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Hallford, Ernest Wilson

SIZING UP THE WORLD: THE BODY AS REFERENT IN A SIZE-JUDGMENT TASK

The Ohio State University

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SIZING UP THE WORLD: THE BODY AS REFERENT IN A SIZE-JUDGMENT TASK

DISSERTATION

Presented in Partial Fulfillment of the Requirements for
the degree Doctor of Philosophy in the Graduate
School of the Ohio State University

By
Ernest Wilson Hallford, B.A., M.A.

*****

The Ohio State University
1984

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VITA

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Chapter 1. Introduction

The metric system, barely approaching 200 years old in its modern form, has become almost universally accepted as the preferred system of notation for measurement, at least in scientific applications. In other applications, however, much older systems are still widely used in many parts of the world (e.g., in the United States). Many of these systems, although now based on standardized units, appear to have developed their linear units from bodily referred standards (Sydenham, 1979; Zupko, 1968; Skinner, 1967; Berriman, 1953; Chisholm, 1877). The present English system, for example, designates the "foot" as one of its basic linear units. Early attempts to standardize the foot as a unit were themselves referred to other parts of the body: the foot was equal to four "palms"; and the palm in turn was equal to the width of the four fingers. Larger units were also pegged to the body. Prior to the reign of Elizabeth I in Great Britain, a mile was 1000 paces, or 2000 steps, or 5000 feet. It is reasonable, of course, to expect people to use their bodies as referents in size judgments. After all, the body is always available for such use. A more compelling reason, though, may involve functional relations between organisms and their environments which determine potential behaviors available to the organisms.

Statement of problem. Clearly the activities of an organism ordinarily are adjusted to its size. Flies and other small insects
can walk on ceilings because molecular adhesion is sufficient to hold
them there; likewise for water bugs on the surface of a pond.
Squirrels, though subject to gravitational forces, nevertheless run
freely along telephone lines, and small arboreal creatures rest
comfortably among the flimsiest of twigs in treetops. Such delicate
acrobatics are barred to larger primates such as humans because of
their size. For them, the effects of gravitational forces far exceed
those of molecular adhesion, and the dangers of a fall of only a few
meters are considerable. On the other hand, many tools, such as
clubs, spears, arrows, axes, and chisels are also limited in their
effectiveness by their sizes. Went (1968) pointed out that a creature
approximately 1 m tall can engender a blow only 1/25 the energy of a
human 1.7 m tall. This, he asserts, is "utterly insufficient" to kill
or even stun larger animals. Likewise, the shaping of lumber or
excavating of minerals from solid rock requires the ability to
manipulate tools suited to creatures at least as large as humans. In
view of the critical impact which the size of humans has had on their
abilities to exploit and control their environments, it is surprizing
that so little attention has been devoted to examining the
relationship between them.

In terms of perception and cognition, this relationship raises
interesting questions regarding organisms' knowledge of or ability to
detect size constraints on their own behaviors. For example, does a
particular aperture afford passage for oneself? Which of several
objects is large enough to serve as a hammer? Can it be readily
grasped and wielded? A recently developing perspective in perceptual
and cognitive theory, called the "ecological approach" (e.g., Gibson,
1982a; Cutting, 1982; Shaw & Turvey, 1981; Turvey, Reed, & Mace, 1981;
Gibson, 1979), provides an interesting framework for developing and
examining such questions.

This approach asserts that the environment is inherently
structured, and that the observer can detect meaningful relationships
in that structure. One of its central concepts is that of an
"affordance." Meaningful relations between environmental structure
and the self are intrinsic to affordances, the detection of which is,
according to Gibson (1979), one of the primary concerns of perceptual
activity. Affordance refers either to what the environment supports
for an organism in a behavioral sense, such as grasping an object, or
walking on a supportive surface; or to what the environment provides
the organism in terms of consequences of events. For example, a
missile may afford injury to an individual if it strikes her,
regardless of whether she perceives it or responds to it prior to
being struck. In short, inherent in the perceiving of an object (or
surface, or event) is an awareness of what one can do with it, or what
it can do to one (Gibson, 1982a; Gibson, 1979; c.f., Ittelson, 1960;
Koffka, 1935; Tolman, 1932).

Thus, the ecological approach avers that the organism and the
environment participate in a reciprocal relationship, where each must
be described relative to the other. According to this description,
the organism usually perceives the environment relative to itself;
i.e., its own dimensions, abilities, and purposes in that environment. The appropriate level of description, then, becomes whole objects, surfaces, and events taken with reference to specific perceiving and acting organisms (c.f., Patten, 1982; Jander, 1975).

These ideas suggest an interesting hypothesis: when object-size information is a major factor in the perception of an affordance, that information is taken with reference to the observer's own body size. (Note: although "size" may refer to a number of different dimensions---e.g., linear, such as height or width; volume; or mass---in the present discussion it will refer to linear dimensions unless otherwise indicated). This hypothesis implies that judgments of object size will be highly accurate when body-scaled. Indeed, they should be more accurate when body-scaled than when scaled to an arbitrary environmental standard. Thus, a person should be more accurate when judging whether she can span and lift an object with one hand than when judging whether the object is narrower than an arbitrary standard such as a 12-in. ruler. They should also be less affected by unusual environmental influences when referred to the body than when referred to an arbitrary environmental standard. For example, the introduction of a heavy object into a series of objects in a weight judgment task will ordinarily result in those objects being judged lighter (c.f., White, Alter, Snow, & Thorne, 1968; Brown, 1953). This means that the objects in the series are perceived relative to one another rather than to a fixed standard. The body, by contrast, should be a highly salient, fixed standard in affordance
judgments. Therefore the introduction of an atypically sized environmental object should not affect affordance judgments involving the sizes of other objects.

This notion that the body is a highly salient referent in affordance judgments is reminiscent of an interesting line of Gestalt theorizing regarding perceptual categories. Although he failed to develop the idea, Wertheimer (1938) suggested that perceptual domains might be structured around focal points within the domain. This idea was operationalized and tested by Rosch (e.g., 1973, 1975), who demonstrated that category membership in some domains (e.g., color, line orientation, and number) is internally structured around perceptually salient prototypes, or "best examples" of the category. Judgments of membership, she found, are generally ordered from better to poorer examples.

Sadalla, Burroughs and Staplin (1980), following Rosch's (1975) lead, investigated the possibility that knowledge of large-scale spatial relations is organized in terms of reference and nonreference points. Specifically, they examined the effects of better and less well known buildings at Arizona State University on peoples' judgments of distances and directions between the buildings. They found that judged distance between better and less well known buildings is asymmetrical, with the latter judged closer to the former than vice versa. Furthermore, reaction times for verifying distances and directions were similarly asymmetrical: they were faster when more familiar buildings were the anchor (reference) points.
Thus it seems that referentiality in the natural environment may be determined by either of at least two possible criteria: intrinsic structure (e.g., focal colors) or familiarity (e.g., more familiar buildings). Affordance theory strongly implies that information specifying functional relationships between organisms and their environments is inherent in the structure of those relationships (Gibson, 1982a, 1982b; Gibson, 1979). However, the extent to which the perception of these relationships is determined by familiarity has not been strongly examined by affordance theorists. In either case, though, this line of research and theorizing suggests another hypothesis regarding the body-referencing idea. That is, if the body is a highly meaningful referent for some object-size judgments, then these objects should be judged nearer in size to the relevant body part than vice versa.

Prior research: Use of one's body as a referent. There has been considerable theorizing with some empirical evidence that the observer's body may indeed serve as a referent in some orientation-, distance- and size-judgment tasks. Recent theorizing (e.g., Oldfield & Phillips, 1983; Larish & Stelmach, 1982; Rieser & Pick, 1976) regarding knowledge of spatial relations has emphasized the role of reference points in the structure of such knowledge. Larish and Stelmach (1982), following Pick's (1976) lead, proposed two categories of spatial reference systems: (1) egocentric, in which orienting actions are based on bodily referenced points; and (2) allocentric (or geocentric), in which orienting actions are based on environmentally
referenced points. Sadalla, et al.'s (1980) findings regarding location referencing in large-scale space may reflect the effects of an allocentric reference system. Larish and Stelmach (1982), on the other hand, have shown that performance on a reproduction task for target localization is enhanced in conditions where egocentric reference points are presumably available. Reproductions (by moving a marker by hand) of a target's location were more accurate for locations which could be referred to the observer's head, shoulder, or arm-length (equal to or less than 30 cm in front of the observer) than for locations which lacked such referents (i.e., locations above the head, or greater than 40 cm in front of the observer). Oldfield and Phillips (1983) used both systems to describe the results of a study on tactile perception. They showed that tactile information is structured around three major axes: high-low, near-far, and left-right. High-low, they found, is geocentrically referenced, along the environmental vertical axis, regardless of the orientation of the observer's body. Near-far, on the other hand, is entirely egocentrically determined, while left-right is initially determined egocentrically, but then runs along the environmental horizontal.

Regarding bodily referencing of object size, Ittelson (1960) argued that functional relationships between familiar objects and the dimensions of human beings underlie the size invariance of those objects. Thus, assumptions by observers about their own bodily sizes would influence perceived metric properties of objects. In a similar vein, Gibson (1979) asserted that children learn to "see" object sizes
in terms of prehension: their grasping spans and the diameters of objects are perceived simultaneously. Both the shapes and sizes of objects "are perceived in relation to the hands, as graspable or nograspable, in terms of their affordance for manipulation" (Gibson, 1979, p. 224). If this is true, then scales of sizes for the child are commensurate with the child's body, not with an arbitrary standard.

The functional utility of referencing object size to body size has been shown in studies of the effects of different object sizes on animal behaviors. Radcliffe, Chiszar, and O'Connell (1980; c.f., Werner & Hall, 1974) showed that rattlesnakes of three different taxa strike and hold smaller (equal to or less than 15 g) rodent prey, but strike and then release larger rodents (larger than 15 g, but small enough to be swallowed by the snake). It is to the snake's advantage to hold the prey after striking, since this eliminates the possibility that it may crawl out of the snake's reach before being paralyzed by the snake's venom. On the other hand, larger prey are more likely to injure the snake by struggling while being held. It is clear, then, that predatory strategies not only differ as a function of prey size, but that these different strategies have different consequences for both predator and prey. However, it is not clear whether these differences are based on pre- or post-strike perceptual or biomechanical information. Similarly, Hollings (1964) demonstrated that attack behaviors of the praying mantis (Mantis Religiosa) can be predicted on the basis of an "optimum" prey size, taken with reference
to the angle of the opening of the praying mantis' foreleg pincher.
The likelihood of attack falls rapidly as prey size diverges from the optimum size for each particular praying mantis.

Knowledge of one's own body size has been investigated among humans by several researchers, but very few of these have attempted to specify any referential relationship between body size and object size. The greater part of this research has capitalized on the notion that judgments of relative distances on the surface of the body might reflect one's knowledge of one's size. One group of these studies has contrasted judged to actual bodily dimensions (e.g., Hester, 1970; Fuhrer & Cowan, 1967; Shontz, 1965a, 1965b; Dillon, 1962). In these studies, participants have typically been asked to judge distances on the body, given various judgment conditions, such as different levels of illumination, or movement versus nonmovement of selected body parts. In the movement conditions, the issue is whether proprioceptive stimulation enhances judgments of the sizes of body parts bounded by actively moved joints. Fuhrer and Cowan (1967) asked observers to make judgments concurrently with the movements, and found that accuracy (the ratio of judged size to actual size) increased with activity. However, Hester (1970) and Shontz (1965) reported no difference between active and passive conditions, when judgments were made immediately subsequent to the movements. Hester (1970) conjectured that his failure to find a difference between the conditions might be attributed to an inability for short-term memory to retain proprioceptive information. In all these studies, the
observer's attention has been directed solely to his body, not to any relation, reciprocal or otherwise, between his body and his environment.

