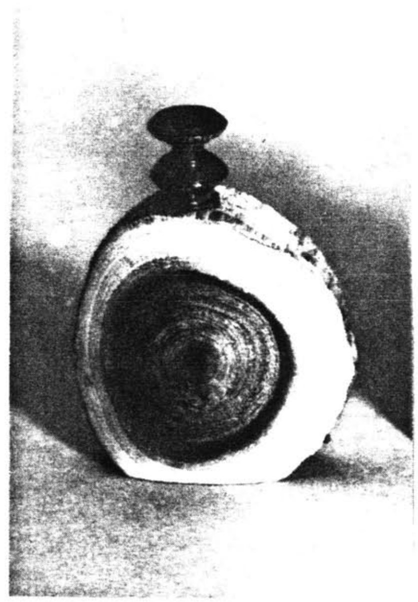

Figure A-66: Object 7 -- Bottle by Stephen M. Paulsen

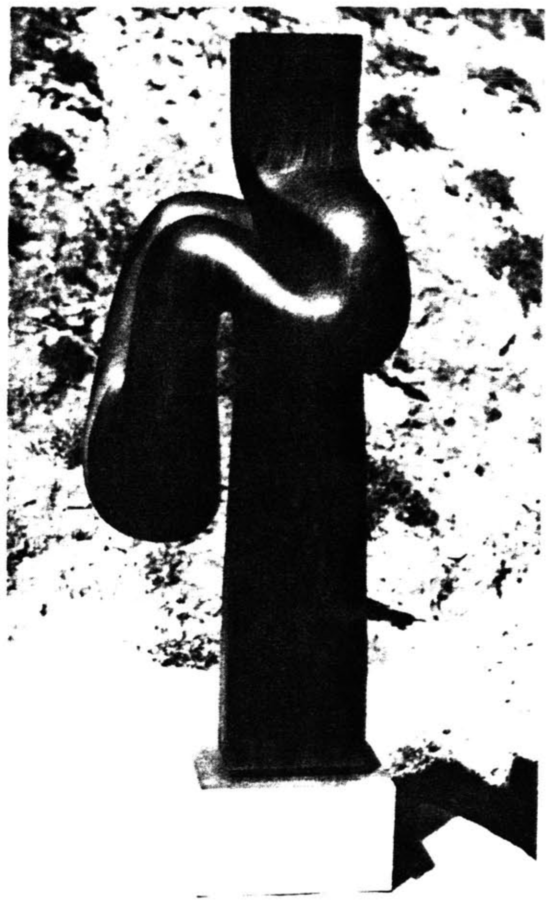

Figure A-67: Object 9 -- Plastic Form 1 by Carl E. Johnson

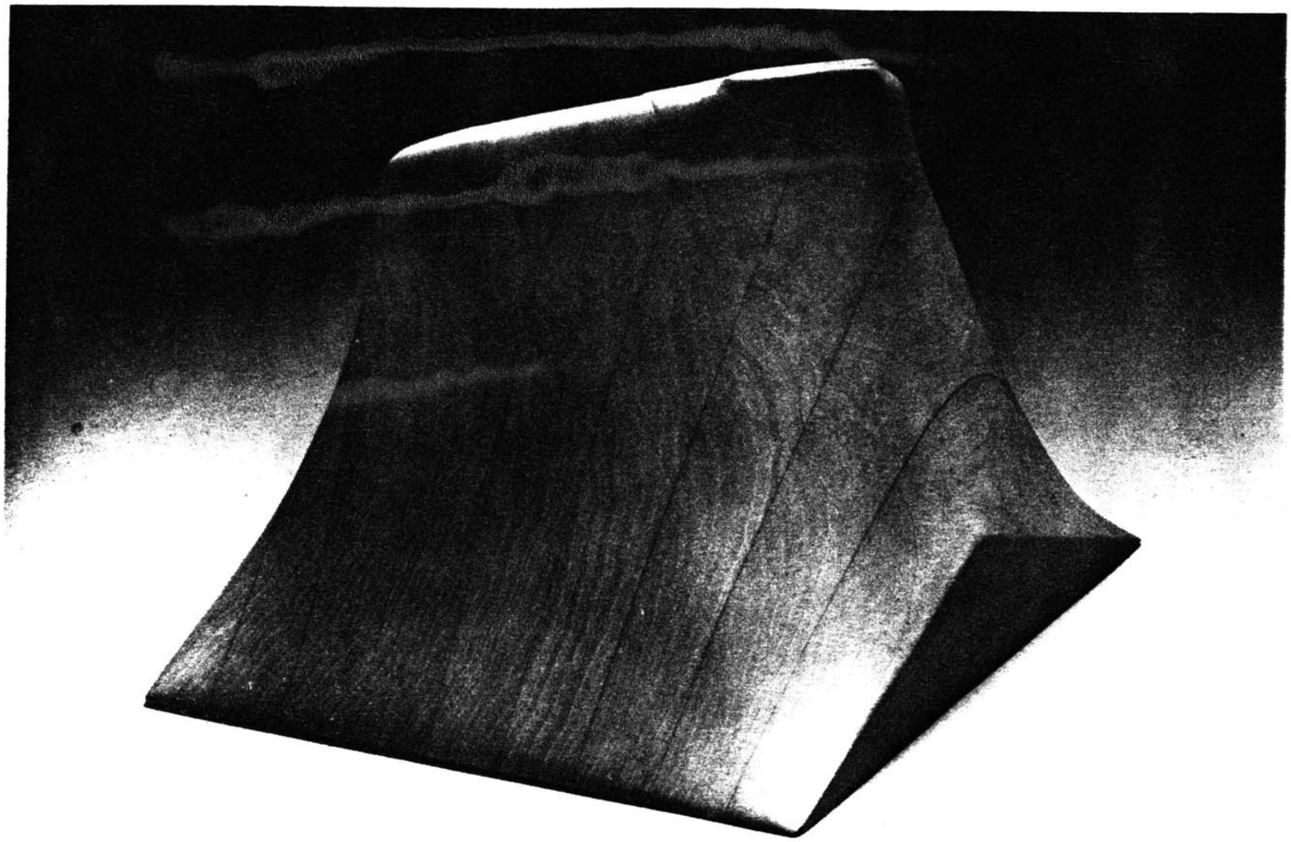

Figure A-68: Object 10 -- Double Ought by Doug Hendrickson

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