A second group of these studies has been concerned with the supposed relation between personality traits and perceptions of one's own body (e.g., Fisher, 1963, 1959; Fisher & Cleveland, 1958) or between supposed organismic states and perceptions of the body (e.g., Schlater, Baker, & Wapner, 1981; Wapner, McFarland, & Werner, 1963; Wapner, Werner, & Comalli, 1958). In these studies, participants are asked to compare the sizes of various parts or areas of the body to one another. For example, they might be asked to state which of their own arms seems longer, given various degrees of confinement in relatively open versus relatively enclosed spaces. Differences in judgments given different conditions are attributed to the effects of personality traits or to changes in organismic state as conditions change. Fisher and Cleveland (1958), for example, claimed that the definiteness of the body boundary (i.e., where the body ends and the environment begins) is linked not to actual physical dimensions of the body, but to various roles and values learned from parental figures. Thus, appropriate estimates of the sizes of the left and right sides of the body depend upon having learned to discriminate clearly between gender roles. That is, the "male" (right side) is conceived as larger and stronger than the "female" (left side).

Werner and his associates (e.g., 1981, 1963) have argued, on the other hand, that judgment differences are caused by different
organismic states, usually "neuromuscular configurations," which change as environmental conditions change. Unfortunately, they have been unable to specify the concomitant changes in organismic state as different surroundings (e.g., open versus enclosed) change. Werner admits that a precise specification of these configurations is not presently possible, but that is because of "technical limitations in physiological research." He is confident, though, that eventually they will be identified. None of these studies have addressed size perception in terms of object size relative to the observer's body size, in terms of anatomical versus anatomical referents, or in terms of the possibility that some standards for size judgments may be more salient than others, and thus may systematically influence such judgments.

In terms of anatomical versus environmental referencing, there is some evidence that distance judgments are more accurate when anatomically scaled. Smith and Smith (1966) compared distance judgments in a body-referencing condition (using the observer's arm length as the standard, in a reaching task) to judgments in an environmental referencing condition (using a 48-inch rod as the standard), and when the observers were active in task relevant ways rather than passive. Unhappily, the superiority for the active condition in this study was contaminated by the fact that the observers were required to stand 18 feet away from the target while making their judgments in the passive condition, but approached it to within arm's length before making their judgments in the active
condition. In a more carefully controlled study, Wolpert (1983) contrasted eyeheight-scaled and ground-texture-unit-scaled metrics for the detection of descent. He found that both metrics had significant effects according to an analysis of variance. However, the eyeheight metric accounted for almost 13% of the variance in error rate and over 10% in reaction time, while the ground-unit metric accounted for only 0.8% and 0.2% respectively.

Although the relation between human and object size has received scant attention in perceptual research, Bruner & Koslowski (1972) have shown that object size may be anatomically referenced in some instances. They presented two balls, sequentially, to infants 8 to 22 weeks of age. One of the balls was graspable and the other not graspable (too large) by the infants using one hand; each was presented in line with the infant's midline. The infants were not yet able to perform reaching behaviors, but they did display grasping at the midline (e.g., clasping hands together, or fingering clothing at the midline) in the presence of the graspable but not the nongraspable ball. This strongly suggests that visual information specifying the graspability of an object is detected by infants even before they have had coordinated reaching and grasping experiences.

**Overview and objectives.** It is evident that the behaviors of organisms must be profoundly affected by the relation between the sizes of the organisms and the sizes of environmental objects. Although few studies have addressed this relationship directly, the available evidence suggests that organisms adjust their behaviors to
fit the size of the object. This implies that object size is perceived in terms of functionally appropriate bodily dimensions; e.g., "Can it be grasped with one hand?" "Can I step over it?" If so, then the body must serve as a particularly effective referent in tasks where size is an important factor. Indeed, contemporary functionalist theories of perception assert that this is so (c.f., Gibson, 1982a; Gibson, 1979). If the body is a highly notable referent in size perception, then functional judgments of object size involving it may show patterns of asymmetries similar to those found in some perceptual category judgments (c.f., Rosch, 1975). That is, objects may be judged nearer in size to a functionally related body part than vice versa.

In the present studies, the grasping span of the observer's hand served as a functional bodily referent in judgments of object size. The hand was chosen as a standard because its role in examining and manipulating the environment is of paramount importance to humans. Thus, it is functionally highly pertinent not only to using objects (e.g., as tools), but also to perceiving them (e.g., directly, by touch; or as an adjunct to other senses, as in turning an object to provide additional views of it, or bringing it to the mouth to taste it). Historically, the hand or its parts were also probably used as units of linear measurement; for example, the palm and the finger were evidently commonly used units of measurement, and the inch was pegged to the breadth of the first joint of the thumb (Zupko, 1968). Thus if the body or its parts can be used effectively as referents in
size-judgment tasks, then the hand surely is one of the most potent of these referents.

Occasional reference will be made herein to "tacit knowledge" of one's hand or body size. In the present context, "tacit" refers only to its standard dictionary meaning of "not spoken" or "implied"; no assumptions are made regarding the origin or the structure of such knowledge. This is by contrast to the very interesting, special meaning developed by Polanyi (1966) and Polanyi and Prosch (1975), in which tacit knowledge involves functional, directional relationships which have become known through experience.

The present studies investigated the relation between body size and object size in terms of adult observers' abilities to judge whether or not they could span and pick up objects with one hand. According to affordance theory (e.g., Gibson, 1979) object sizes which are relevant to an affordance should be perceived relative to the observer's own body size. Assuming that adults have a good sense of their body size, then they should be highly accurate in determining which objects they can span and lift with one hand. Unfortunately, there is no clear criterion for accuracy in such a task, so one purpose of the present studies was to establish such a criterion.

The relative stability of bodily versus environmentally referred judgments of object size was also compared. Studies of the scaling of a series of items on a particular dimension (e.g., weight, or moral probity) have shown that the items are judged relative to one another (c.f., Marsh & Parducci, 1978; White, Alter, Snow, & Thorne, 1968;
Stevens, 1957; Brown, 1953). These judgments can be considerably altered merely by introducing additional items which extend the range of the original series in a particular direction. Judgments of the weights of objects, for example, shift toward lighter when a heavier object is introduced into the group being judged (Brown, 1953). Affordance judgments of object size, however, are referred to a highly salient, fixed standard: the observer's body. Since these judgments do not involve comparisons of the objects to one another, they should not be affected by the introduction of a larger object into the group to be judged.

A third issue examined in these studies, though not completely tested, is the notion that comparative judgments involving some kinds of highly salient referents may show patterns of asymmetries (c.f., Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976; Rosch, 1975, 1973). Studies investigating such asymmetries frequently use ratings (e.g., of similarity, or proximity) as a dependent measure. In such experiments, less typical instances of a category are rated as, for example, more similar to a highly typical instance than vice versa. If the body is indeed a highly salient referent for object-size judgments, then it may be that such judgments will also be asymmetrical. However, the studies reported here used binary judgments ("yes"/"no") rather than ratings as the dependent measure. In this case, an asymmetry could only appear as a bias in the judgments. That is, the target objects should be judged closer in size to the grasping span than they actually are. Because of
constraints in the designs of these studies, this should appear as a positive bias, in which objects will be judged as graspable when in fact they are too wide to be grasped.

A final concern of these studies was to clarify the concept of functionality as it relates to body referents for judgments of object size. The basic task for the observer was to judge the sizes of objects in terms of the widest hand-span she could use for spanning and lifting objects. Although this span can be operationally defined quite easily for the observer, it may not be the largest span she would ordinarily use. The functionally largest span for such a task may actually be somewhat smaller than that (c.f., Hollings, 1964).
Chapter 2. Study 1: A criterion for accuracy

One of the preliminary problems for the initial study of this series of experiments was to specify a criterion for accuracy in terms of the correspondence between judgments of object size and the relevant bodily dimension in a particular task. In an earlier experiment, McConkie (1977) showed observers eight fiberboard disks (D1 - D8 in ascending size) which incremented in diameter in 1-cm steps. The observers judged verbally whether the disks were graspable/ nongraspable by spanning with one hand, then rated their confidence in the correctness of each judgment on a 3-point scale, where 1 = least confidence and 3 = greatest confidence. Disk 4 (D4) was always the largest graspable disk for each observer. Mean percent correct (PC) was considerably lower on the disks near the middle of the range (D4, D5, and D6: PC = 85%, 35%, and 55% respectively) than on the disks at the extremes of the range (PC 95% for D1, D2, D7, and D8). Confidence rating showed a similar pattern, with mean confidence rating of 2.0 or less on D4 through D7, but 2.8 or above on the other disks. Thus, in this experiment, error was greater and confidence rating lower on disks within 2 to 3 cm of the largest graspable disk.

It is interesting that these errors and lower confidence were not distributed symmetrically around the largest graspable disk, but rather tended to fall more on larger disks (D5, D6, and D7). It
should be noted, however, that a disk can be grasped across a chord somewhat smaller than its diameter. This may have inflated false positive judgments (i.e., "I can grasp it," when in fact it was not graspable) on the larger disks. This would reduce percent correct on these disks, since observers could have been influenced by knowledge of that fact in making their judgments. The objects in the present study were composed of rectangular tiles in order to obviate this problem. Size increments were decreased from 1.0 to .5 cm in order to demarcate more precisely both the largest graspable object and the shapes of the functions describing areas of greater and lesser judgment accuracy and confidence relative to tile size.

The first two experiments reported in this chapter assessed each observer's ability to make object-size judgments using the grasping span as a referent. The primary goal was to establish a criterion for accuracy in such judgments. The ability to make such judgments should parallel the detection of a functional relationship between the observer and the environment. If this relationship is truly functionally viable, then these judgments should be marked by considerable accuracy. A second goal was to test for a bias in judgments. That is, the presumed high referentiality of the hand should result in the target objects' being judged nearer in size to the hand than they actually are. A third experiment contrasted judgments using the grasping span as the referent to judgments using an arbitrary environmental standard as the referent. Affordance judgments involve the detection of a functional relation between the
environment and the observer. According to Gibson (1979), this accomplishment is integral to perceptual activity. Thus, affordance theory would predict that functional, bodily referred judgments will be both highly precise and stable over time for most people. It is conceivable, however, that arbitrary, environmentally referred judgments of object size might be similarly precise and stable. The primary purpose of the third experiment was to determine whether judgments using an environmental standard actually differed from anatomically referred judgments in terms of accuracy or stability over time.

Experiment 1

According to affordance theory (Gibson, 1979), the observer is highly sensitive to readily available (i.e., neither ambiguous nor obscured) environmental information germane to the performance of a particular task—in this case, grasping an object by spanning it with one hand. In order to make accurate judgments regarding his ability to perform this task, the observer must perceive the width of the object taken with reference to the size of his hand. In this experiment the object was presented visually, while information regarding the size of the observer's hand was assumed to be tacitly available to him.

Method

Participants. Twenty undergraduates at the Ohio State University participated in this experiment in partial fulfillment of requirements for an introductory psychology course.
Materials. Forty rectangular fiberboard tiles served as a domain from which 8 tiles were selected for presentation to each observer. The tiles were 30 cm long and ranged from 10 to 30 cm wide in increments of .5 cm, by .3 cm thick. The 8 tiles were ordered by size such that on half of the trials, Tiles 1 through 3 (T1 - T3) could be grasped (i.e., spanned and lifted with one hand) by the observer. On these trials, T3 was the largest graspmable tile (LGT) for each observer, with Tiles 4 through 8 too large for the observer to grasp. On the other half of the trials, Tiles 1 through 5 were graspmable, with the LGT = T5, and Tiles 6 through 8 too large for the observer to grasp. The LGT served as an approximation of the observer's maximum grasping span. For some observers, this approximation would have been a nearly perfect match, while for others it would have been short by nearly .5 cm; thus the mean difference would be approximately .25 cm. The order of presentation of these trials was counterbalanced across observers.

Procedure. Prior to the beginning of the experiment, an outline of the observer's fully outstretched hand was traced. Then away from his view, the distance on the tracing from the center of the outermost phalanx of the thumb to the same of the middle, ring, or little finger, whichever was farthest, was measured. This measurement served as an approximation of the observer's LGT. After this was determined, the 8 tiles were scattered randomly on the table for visual inspection and judging, with the constraint that none of the tiles overlapped. The observer was instructed to keep his hands out of sight, and to
state which of the displayed tiles was the largest he could grasp. He then rated his confidence in the correctness of his judgment on a 3-point scale, where 1 represented the least and 3 the greatest confidence.

Each observer was tested on 2 trials. After the first trial, the observer participated in four other experiments in which knowledge of body size along several other dimensions was assessed, and which served as distractors between the first and second trials in this experiment. During this time the tiles were removed from the observer's view, and then redistributed on the table for the second trial.

Results. A comparison of judged versus actual LGT showed that mean judged LGT (18.23 cm) slightly exceeded mean actual LGT (17.67 cm), $t = 2.34, p < .03$ (see Figure 1). Observer differences accounted for most of the variance in this difference score, variance accounted for, $r^2 = 89.6\%$. Mean confidence rating was 2.38 (on a 3-point scale), indicating a substantial degree of confidence on the average. Observer differences in confidence again accounted for most of the variance, $r^2 = 73.8\%$.

Discussion. The finding of a close correspondence between judged and actual LGT indicates that observers are able to use the body quite effectively as a referent in affordance judgments. Mean judged LGT differed from mean actual LGT by only 3%, which seems a sufficiently small margin of error to warrant the term "highly accurate" for this kind of judgment.
Figure 1: Experiment 1. Judged largest graspable tile by actual largest graspable tile (in cm). Means over the 20 observers are shown. The diagonal line represents the ideal regression line if all judgments had matched actual LGT's.

(Note: LGT = largest graspable tile
JLGT = judged largest graspable tile)
This slight error tended to be in the direction of overestimations, which is consistent with the similar finding in McConkie's (1977) experiment. Thus, the asymmetrical distributions of errors and confidence ratings in his experiment may not have been merely due to ambiguity regarding the exact chord across which a disk can be grasped. Rather, some inherent biasing factor in these judgments may be drawing them slightly toward overestimations.

A possible basis for these overestimations may lie in an extension of Rosch's (1973, 1975) findings and theorizing regarding perceptual and "natural" categories. She has proposed that some perceptual categories are defined in terms of better and worse instances of the categories. Category membership is determined by comparing a candidate to most exemplary instances ("prototypes") of the category. These prototypes occur naturally in some perceptual categories (e.g., color, line orientation), and are readily perceived by most observers. One of the attributes of these prototypes is that similarity judgments between them and less typical instances are often asymmetrical. That is, less typical instances are judged more similar to prototypes than vice versa.

Affordance theory (Gibson, 1979) suggests that the body itself acts as a natural, highly meaningful referent for object-size judgments in some functional tasks. If so, objects near in size to a body part which is meaningfully related to the objects may be judged closer to the part in size than they in fact are. If the hand, specifically, is such a referent, then there should be an asymmetry in
judgments such that objects are judged closer to the size of the hand than vice versa (c.f., Rosch, 1975; Sadalla, et al., 1980).

In the present task, the observer was asked to make a functional judgment regarding the graspability of objects. Since the grasping span is the defining referent for graspability, then objects near in size to this span should be judged closer to it's size than they actually are. That is, some of these objects would seem graspable when in fact they are not, so an asymmetry in this task would appear as an overestimation, which was indeed the case.

The tiles for judging in this experiment were presented simultaneously, with each observer selecting only one tile from the group as his LGT. This procedure precluded the determination of relative differences in judgment across all the tiles. In the next experiment, tiles were presented sequentially, and each observer judged the graspability of each tile.

**Experiment 2**

This experiment replicated McConkie's (1977) experiment, with the changes noted above (i.e., rectangular tiles rather than disks were used as objects for judging, and sizes incremented by .5 rather than 1.0 cm). Observers made a graspability judgment for each tile so that distributions of accuracy and confidence by tile size could be determined. Confidence was included as a measure because it can be used to detect sensitivity across a broader range of stimulus differences than binary judgments alone (c.f., Woodworth & Schlosberg, 1954; Emmerich, Gray, Watson, & Tannis, 1972).
According to the affordance notion, these distributions should show accuracy and confidence to be generally quite high. The findings of McConkie (1977) and Experiment 1 suggest, however, that both distributions may be shifted downward on tiles within a narrow range (approximately 1 cm) of the LGT. This follows from McConkie's (1977) finding that percent correct was lower for disks (especially larger ones) near in size to the largest graspable one; and the finding in Experiment 1 of this study that observers tended to overestimate slightly the largest tile they could grasp. In terms of asymmetry, the tendency toward an overestimation in Experiment 1 should appear here as a bias favoring positive responses. That is, if observers frequently overestimate the width of objects they can grasp, then in the present experiment they will tend to say "Yes" for tiles which should elicit a "No" response. Thus, accuracy and confidence should be slightly higher on graspable than on nongraspable tiles.

Method

Participants. The participants were similar to those in Experiment 1 except that a different group of 20 students participated.

Materials. The materials were the same as Experiment 1 except that 12 tiles were presented to each observer for judging. These 12 tiles were ordered by size such that Tiles 1 through 6 (T1 - T6) could be grasped (i.e., spanned and lifted with one hand) by the observer, with T6 being the largest graspable tile (LGT) for each observer. Tiles 7 through 12 were too large to be grasped by the observer.
Apparatus. A Hewlett-Packard Universal .01-sec timer was connected to a simple on-off switch mounted in the base of a small wooden block (10 x 10 x 5 cm), which supported each tile while it was viewed by the observer. The timer began operating whenever the tile was lifted from the block, and stopped when the tile touched the switch again. The block stood in the center of a table (92.2 x 184.3 x 76.8 cm high) with a dark wood-grain surface. The observer stood so that his body touched the center of the long side of the table, 46.1 cm from the center of the wooden block.

Procedure. Graspability was determined by having the observer, with eyes closed, attempt to grasp and lift each tile by spanning it with one hand. The tiles were presented in a different random order without replacement to each observer. Graspable tiles were defined as those which could be lifted and held above the switch block for at least 3 sec. After the LGT was determined, the observer curled each of his hands into a fist, and kept them behind his back for the remainder of the experiment. This was intended to preclude the observer's surreptitiously gaining tactile information about the extent of his grasping span during the course of the experiment. He then viewed the tiles one at a time in random order in 3 blocks of trials (presentation order was re-randomized for each observer). In each block the 12 tiles were presented one at a time on the wooden block for judging. The observer was instructed to state whether or not the displayed tile was equal to or less than the widest tile he could grasp. He then rated his confidence in the correctness of his
judgment on a 3-point scale, where 1 represented the least and 3 the
greatest confidence. Each judgment was made without feedback.

Each observer was tested on 36 trials in a 3 x 2 x 6 factorial
design which included the following factors: Block (3), Relative Size
(2: larger versus smaller than the maximum grasping span), and Tile
Size (6).

Results

Observers were slightly more accurate on smaller (graspable) than
on larger (nongraspable) tiles, F(1, 200) = 7.68, p < .007, r² = 0.7%,
PC = 88% versus 82%, respectively. There was a considerable
difference in accuracy by Tile Size, F(5, 200) = 39.28, p < .0001, r²
= 17.0%, such that accuracy decreased as Tile Size approached the
maximum grasping span. A post-hoc analysis (Student-Newman-Keuls) of
this factor revealed significant differences among tiles within 1.25
cm of the maximum grasping span, but no difference among tiles outside
this range (see Figure 2). There was a slight improvement in accuracy
across the three blocks of trials, F(2, 200) = 3.05, p < .05, r² = .5%,
PC = 82%, 86%, and 88% respectively. Observer differences and
interactions involving Observer accounted for nearly half of the
variance in accuracy (total r² for all combinations involving Observer
= 47.5%).

Confidence rating followed patterns similar to those for
accuracy. Observers were more confident on smaller (graspable) than
on larger (nongraspable) tiles, F(1, 200) = 16.51, p < .0001, r² =
Figure 2: Experiment 2. Mean percent correct by tile width (in cm) compared to referent. The referent is each observer's maximum grasping span. Tiles to the left of the referent are graspable, while tiles to the right are too large to grasp.
1.3%, mean confidence rating = 2.57 versus 2.41 respectively. Confidence rating differed considerably by Tile Size, F(5, 200) = 33.44, p < .0001, r² = 13.0%. A post-hoc test (Student-Newman-Keuls) revealed that most of these differences occurred among tiles within 1.75 cm of the maximum grasping span (see Figure 3). There was no change in mean confidence rating across the three Blocks of trials, F(2, 200) = 0.58, n.s. Observer differences and interactions involving Observer accounted for the larger part of the variance in confidence rating (total r² for all combinations involving Observer = 69.5%)

An analysis of "yes"/"no" responses revealed a bias favoring "yes" responses (percent "yes"/"no" = 53%/47%). An examination of the distribution of responses across tiles indicated that this difference in usage occurred more on tiles within 1.25 cm of the maximum grasping span than on tiles outside this range.

Discussion. Judgments failed to surpass 90% correct only on tiles within 1.25 cm of the maximum grasping span on graspable tiles, and within 1.75 cm on nongraspable tiles. Confidence rating showed a similar effect, being less than 2.5 only on tiles within 1.25 cm of the maximum grasping span on graspable tiles, and within 1.75 cm on nongraspable tiles. These findings are consonant with those of Experiment 1, suggesting that tacit knowledge of one's grasping span does serve as a highly effective referent for functional judgments of object size. That is, although (1) ignorant of the exact nature of the task prior to the beginning of the experiment; (2) without looking
Figure 3: Experiment 2. Mean confidence rating by tile width (in cm) compared to referent.
at their hands prior to or while making judgments; and (3) without feedback as to the correctness of each judgment, adult observers were consistently highly accurate and confident in determining whether they could span and lift objects to within about 1.25 cm of their maximum grasping spans.

The greater accuracy and higher confidence rating for judgments on graspable than nongraspable tiles mirrored a bias favoring positive responses. This bias operated mostly on tiles within 1.25 cm of the maximum grasping span; outside that range the bias disappeared, and percent correct was nearly equal for graspable and nongraspable tiles. Thus, there were asymmetries in the distributions of percent correct, confidence rating, and "yes"/"no" response usage, in the direction predicted by the body-referencing hypothesis. That is, taking the maximum grasping span as a referent, nongraspable tiles were more often judged equal to or less than it in width than graspable tiles were judged greater than it. These asymmetries were limited, however, to a very narrow region around the maximum grasping span. Beyond about 1.25 cm larger or smaller than the LGT, all three distributions were approximately symmetrical.

The findings of Experiments 1 and 2 support the notion that observers have tacit knowledge of their anatomical dimensions. Furthermore, this knowledge can evidently be used quite effectively as a referent in making functional judgments of object-size. Nevertheless, it is not clear whether or not such referencing skill stems from an a priori greater skill on the part of observers in
judging the sizes of objects in terms of their own bodies. After all, any other clearly defined standard might serve equally well as a judgment referent. In Experiment 3, judgments of object size using the observer's maximum grasping span as a referent were contrasted with judgments using an arbitrary environmental standard as a referent.

Experiment 3

Verbal judgments about the sizes of objects in terms of their graspability were contrasted with verbal judgments about the sizes of objects relative to an arbitrary standard. This experiment tested two hypotheses: (1) that affordance judgments involving object-size information will closely mirror relevant bodily dimensions of the observer; and (2) that judgments of object size will be more accurate when self scaled than when scaled by an arbitrary standard.

Method

Participants. The participants were similar to those in Experiment 1, except that a different group of 20 students participated.

Materials. The materials were the same as in Experiment 1 except that 20 tiles were selected for presentation to each subject. Ten of these tiles were ordered by size such that five of them (T1 – T5) were graspable by the observer, where T5 was the largest graspable tile (LGT) for each observer. The remaining five (T6 – T10) were too wide to be grasped. The other ten tiles were also ordered by size, but
they were chosen so that $T_5 = 12.5$ cm (approximately 5 in.) wide. This tile was equal in width to a 3 x 5 in. (7.5 x 12.5 cm) index card, which served as an arbitrary referent for this group of trials, such that tiles $T_1$ through $T_5$ were equal to or less than it in width, while $T_6$ through $T_{10}$ were greater than it.

**Apparatus.** The apparatus was the same as in Experiment 2.

**Procedure.** Graspability was determined as in Experiment 2. After the LGT was determined, the tiles were shown one at a time in different random orders for each observer in eight blocks of trials. In four blocks the ten graspable/not graspable tiles were presented on the wooden block for visual inspection and judging, with the observer keeping her hands out of sight. In the other four blocks the tiles for the environmentally referred judgments were similarly presented for inspection and judgment. The two block types were presented in alternating order, with half of the observers starting with an anatomically referred block, and the other half starting with an environmentally referred block. Prior to the first block of the environmentally referred trials, the arbitrary standard was given to the observer for visual examination. The observer was told that it was a 5-in. wide index card, and that the 5-in. width was the standard against which the widths of the tiles in this condition were to be judged. After 30 sec the observer was instructed to hold both hands and the card behind her back until the testing was completed. The observer was then instructed to state whether or not the displayed tile was equal to or less than her LGT in width in the anatomically
referred blocks of trials; or whether or not it was equal to or less
than the 5-in. card in width in the environmentally referred blocks.
She also rated her confidence in the correctness of her judgment on a
5-point scale, where 1 represented the least and 5 the greatest
confidence.

Each observer was tested on 80 trials (20 trials per block) in a
4 x 2 x 2 x 5 factorial design which included the following factors:
Block (4), Referent (2), Relative Size (2: larger/smaller than the
referent) and Tile Size (5).

Results. Anatomically referred judgments were more accurate than
environmentally referred judgments, F(1, 552) = 31.01, p < .0001, r^2 =
1.1%, mean PC = 83% vs. 75% respectively. As can be seen in Figure
4, Referent interacted with Relative Size, F(1, 552) = 47.59, p <
.0001, r^2 = 1.6%, such that accuracy was approximately equal for both
Referents on smaller tiles, but it was much greater for anatomical
referencing than environmental referencing on larger tiles. There was
also an interaction among Referent, Relative Size, and Tile Size, F(8,
552) = 1.98, p < .05, r^2 = 0.5%, such that percent correct was notably
less on all but one of the larger tiles in the environmental than in
the anatomical condition, and it decreased as tile size approached the
referent in both referencing conditions, for both larger and smaller
tiles (see Figure 4). There was a slight improvement in accuracy in
the anatomical referencing condition across the three blocks of
trials, but a considerable decrement in the environmental referencing
condition, F(3, 552) = 4.32, p < .006, r^2 = 0.5 (see Figure 5).
Figure 4: Experiment 3. Mean percent correct by referencing condition by tile width (in cm) compared to referent. Tiles to the left on the horizontal axis are smaller than the referent in either condition, while those to the right are larger.
Figure 5: Experiment 3. Mean percent correct by referencing condition by block of trials.
Observer differences accounted for only a small amount of the variance in accuracy as a main effect, but interactions among Observer and other factors accounted for much of the variance (for all combinations of Observer effects, total $r^2 = 76\%$).

Confidence rating followed a pattern similar to that for accuracy, with observers expressing greater confidence in their judgments in the anatomical than in the environmental reference condition $F(1, 552) = 67.02, p < .0001, r^2 = 2.0\%$, mean confidence rating = 4.0 versus 3.7, respectively. There was no change in confidence ratings across the three blocks of trials. $F(1, 552) < 1$. Referent interacted with Relative Size, $F(1, 552) = 54.99, p < .0001, r^2 = 1.7\%$, and with Relative Size by Tile Size, $F(8, 552) = 2.21, p < .03, r^2 = 0.3\%$. As shown in Figure 6, these interactions revealed that confidence rating was only slightly greater in the anatomical than the environmental referencing condition on smaller tiles, but was increasingly greater in the anatomical than the environmental referencing condition on larger tiles; however, confidence rating decreased as tile size approached the referent in both conditions, for larger and smaller tiles. Observer differences accounted for much of the variance in confidence rating as a main effect and in combination with other factors (for all combinations of Observer effects, total $r^2 = 80\%$).

These differences in accuracy and confidence mirrored a bias favoring positive responses in the environmentally referred but not the anatomically referred condition (percent "yes"/"no" = 57%/43% vs. 47%/53% respectively).
Figure 6: Experiment 3. Mean confidence rating by referencing condition by tile width (in cm) compared to referent.
Discussion. Measures of accuracy and confidence in the anatomical condition of this experiment were distributed very similarly to those in Experiment 2. Percent correct and confidence rating were both quite high on all tiles except those within 1.25 cm of the maximum grasping span. Furthermore, judgments using this bodily referent were quite stable across time; indeed, they showed a slight net improvement in accuracy across the four blocks of the experiment, even though judgments were made without feedback. Although this improvement was small, it parallels a similar finding in Experiment 2. The present study was not designed to test for learning effects, and the smallness of these improvements in performance preclude the drawing of major inferences in this case. Nevertheless, such an improvement is consistent with the assertion that perceptual learning can occur without feedback (Gibson, 1969), and with several studies which have shown improvements of similar magnitudes in no-feedback learning tasks (e.g., Owen, 1982; Owen & Machamer, 1978; Smallwood & Arnoult, 1974; and Brown & Evans, 1969).

These findings again confirm the affordance-theory prediction that observers will be able to use tacit knowledge of their grasping spans very effectively as a referent in functional judgments of object size. Except on the first block of trials, the anatomical standard proved superior to the environmental standard as a referent, both in terms of greater accuracy and greater confidence. It also proved more reliable over time, since environmentally referred judgments showed a considerable decline in percent correct over the four blocks of
trials, while the anatomically referred judgments remained stable. If the use of the body as a referent in such a task as this is indeed an integral part of perceptual activity, as affordance theory asserts, then bodily referred judgments should be stable over time. Environmentally referred judgments, however, rely on a standard which is neither part of the organism's inherent structure, nor necessarily highly familiar. The observer in the present experiment had seen the environmental standard only moments before making his judgments in the first block of the environmentally referred trials. Thus it is not surprising that accuracy for those judgments equalled that for the anatomically referred judgments. However, in subsequent blocks the observer was unable to refresh his knowledge of the width of the environmental standard. Since this standard lacks the advantages which accrue to the anatomical referent (integrality to organismic structure; high familiarity), it is reasonable to expect that its efficacy as a referent would deteriorate over time.

The failure to find asymmetries in accuracy and confidence in the anatomical condition of this experiment, favoring graspable over nongraspable tiles, is inconsistent with the findings of Experiments 1 and 2. Asymmetries in accuracy and confidence induced by a high degree of referentiality for the grasping span should have appeared as greater accuracy and confidence on the graspable (smaller) versus the nongraspable (larger) tiles, mirroring a positive response bias, as in Experiment 2. However, the maximum grasping span may not be a particularly meaningful functional referent for most observers. A
grasping span slightly smaller than the maximum probably would be more functional, both in the ordinary environment and in the present task. Observers often remarked that they had difficulty holding the LGT for the prescribed 3 sec. Further, experimenters frequently noted that observers seemed to have considerable difficulty finding the best placement of the hand over the LGT in order to lift it, and the observer's hand often trembled while holding it up. This observational evidence is strongly bolstered by the lower accuracy and confidence on tiles within 1.25 cm of the maximum grasping span during the judgment phase of Experiments 2 and 3. It seems unreasonable that tile widths characterized by difficulty in grasping, lower judgment accuracy, and lower judgment confidence should be considered functionally graspable under ordinary circumstances (c.f. Hollings, 1964; Went, 1968). Rather, a tile approximately 1.25 cm smaller would more likely mark the usual functional limit for most observers' grasping spans.

The affordance concept, by definition, asserts that tacit knowledge of bodily dimensions is in terms of functional relations with the environment. The influence of tacit knowledge of the functional grasping span may have appeared in Experiment 3, where judgments tended to be slightly conservative. This appeared as a bias favoring negative responses (i.e., saying the tiles were not graspable, even though they often actually were). This is especially notable with regard to tiles very near in size to, but smaller than, the LGT, since these tiles probably are slightly larger than the
ordinary functional grasping span. Thus, judgments in the anatomical condition may have been influenced by antagonistic effects: (1) an asymmetry favoring positive responses on tiles near the grasping span in width; and (2) a conservatism favoring negative responses on tiles equal to or smaller than the LGT but larger than the functional grasping span. These effects would tend to cancel one another within each experiment of this study, or else produce variable results across experiments, depending on which happened to be more influential in each case.

The finding that accuracy declined considerably in the environmental but not the anatomical condition over the four blocks of trials for each condition is perhaps not particularly surprising, as noted above. However, the locus of the differences in both accuracy and confidence between the two conditions is especially interesting. Both measures were approximately equal for the two conditions on tiles which were equal to or less than the referent in width; but on tiles which were greater than the referent, both accuracy and confidence dropped considerably only in the environmental condition. That is, there was a notable asymmetry in percent correct and confidence rating near the environmental but not the anatomical referent.

This asymmetry seems inexplicable in terms of current asymmetry hypotheses (c.f., Rosch, 1975; Sadalla, et al., 1981), which assert that such asymmetries should occur near highly salient or natural referents. The index card would hardly seem to be such a referent in the present judgment task. However, these asymmetries may actually
reflect the effects of the grasping span as a referent. The anatomically referred judgments were highly stable over time, they were notably accurate, and observers were highly confident in them. So it is plausible that tacit knowledge of the grasping span may serve as an implicit alternative referent in any judgments where its use as a standard could be appropriate. Environmentally referred judgments, by contrast, were less stable, less accurate, and marked by lower confidence ratings. Furthermore, the environmental referent was only 12.5 cm wide, which was considerably smaller than the grasping span of any of the observers (mean LGT = 17.5 cm; smallest LGT = 14.5 cm). Thus even the largest tile in the environmental condition was graspable by most observers. The effect, then, of this implicit alternative referent would be to induce false positive judgments in the environmental condition of this experiment, since the grasping span was usually considerably larger than any of the judged tiles in that condition.

It appears evident that the grasping span can be used quite effectively as a functional standard for judgments of object size in some tasks. This efficacy holds for widths to within 1.25 cm of the largest graspable tile for most observers. However, the failure to find judgment asymmetries in Experiment 3 consonant with the notion that the hand serves as a highly meaningful "natural referent," suggests that the maximum grasping span is actually slightly larger than the referent the observer ordinarily would use. With regard to the environmental referent, it should be noted that the use of the 3 x
5 in. index card as the standard provided the observers with interval-scale information, while the anatomical referent involved only ordinal-scale information. It is possible that this differentially affected the observers' judgments in the two conditions.
Chapter 3. Relative stability in size judgments

The experiments reported in Chapter 2 showed that judgments of the sizes of objects are highly precise when taken with reference to an appropriate anatomical dimension, and that these judgments remain highly precise over trials. This supports the notion that the body is an especially effective referent for object-size judgments in a functional task. This notion is integral to the affordance concept (Gibson, 1979), which asserts that the organism perceives the environment relative to itself (c.f., Went, 1968). The study reported in this chapter primarily tested further the reliability of the grasping span as a referent. A subsidiary purpose was to examine further the possibility that the maximum grasping span may not coincide with the largest functional grasping span which people ordinarily use.

A second method for examining the stability of these judgments is to introduce additional larger or smaller objects into the series of objects to be judged. A common finding in anchoring experiments is that the magnitude of the end item relative to the others in a series on a given dimension (e.g., weight) will affect observers' judgments of the magnitudes of the other items (c.f., Marsh & Parducci, 1978; White et al., 1968; Stevens, 1957; Brown, 1953). Thus in judgments of the heaviness of each weight in a series, observers typically judge the weights to be lighter after the introduction of a weight (i.e., an
"anchor") which is considerably heavier than any of the others (c.f., White, et al., 1968). This contrast effect was called "hysteresis" by Stevens (1957).

In terms of size, hysteresis should shift judgments toward "smaller" when a relatively larger object is introduced into a series of objects to be judged. Thus, regarding grasping judgments per se, the introduction of a larger object should induce more false positive judgments. This would be most notable for objects which were only slightly larger than the grasping span, since they should then often seem graspable. A parallel shift should also occur in arbitrarily referred judgments. These predictions presume, however, that object size is environmentally referred, and is taken relative to other items in the series. If, on the other hand, object size is naturally anatomically referred (Gibson, 1979; Went, 1968), then the predicted judgment shift should be very slight, if at all, when the body is the explicit standard. This naturally occurring referent is not taken relative to the other items, but rather is fixed. Since these items are referred to it and not to each other, judgments on them should resist shifts in the presence of end anchors. In the environmentally referred condition, judgments are ostensibly also referred to a fixed standard. However, affordance theory can be extended to predict that this referent, being arbitrary, will be less stable for the observer. Therefore judgments in this condition should be more subject to external influences, and thus should show a greater hysteresis effect.
A second issue raised in Experiments 1 through 3 is whether the maximum grasping span is appropriate as a functional referent for judgments of the graspability of objects. The functionality of day-to-day relationships is likely to be rather hazy at their limits, since the extremes of an organism's capabilities are ordinarily rarely tested. Thus these relationships may be better described in terms of optimal ranges rather than absolute delimitors. Hollings (1964), for example, showed that attack behaviors by praying mantises can be effectively predicted by comparing the size of the prey to an optimum size for each praying mantis. Optimality is a function of the angle of the opening of each praying mantis' foreleg pincher. The likelihood of attack falls rapidly as prey size diverges from the optimum size.

Similarly, Rosch (1973, 1975) has asserted that one of the crucial characteristics of natural categories is that they tend to have "fuzzy" boundaries. That is, natural relationships are not usually neatly divided into instances and nonstances of particular categories. Rather, they are specified in terms of "best examples" of the relevant category. Rosch (1973) showed that associations (e.g., of names to colors) are learned faster for more exemplary than for less exemplary instances of categories in perceptual domains. Further, she (1975) has shown that judgment time for determining membership in semantic categories is faster for more, versus less, representative members of the category. Thus, an instance from the ill-defined boundary region of a natural category is a poor standard
for judgments of category membership either for humans or for praying mantises.

The three experiments reported in this chapter examined each of the foregoing questions in turn. Experiment 4 replicated Experiment 3, with modifications designed to clarify several methodological ambiguities. Experiment 5 tested the stability of size judgments using anatomical versus environmental referents, given the introduction of large end anchors. Experiment 6 specifically examined the salience of the maximum grasping span as a referent for functional judgments of object size.

Experiment 4

This experiment replicated Experiment 3, but with two major changes. Rather than judging blocks of tiles in alternating order by reference type, observers judged all blocks of tiles using one referent prior to judging those using the other referent. If the grasping span is a highly effective, natural referent, then judgments of graspability should be very precise and stable, regardless of the order in which the two referents are used. Further, if the grasping span serves as an implicit standard which affects some judgments in the environmentally referred condition, then those effects (appearing as a positive response bias) should also appear regardless of the order in which the two referents are used.

The arbitrary environmental standard was changed to a common textbook, in order to eliminate the interval-scale information made
available to the observers in Experiment 3 by the use of the 3 x 5 in. index card. Since only ordinal-scale information was available in the anatomical condition, those observers may have made their judgments differently in this condition than in the environmental condition because of the difference in scaling information.

Method

Participants. The participants were similar to those in Experiment 3, except that 28 different students participated.

Materials. The materials were the same as in Experiment 3, except that the ten tiles used in the environmentally referred condition were chosen so that T5 = 13.5 cm wide. This tile was .25 cm less in width than a paperback textbook, which served as an arbitrary referent for this group of trials. Thus tiles T1 through T5 were less than it in width, while T6 through T10 were greater than it.

Apparatus. The apparatus was the same as that used in Experiment 3.

Procedure. The procedure was the same as in Experiment 3 except for the following changes. Half of the observers responded in all four of the anatomically referred blocks of trials, then in the environmentally referred blocks, with the other half responding in the reverse order. After allowing the observer to hold and visually inspect the environmental standard for 30 sec immediately prior to the environmentally referred block of trials, the experimenter removed the standard from view. The observer was instructed to clasp his hands
into tight fists (in order to preclude his obtaining tactile information about the size of his grasping span during the course of the experiment) and to keep them behind his back for the remainder of the experiment.

Each observer was tested on 80 trials in a 4 x 2 x 2 x 5 factorial design which included the following factors: Block (4), Referent (2: anatomical versus environmental), Relative Size (2: larger versus smaller than the referent), and Tile Size (5).

Results. There was no main effect on percent correct for Referent, F(1, 26) = 0.39, n.s., nor for Order by Referent, F(1, 26) = .28, n.s. However, there was a strong interaction between Referent and Relative Size, F(1, 26) =10.21, p .0037, r^2 = 3.3%, such that percent correct was greater on larger tiles in the anatomical condition than in the environmental condition, but the reverse was true on smaller tiles (see Figure 7). There was also an interaction among Referent, Relative Size, and Tile Size, F(4, 104) = 5.74, p .0003, r^2 = 1.4%, such that the differences in percent correct between the two referencing conditions were greater on tiles nearer the referents, and greater on smaller tiles than on larger tiles (see Figure 7).

The results for confidence rating were similar to those for accuracy, with no main effect for Referent, F(1, 26) = 0.00, n.s., nor for Order by Referent, F(1, 26) = .01, n.s. However, a strong interaction between Referent and Relative Size, F( 1, 26) = 12.88, p .0014, r^2 = 3.2%, revealed that confidence rating was greater in the
Figure 7: Experiment 4. Mean percent correct by referencing condition by tile width (in cm) compared to referent.
anatomical than the environmental condition on larger tiles, but the reverse was true on smaller tiles (see Figure 8).

These differences in accuracy and confidence reflected a strong bias favoring positive responses in the environmental condition, and a slight negative bias in the anatomical condition, percent "yes"/"no" = 60%/40%, and 47%/53%, respectively. Separate analyses of responses from each referencing condition were conducted to test for the effects of these asymmetries on percent correct and confidence rating in each condition. Percent correct was reliably greater on smaller than on larger tiles in the environmental referencing condition, (94% vs. 74% respectively), $F(1, 27) = 13.67, p < .001, r^2 = 7.3%$. In the anatomical condition, by contrast, judgments were slightly more accurate on larger than on smaller tiles (86% vs 79% respectively), but this difference was not significant, $F(1, 27) = 1.33, p < .26$.

Confidence rating followed similar patterns, being greater on smaller than on larger tiles in the environmental condition (4.32 vs 3.76 respectively), $F(1, 27) = 10.82, p < .03, r^2 = 6.0%$. It was greater on larger than on smaller tiles in the anatomical condition, (4.18 vs 3.91, respectively), but this difference was not significant, $F(1, 27) = 2.33, p < .14$.

Discussion. As in Experiments 2 and 3, anatomical referencing resulted in consistently highly accurate judgments and high confidence on all tiles except those within 1.25 cm of the maximum grasping span. The distributions of percent correct and confidence rating were both
Figure 6: Experiment 4. Mean confidence rating by referencing condition by tile width (in cm) compared to referent.
approximately symmetrical, although there was a slight tendency for both to be elevated on larger tiles, reflecting the slight bias favoring negative responses. This tendency appeared mostly on tiles within 1.25 cm of the maximum grasping span for percent correct, but across all tiles for confidence rating. Thus, as in Experiment 3, anatomically referred judgments were quite precise but slightly conservative, most notably on tiles nearest the maximum grasping span in width.

It might seem plausible to suggest that the slight conservatism in the anatomical condition merely reflects a hysteresis effect from the tiles used in the environmental condition. Most of these tiles were smaller than the grasping spans of all observers, and conceivably could have caused the anatomically referred tiles to seem larger than they actually were, compared to the grasping span. After all, this conservatism only appeared in Experiments 3 and 4, which included the arbitrary referencing condition. Experiments 1 and 2 used only anatomical referents, and both produced positive, not negative, response biases. However, the failure to find an Order effect in this experiment showed that the conservatism was not a hysteresis phenomenon, since it appeared regardless of whether the anatomically referred judgments preceded or followed the environmentally referred judgments.

Distributions of percent correct and confidence rating for judgments in the environmental reference condition, by contrast, were highly asymmetrical. This asymmetry reflected a strong
positive-response bias, such that people tended to judge tiles to be smaller than the environmental referent even though they actually were larger. In line with the foregoing discussion, this bias cannot be explained in terms of a hysteresis effect, since the latter would have appeared as an Order effect. That is, most of the tiles in the anatomical condition were considerably larger than those in the environmental condition. A hysteresis effect would have resulted in the latter tiles' seeming smaller than they actually were, when the environmental condition followed the anatomical condition, but not when this order was reversed. Since these asymmetries appeared regardless of the order in which the referents were used, some other factor must underlie them. If the grasping span were an implicit alternative standard on these judgments, any effect from it would be in the direction found: a tendency to make false positive judgments, regardless of Order. Such a tendency, based on an implicit, fixed standard, would be impervious to Order effects.

The failure to find main effects for greater accuracy or confidence in the anatomical over the environmental condition seems peculiar, if the body is indeed a natural, highly effective referent in this task. However, the strong positive-response bias in the environmental condition, resulting in highly elevated accuracy and confidence on the smaller tiles, must underlie this failure. That is, this artificial superiority for environmental referencing on smaller tiles offsets the superiority for anatomical referencing on larger tiles.
As predicted, hysteresis did not occur in this experiment. This is consistent with the hypothesis that the body not only serves as an effective referent for some object-size judgments, but that it is also a highly stable referent. However, the tiles in the two referencing conditions were never viewed in a combined series, but rather were viewed separately. So it is not clear that the tiles in one condition acted like true anchors for the other condition, since anchors are ordinarily included directly in the series of items to be judged. In the next experiment, a relatively larger tile was included in the series to be judged for each referencing condition.

Experiment 5

This experiment replicated Experiment 4, except that a large end anchor was included in the series of tiles to be judged in each referencing condition. If the body serves as a highly salient, natural referent, then judgments using it as a standard should resist hysteresis effects. These effects depend on the scaling of items in a series relative to one another. The body, however, according to affordance theory, is a fixed referent, against which items which are functionally related to it are judged. Thus they are scaled in terms of relevant body parts rather than in terms of each other. Environmental referents are also fixed, relative to the series of items to be judged. However, being arbitrary, they are likely to be less salient to the observer than are bodily referents. According to affordance theory, environmental referencing should therefore be less
stable and thus more subject to external influences. That is, in the present case, it should be subject to hysteresis effects.

**Method**

*Participants.* The participants were similar to those in Experiment 4, except that a different group of 28 students participated.

*Materials.* Materials for Experiment 5 were the same as those for Experiment 4, except that an extra (end-anchor) tile was included in both the environmental and the anatomical conditions. This tile was approximately 5 cm wider than the referent in both conditions. That is, in the environmental condition, it was 18.5 cm wide, and in the anatomical condition, it was 5 cm wider than the observer's LGT.

*Apparatus.* The apparatus was the same as in Experiment 4.

*Procedure.* The procedure was the same as in Experiment 4, except that on the second trial of each block of trials the end-anchor tile was displayed. The observer judged the width of this tile relative to the prescribed standard, then continued judging the other tiles in random order. Each observer was tested on 80 trials in a 4 x 2 x 2 x 5 factorial design which included the following factors: Block (4), Referent (2), Relative Size (2), and Tile Size (5).

*Results.* Judgments were slightly more accurate in the anatomical than the environmental condition (81% versus 77%, respectively), but this difference was not reliable, F(1, 26) = 1.89, n.s. There was also no Order-by-Referent effect on accuracy, F(1, 26) = 1.14, n.s.
However, Referent interacted with Relative Size $F(1, 26) = 34.15, p < .0001, r^2 = 8.5\%$, such that percent correct was greater in the anatomical than the environmental condition on larger tiles, but the reverse was true on smaller tiles (see Figure 9). Referent also interacted with Tile Size $F(4, 104) = 6.08, p < .0002, r^2 = 0.5\%$, such that these differences in accuracy were greater on tiles nearer the referents than on tiles farther away. A three-way interaction among Referent, Relative Size, and Tile Size, $F(4, 104) = 8.93, p < .0001, r^2 = 1.4\%$, showed that this difference by tile size was more pronounced on smaller tiles than on larger tiles.

There was no advantage in confidence rating for either anatomical or environmental referencing ($4.04 \text{ vs. } 4.01$ respectively), $F(1, 26) = 0.37, \text{n.s.}$ However, there was a strong interaction between Referent and Relative Size, $F(1, 26) = 17.68, p < .0003, r^2 = 5.5\%$, such that confidence rating was much greater in the anatomical than the environmental condition on larger tiles, but the reverse was true on smaller tiles (see Figure 10). A three-way interaction among Referent, Relative Size, and Tile Size, $F(4, 104) = 4.44, p < .0023, r^2 = 0.8\%$, revealed that this difference was more pronounced on larger than on smaller tiles. There was no effect for Order by Referent, $F(1, 26) = 0.30, \text{n.s.}$

These differences in accuracy and confidence rating reflected a strong positive-response bias in the environmental condition but a slight negative bias in the anatomical condition, percent "yes"/"no" = $68\%/32\%$ versus $45\%/55\%$ respectively. A separate analysis of responses
Figure 9: Experiment 5. Mean percent correct by referencing condition by tile width (in cm) compared to referent.
Figure 10: Experiment 5. Mean confidence rating by referencing condition by tile width (in cm) compared to referent.
from each referencing condition showed that these biases had pronounced effects on percent correct and confidence rating in the environmental but not the anatomical referencing condition. That is, percent correct was much greater on smaller than on larger tiles in the environmental condition (94% vs. 59% respectively), $F(1, 26) = 23.11, p < .0001, r^2 = 17.5\%$. This difference was greater on tiles nearer the referent than on those farther away, $F(4, 104) = 7.09, p < .0001, r^2 = 2.2\%$ (see Table 1). Confidence likewise was greater for judgments on smaller versus larger tiles in the environmental condition, 4.4 vs. 3.6, respectively, $F(1, 26) = 17.97, p < .0002, r^2 = 2.1\%$, but here the difference was less pronounced on tiles nearer the referent than on those farther away, $F(4, 104) = 8.16, p < .0001, r^2 = 1.1\%$ (see Table 2).

Although percent correct was greater on larger than on smaller tiles in the anatomical condition, (87% versus 74%, respectively), this difference was only marginally reliable, $F(1, 26) = 3.77, p < .063$; this difference fell mostly on tiles near the referent, $F(4, 104) = 2.48, p < .049$ (see Table 1). The difference in confidence rating favoring larger over smaller tiles (4.2 vs. 3.9, respectively) likewise reached only marginal significance, $F(1, 27) = 3.41, p < .076$ (see Table 2).

**Discussion.** The general findings in this experiment parallel those of Experiments 1 through 4. Anatomically referred judgments were consistently precise and marked by high confidence on tile sizes approaching 1.25 cm of the observer's maximum grasping span. Percent
Table 1. Experiment 5: Percent correct by referencing condition by tile width (in cm) compared to referent.

<table>
<thead>
<tr>
<th>Tile compared to referent</th>
<th>Environmental</th>
<th>Anatomical</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 2.25</td>
<td>100%</td>
<td>95%</td>
</tr>
<tr>
<td>- 1.75</td>
<td>99%</td>
<td>89%</td>
</tr>
<tr>
<td>- 1.25</td>
<td>96%</td>
<td>84%</td>
</tr>
<tr>
<td>- .75</td>
<td>93%</td>
<td>62%</td>
</tr>
<tr>
<td>- .25</td>
<td>83%</td>
<td>41%</td>
</tr>
<tr>
<td>+ .25</td>
<td>33%</td>
<td>63%</td>
</tr>
<tr>
<td>+ .75</td>
<td>48%</td>
<td>83%</td>
</tr>
<tr>
<td>+ 1.25</td>
<td>60%</td>
<td>93%</td>
</tr>
<tr>
<td>+ 1.75</td>
<td>68%</td>
<td>96%</td>
</tr>
<tr>
<td>+ 2.25</td>
<td>86%</td>
<td>100%</td>
</tr>
</tbody>
</table>
Table 2. Experiment 5: Confidence rating by referencing condition by tile width (in cm) compared to referent.

<table>
<thead>
<tr>
<th>Tile compared to referent</th>
<th>Environmental</th>
<th>Anatomical</th>
</tr>
</thead>
<tbody>
<tr>
<td>- 2.25</td>
<td>4.83</td>
<td>4.56</td>
</tr>
<tr>
<td>- 1.75</td>
<td>4.70</td>
<td>4.08</td>
</tr>
<tr>
<td>- 1.25</td>
<td>4.62</td>
<td>3.79</td>
</tr>
<tr>
<td>- .75</td>
<td>4.18</td>
<td>3.52</td>
</tr>
<tr>
<td>- .25</td>
<td>3.75</td>
<td>3.49</td>
</tr>
<tr>
<td>referent</td>
<td>----</td>
<td>----</td>
</tr>
<tr>
<td>+ .25</td>
<td>3.55</td>
<td>3.70</td>
</tr>
<tr>
<td>+ .75</td>
<td>3.54</td>
<td>3.96</td>
</tr>
<tr>
<td>+ 1.25</td>
<td>3.49</td>
<td>4.29</td>
</tr>
<tr>
<td>+ 1.75</td>
<td>3.59</td>
<td>4.42</td>
</tr>
<tr>
<td>+ 2.25</td>
<td>3.82</td>
<td>4.61</td>
</tr>
</tbody>
</table>

Note: 1 = least confidence, 5 = greatest confidence.
correct and confidence rating were both distributed slightly asymmetrically around the maximum grasping span; each was slightly higher on larger tiles, reflecting a slight bias favoring negative responses. This bias may stem from the use of a grasping span as a standard which slightly exceeded the range of an optimum grasping span for most observers.

The introduction of a large end anchor had no effect on anatomical referencing. A hysteresis effect from a large anchor should have resulted in the other tiles in the series appearing smaller than they otherwise would, thus tending to induce false positive judgments. This would have appeared as a bias favoring positive responses, and elevated accuracy and confidence on smaller versus larger tiles. In fact, the reverse of each of these occurred. There was, however, a large hysteresis effect on environmental referencing. Since this referencing, as revealed in Experiments 3 and 4, is inherently subject to a positive response bias, a hysteresis effect from a large anchor should appear as a notable increase in positive responses. As shown in Figure 11, the expected shift did occur in percentages of "yes"/"no" response usage, since the ratio favored positive responses considerably more in Experiment 5 than in Experiment 4. Furthermore, the difference in percent correct on smaller versus larger tiles for environmental referencing in Experiment 4 was 20%, but it rose dramatically to 34% in Experiment 5. Confidence rating showed a parallel though less sharp increase. Thus, unlike an arbitrary, environmental referent, an appropriate bodily
Figure 11. Hysteresis effect on mean percent correct: Experiment 4 versus Experiment 5. The shaded area highlights the difference between the two experiments in environmentally referred judgments.
referent not only underlies consistently highly accurate judgments of object size, but this consistency is maintained over time and in the face of potentially distracting influences such as anomalously sized objects.

Although the maximum grasping span clearly can be used very effectively as a referent in judging the sizes of objects, it nevertheless produced a theoretically inexplicable result. Affordance theory asserts that the organism ordinarily perceives the environment in terms of itself. Assuming that an appropriate bodily standard is selected, judgments about the sizes of objects ought to be highly precise to within a narrow range of sizes approaching that of the standard. However, affordance theory makes no predictions about the direction of the errors that do occur. Rosch (e.g., 1975) and others have pointed out that highly salient, or natural, referents in a judgment task will give rise to systematic asymmetries in the judgments. As noted above, if the body is indeed a highly salient referent, as affordance theory asserts, then an asymmetry effect in the present task should be exemplified by a tendency to make false positive judgments, especially on tiles only slightly larger than the bodily referent. Such a tendency evidently appeared in Experiments 1 and 2, but not in Experiments 3, 4 and 5. It is likely, however, that the maximum grasping span is somewhat larger than a truly functional—and thus more salient—grasping span. Thus these contradictory findings may reflect a conflict between asymmetry effects near a natural referent, tending to induce false positive
responses, and knowledge of an optimum (versus maximum) grasping range, tending to induce false negative responses in the present group of experiments. The next experiment investigated the possibility that the optimum range of the functional grasping span ends short of the maximum grasping span.

Experiment 6

The results of experiments 3, 4, and 5 intimated that the maximum grasping span may actually be slightly larger than a truly functional grasping span. Affordance theory is an inherently functional theory, in that it asserts that the environment is perceived in relation to oneself: what one can do with or in the environment, or what the environment can do to oneself (c.f., Gibson, 1979). It may be that functionality is ordinarily a matter of optimum rather than absolute relationships (c.f., Hollings, 1964), so that delimiters of the extremes of possible relationships do not actually mark ordinary functional limits. Thus, in the case of graspability judgments, the maximum grasping span marks the limit of the widest object which a person can grasp. This span was the standard observers were asked to use as a referent in the anatomical conditions of the preceding experiments. However, a functionally largest span—one characterized by frequency and ease of use, and ability of the observer to recognize objects which match it—likely is somewhat smaller than this maximum span. In the following experiment, observers were asked to determine which tiles they were absolutely certain were equal to or smaller than the largest they could grasp.
In a control condition, they were asked to determine with absolute certainty which tiles were equal to or smaller than an arbitrary, environmental standard. If the optimum grasping span is less than the maximum grasping span, and if observers have tacit knowledge of the difference, then positive responses in this condition should end on a tile smaller than the maximum grasping span. Further, if functionality is truly an issue in such judgments, then there should be little or no effect of the foregoing instructions on judgments in the environmental referencing condition.

**Method**

**Participants.** The participants were similar to those in the preceding experiments, except that a different group of 28 students participated.

**Materials.** Materials were the same as in the preceding experiments, except that 32 tiles were used, 16 in the anatomical and 16 in the environmental referencing condition. Eight tiles were equal to or less than the width of the referent in each condition, and eight were greater.

**Procedure.** The determination of each observer’s LGT was the same as in the preceding experiments. Half of the observers were tested on 14 anatomically referred trials then 14 environmentally referred trials, with the other half tested in the reverse order. On each trial the observer viewed several tiles, presented sequentially and in order by size. On half of the trials, the presentations started on a tile smaller than the referent while on the other half they started on
a tile larger than the referent. Specifically, they either started on a tile 3.75, 3.25, or 2.75 cm smaller than the referent, with each new tile .5 cm larger than the preceding tile; or else they began on a tile 3.75, 3.25, or 2.75 cm larger than the referent, with each new tile .5 cm smaller than the preceding tile. Starting points were randomly ordered across trials. Trials starting on a small tile were alternated with those starting on a large tile; small/large starting order was counterbalanced across observers.

The observer's task on each trial was to determine which tiles she was absolutely certain were equal to or smaller than the referent in width. Thus, on trials starting on a small tile (small anchor), the observer was instructed to say "yes" on each new tile only so long as she was absolutely confident that each new tile was equal to or smaller than the referent; else she was to say "no." On trials starting on a large tile (large anchor), the observer was instructed to say "no" on each new tile until she was absolutely confident the new tile was equal to or smaller than the referent, at which time she was to say "yes." Each observer was tested in a 2 x 2 factorial design which included the following factors: Referent (2) and Anchor (2).

Results. Positive judgments in the anatomically referred condition stopped short of the referent by 1.09 cm, while in the environmentally referred condition they continued beyond the referent by .34 cm, F(1, 26) = 37.28, p < .0001, r^2 = 26.6% (see Table 3). There was also a main effect for Anchor, F(1, 26) = 45.32, p < .0001,
Table 3: Experiment 6. Referencing condition by anchor (i.e. starting point for each trial) by judged largest tile (in cm) compared to referent.

<table>
<thead>
<tr>
<th>Anchor</th>
<th>Environmental</th>
<th>Anatomical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>+ .01</td>
<td>- 1.44</td>
</tr>
<tr>
<td>Large</td>
<td>+ .68</td>
<td>- .74</td>
</tr>
<tr>
<td>Mean</td>
<td>+ .34</td>
<td>- 1.09</td>
</tr>
</tbody>
</table>
\[ r^2 = 6.3\% \], such that positive judgments on large-anchor trials stopped on a tile approximately .70 cm larger than on small-anchor trials in both referencing conditions (Table 3).

Separate analyses for each referencing condition showed that the underestimation in the anatomically referred judgments was reliable, \( t = 12.46, p \leq .0001 \). The overestimation in the environmentally referred judgments was also reliable, \( t = 6.76, p \leq .0001 \).

**Discussion.** The tendency toward conservative judgments in Experiments 3 through 5, given the maximum grasping span as a referent, suggested that this span was slightly larger than the upper limit of an optimum grasping range for most people. Both accuracy and confidence were lowest on tiles within 1.25 cm of the maximum grasping span, with the most notable deficits falling on tiles .25 and .75 cm smaller than this span. Thus it appeared that an optimum grasping span's range might have an upper limit approximately 1.0 to 1.25 cm less than the observer's maximum grasping span.

In the present experiment, observers stopped short of their maximum grasping spans by approximately 1.0 cm when asked to determine with complete confidence which objects they could grasp. This strongly supports the intimations from Experiments 3 through 5 that the maximum grasping span is a bit too large to serve as an ideal referent for graspability judgments. Rather, an optimum range for grasping, insofar as high confidence reflects such a range, ends at 1.0 to 1.25 cm smaller than the maximum grasping span.
Environmentally referred judgments, by contrast with the above, were not conservative in the present experiment. Rather, the overestimations in the environmental condition seen in Experiments 3 and 4 were paralleled here. (Note: the present finding should not be compared to the finding in Experiment 5, since the overestimation there was artificially elevated by the hysteresis effect). This is especially notable, since it indicates that the instruction to respond positively only when highly confident did not in itself lead to conservatism. That is, such an instruction evidently had a considerable impact on the functional, bodily referred judgments, but not on the arbitrary, environmentally referred judgments.

The results from Experiments 4, 5, and 6 strongly support the notion that the body serves as a highly salient referent for functional judgments of object size. Not only are judgments marked by considerable accuracy and high confidence to within a narrow range of the maximum grasping span, but they are highly stable both across time and in the face of distracting environmental influences (i.e., large end anchors). They also suggest that observers' knowledge of their grasping spans is in terms of a functional range, the upper limit of which is slightly smaller than their maximum grasping spans. This difference may have been sufficient to obscure an asymmetry effect near the referent. That is, if the grasping span is indeed a natural referent, then tiles similar to it in size should be judged closer to it in size than vice versa. In the present study, such an asymmetry would have resulted in tiles slightly larger than the grasping span.
being judged equal to or smaller than it in width. However, the use of a smaller, functional referent in these judgments, rather than the maximum grasping span, would have cancelled this effect. Finally, implicit knowledge of this functional referent seems to have been sufficiently powerful to affect some judgments where an arbitrary environmental object was the standard. That is, the latter judgments were biased in favor of positive responses, which is the direction such an effect would point in the present series of experiments.
Chapter 4. Conclusions

The studies reported here examined the relation between object size and body size in terms of observers' abilities to make functional judgments of the sizes of objects with reference to a bodily standard. These judgments were consistently characterized by high accuracy and confidence on all sizes except for a very narrow range about the standard. Further, they were not only stable over time even though there was never feedback, but they were impervious to the effects of potentially biasing extraneous influences (i.e., large end anchors). The standard for the judgments was each observer's maximum grasping span, which evidently was slightly larger than the usual limit of the functional grasping span. Under ordinary circumstances this functional span probably reaches its greatest extent approximately 1 to 1.25 cm smaller than the maximum grasping span.

These findings are highly consistent with predictions from an ecological perspective using the affordance concept (c.f., Gibson, 1982a; Gibson, 1979), which often emphasizes the utility of perception. Thus, the organism perceives meaningful relationships between itself and environmental structure. Specifically, the organism perceives affordances, which are what the environment provides the organism, either as support for potential behaviors, or else as consequences of behavioral and environmental events.
According to this approach, when object size is a crucial factor in an affordance judgment, that size will be perceived in terms of the bodily dimension relevant to the judgment. This prediction is especially pertinent, in view of the strong constraints which the sizes of organisms place on their activities. Regarding humans per se, it seems particularly notable, given the crucial role which the use of tools and hand weapons have played in the development of our technology and in the control and exploitation of one another and of animals (c.f., Went, 1968). In the present studies observers were asked to judge the graspability of objects of various sizes, which is a very simple affordance judgment. The notable precision with which most observers made the judgments, the stability of the judgments, and the high confidence which accompanied them all accord with the affordance concept. According to it, observers ought to be quite good at making such judgments, and so they are.

In three experiments these judgments were contrasted to object-size judgments which were referred to an arbitrary environmental standard. The latter judgments proved less stable than the affordance judgments: most notably, they were highly susceptible to hysteresis effects, while affordance judgments were not. They were also consistently subject to a strong bias wherein larger objects were frequently judged smaller than the arbitrary standard. This underlying bias cannot be explained in terms of a hysteresis effect, but it does suggest that the observers were using an implicit alternative standard on at least some of these environmentally
referred judgments. Assuming a functional grasping span to be a highly salient natural referent, as it certainly appears to be in the present studies, then it may serve as such an implicit standard. This anatomical standard was, in fact, larger than the environmental standard in the present experiments, so its effect on judgments in the environmentally referred condition would have been to induce the aforementioned bias. That is, tiles larger than the environmental referent were almost always smaller than the anatomical referent. Thus these larger tiles could have been erroneously judged smaller, by virtue of the fact that they actually were smaller than the implicit standard of most of the observers.

The efficacy of the grasping span as a referent suggests that it may have an effect in the functional category of graspable objects similar to that of prototypes in perceptual or semantic categories (c.f., Rosch, 1975). One of the most important attributes of real world objects is their functional utility. A basic functional attribute of a chair, for example, is that it is "sit-on-able" (Gibson, 1979, 1966; Rosch, et al., 1976). The ordering of objects along a functional dimension, such as graspability, may occur very similarly to orderings in perceptual domains. If so, then the most salient referents in that dimension may induce asymmetries in judgments involving them. Regarding the single hand-span, for example, an object 1.5 to 2 cm smaller than a person's widest grasping span might be a good candidate for a functional referent for graspability judgments. If so, then other objects which, although
graspable, are considerable narrower (e.g., a pin) or wider (e.g., a large pocketbook) than this object should be judged more similar to it in terms of graspability than vice versa.

Previous studies of asymmetry effects have relied on paired comparisons between the prototypical and less typical instances of the category to reveal these effects (c.f., Sadalla, et al., 1980; Rosch, 1975). Thus instances which differed from the prototype in any direction on a given dimension could be used to reveal the usual asymmetry: less typical instances are judged more similar to the prototype than vice versa. The present studies, however, called for a "yes"/"no" affordance judgment on each object taken alone, rather than a similarity rating of a pair of items. Since the grasping span is the defining referent for graspability, graspable objects themselves cannot be used in such a binary judgment task to reveal the usual asymmetry involving the referent. That is, a simple positive judgment of a graspable object fails to reveal its relative typicality as such an object. A false positive judgment of an object too large to grasp, however, reveals much more. The nearer such an object seems in size to the grasping span, the greater the likelihood of such a judgment. McConkie's (1977) experiment and Experiments 1 and 2 of these studies showed results consistent with the foregoing. False positive judgments considerably outnumbered false negative ones, which is the direction an asymmetry should have in this case. However, Experiments 3 through 5 of these studies failed to show this asymmetry. Indeed, the reverse occurred, though only to a small degree.
This reversal intimates the last problem addressed in these studies. Each observer's maximum grasping span was the implicit bodily standard to which the object-size judgments were referred. However, this maximum grasping span requires considerable effort to use, and its use is good only for brief durations. Thus it probably would be used only in the most pressing circumstances. Ordinarily, two hands would be better than one for holding larger objects. In view of this, observers could have been influenced by tacit knowledge of a slightly smaller but more functionally useful span. If so, then object sizes falling between the maximum grasping span and the upper limit of a smaller but more functional span should be especially revealing of this. That is, although technically the observer ought to judge these sizes to be graspable, in fact he is very likely to respond negatively because of the influence of his functional standard. In fact, object sizes only .25 and .75 cm smaller than the maximum grasping span were most subject to such conservative responses. The explicit attempt in Experiment 6 to establish the upper limit of a functional grasping span suggested that such a span ordinarily ends approximately 1 cm smaller than the maximum grasping span.

Although individual differences were not among the major concerns of these studies, it should be noted that they actually were quite marked in several of the experiments. For example, percent correct was considerably more variable among observers in the environmental referencing condition than in the anatomical condition in Experiment 3
(50 to 95% versus 73 to 90%, respectively), even though the arbitrary referent was the same for every observer and the anatomical referent varied with observer. It is plausible, of course, to assume that affordance judgments involve perceptual skills which differ among individuals. Furthermore, both efficiency and effectiveness in the use of body referents may depend in part on prior experience, and in part on differences in perceptual and cognitive style. Wallace (1977) found that some participants in a target localization task were unable to position their arms accurately in line with a body referent (the midline). It is not clear what the locus of this deficiency was (perhaps they were simply unsure where their midlines were; or they were unable to coordinate the localization movements with their perceptions of their midlines), nor whether training on perceiving body reference points would enhance performance on a localization task.

Sadalla, et al. (1980) showed that one of the determinants of greater and lesser referentiality in large scale space is familiarity. Similarly, Ittelson (1960) suggested that size invariance is determined by a combination of familiarity with objects and functional relations between the objects and the observer's body. The hand and its role in grasping and manipulating objects are both doubtless highly familiar to most people. Nevertheless, even here perceptual skill varies, especially in a task where observers are asked to make explicit judgments about the largest objects they can grasp.
The arbitrary standard, by contrast, at least in its role as a referent for object-size judgments, likely would be highly unfamiliar to most people. Even familiarity with the use of an arbitrary standard in making such judgments, although widely taught in schools, likely varies considerably, especially compared to the grasping span's familiarity. So prior experience alone, by determining the relative familiarity both of the referents and their uses in the present role, could have considerably increased the variability among the observers. It should be noted, however, that the present studies failed to support this idea. Observer variability changed very little with practice (i.e., across blocks of trials).

The findings of these studies are compatible with the ecological approach to the study of perception and cognition. This approach asserts that these are activities which can be advantageously described in terms of information specific to behaviorally salient units (c.f., Cutting, 1982; Patten, 1982; Gibson, 1982; Ben-Zeev, 1981; Shaw & Turvey, 1981; Gibson, 1979). Thus, people perceive chairs, for example, as objects which afford sitting; floors as surfaces which afford support for standing, walking, or running; doorways as apertures which afford passage; and other people and animals as organisms which afford social interactions, or perhaps danger. Rosch, et al. (1976) have shown that knowledge of the environment is categorized hierarchically, reflecting structural relationships inherent in the environment. A crucial component of this hierarchy is the "basic" category, which includes sufficient
common attributes of instances to be well defined, but not so many as
to lose its value as a mechanism for organizing everyday knowledge.
Included in this basic level are broad functional attributes of
objects or surfaces. Chairs, for example, regardless of their
pedigree in antiquity, or their specific function in the home (kitchen
or den), are all "sit-on-able." This basic level of categorization,
according to Rosch (c.f., Gibson, 1979, 1966) seems to be the level at
which people ordinarily conceive of the relations between themselves
and their environment.

Integral to perception and cognition, then, is an awareness by
the perceiver of what he can do in his environment (e.g., grasp an
object, or walk through an opening). They also include an awareness
of consequences for the organism which are entailed by various events.
For example, a looming object, barring an intervening event which
stops it, will strike the organism which fails to move out of its
path. That organisms respond unequivocally by moving when provided
with information specifying a rapidly looming object has been
demonstrated in several studies (e.g., Bower, 1970; Yonas, 1977).

Thus, perceptual cognition, according to ecological psychology,
is an ongoing activity whereby the organism gains and uses information
about the environment. That is, the organism knows what to look for
and how to look for it, and then knows what to do given the desired
information. This information is germane to its own needs and
interests, and is taken in terms of its own dimensions and abilities
(Gibson, 1982; Gibson, 1979; c.f., Patten, 1982; Lorenz, 1973; Went,
1968). It is possible, of course, to use many different levels of description to characterize an organism in terms of its environment (or vice versa). A pathologist may want to use a cellular description to account for the effects of viral or bacterial activity in the body. A physicist may want to use an atomic level of description to characterize the behaviors of different kinds of radiation and their effects on different organisms. But such descriptions are highly abstract compared to the level of ordinary concerns and motor behaviors of larger organisms. These organisms' perceptual and cognitive concerns are in terms of what they can do or what might happen to them in a particular environment. For example, "Can I grasp this object? Is it suitable for use as a hammer?" This level of description can be used to great advantage by psychologists to understand and predict perceptual and cognitive activities, and their concomitant motor behaviors, of organisms.

Evaluation and proposals for further study. In four of the six experiments reported here, anatomically and environmentally referred judgments of object size were contrasted. Both were binary judgments involving ordinal relations (larger/smaller) between a referent and a set of target objects. However, judgments in the anatomically referred condition were clearly tied to a functional question (Is the object graspable?), while the environmentally referred judgments were not specific to a functional question. Thus it is not clear whether the differences which were found between the two judgment conditions stem from the fact that one condition involved a functional question
while the other did not, or from the fact that one referent was anatomical while the other was environmental. The functional issue could be addressed by including a condition in which the environmentally referred judgments were functional. For example, the observers might be asked to judge whether a target tile would fit into a particular space.

The functional issue could be further examined by having observers make affordance judgments with reference to the functional grasping span, to the absolute hand span, and to a well-defined but rarely used bodily standard such as the distance from the elbow to the wrist. The functional hypothesis would be that judgments referred to the functional grasping span would be most precise and stable; the hand span next, since it most nearly approximates the functional span, and furthermore it is occasionally used itself as a standard; and the forearm last, being the least useful.

It should be noted that the anatomically referred judgments were consistently slightly conservative in four of the experiments, perhaps due to the use of a functional referent somewhat smaller than the maximum grasping span. This conservatism runs directly counter to an asymmetry effect. Thus the two effects, if both actually exist, would have tended to cancel one another in these studies. The two could be untied and tested independently in separate experiments. The asymmetry hypothesis could be tested by using a paired comparison in which the functional grasping span for each observer is paired with various object sizes (both larger and smaller than the span). On half
of the trials, the grasping span would be the explicit standard, while on the others, the object would be the standard. Using a predetermined scale (e.g., 0 = same size; 1 = very nearly same size; and so forth to n = very different in size), the observer would compare the sizes of the objects with the grasping span. According to the hypothesis, the objects ought to be judged nearer in size to the grasping span than vice versa.

Another problem in this series of experiments lies in the fact that the mean width of each group of tiles to be judged was equal to the referent in width. This may have affected the stability of the judgments in the two conditions. However, uncoupling the two should actually not affect the anatomically referred judgments, assuming that the anatomical referent is as powerful as affordance theory and the present findings suggest. It likely would affect the environmentally referred judgments, though, since they are evidently less stable, and thus would be subject to effects not only from changes at the ends of the series of judged tiles, but also from shifting the mean.

In view of the historical role which the body may have played in providing standard units for linear measurements, it would be interesting to test for the possibility that people can recognize regularly recurring bodily referred units. For example, they might judge 2 times their hand spans to be more referential than 1.5 times or 2.3 times their spans.

This line of research into people's knowledge of their own physical dimensions should have considerable implications for studies
of body awareness in clinical settings. Kalliopuska (1982) has pointed out that clinicians studying the effects of psychic disturbances on body awareness frequently use diagnostic tools which are highly subjective. A standard instrument, for example, is the draw-a-person technique, in which patients are asked to draw representations of human figures. Distortions in these drawings, as interpreted by the diagnostician, supposed reflects various problems which the patient has in his self-image. It would be both interesting and useful to determine whether such psychic disturbances affect a patient's ability to make bodily referred affordance judgments of object size. If so, then it should be possible to devise objective tests of body-image disturbances based on quantifications of such judgments.

Clinical studies concerned with the development and use of prosthetic devices could also profit from extensions of the present studies, while at the same time providing insights into very interesting theoretical questions in perception and learning. For example, do prosthetic devices become integral features of one's body awareness? That is, do object-size judgments in terms of such devices have the same characteristics as those which are referred to original body parts? Certainly it would be of great theoretical interest to determine the manner in which the ability to make object-size judgments develops during normal human development. But it would also be of both theoretical and applied interest to determine whether the ability to make such judgments in terms of prosthetic devices develops
in a manner similar to its usual development. If this ability is advantageous to the user of such devices, then a very pertinent question would be whether its development can be speeded up or otherwise enhanced by training.

Bodily referred knowledge of the environment has been little investigated thus far in perceptual and cognitive studies. However, its potential for affecting the course of the development of perceptual and cognitive theory seems considerable. Further, it has interesting implications for clinical issues involving one's self image and the development and use of prosthetic devices, as well as for the development of artificial extensions of normal bodies. These considerations certainly warrant both further empirical studies and the examination of theoretical implications of such knowledge.
List of References


