

## **Are human bodies represented differently from other objects? Experience shapes object representations**

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This study investigated the cognitive organization of the human body representation and its relationship to other object representations. It addressed whether (1) all objects and their parts were organized similarly, (2) animate objects and their parts were organized differently from inanimate objects and their parts, and (3) the human body was organized differently from all other objects. The relations among the parts of three exemplar objects (human body, bear, and bicycle) were examined. Participants performed a series of sorting tasks using stimulus cards illustrating various part and part combinations of these objects; the cards were constructed so that the same strategies could be used to categorize all three objects. Dissimilarity data were analysed using multidimensional scaling techniques. Results indicated that the human body was organized differently from the other objects, and that categorization did not follow the animate–inanimate distinction. Although animate objects were represented more on their visual characteristics and inanimate objects were represented more on functional characteristics, the human body was represented on its ability to perform actions. Representations of the other objects suggested that their organization was embodied in that they appear to be shaped by how the human body interacts, or doesn't interact, with the object.

The purpose of this study was to investigate the cognitive organization of the human body representation and its relationship to other object representations. Human viewers may use different strategies to visually perceive different types of objects. Previous research has suggested that the representation of the human body may be different from representations of other animate and inanimate objects (e.g., Caramazza & Shelton, 1998; McBeath, Morikawa, & Kaiser, 1992; Ogden, 1985; Reed, 2002; Reed & Farah, 1995). One reason for specialized representations of the human body is that they may help humans discriminate conspecifics from other species, enabling effective survival in a threatening

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environment. Most importantly, specialized representations of the human body may help humans prepare their bodies for action in the environment. This type of representation is not necessary for other objects.

To provide evidence for differences between representations of the human body and other objects, this study investigates (1) whether all objects and their parts are organized similarly, (2) whether animate objects and their parts are organized differently from inanimate objects and their parts, or (3) whether the human body—by virtue of its unique ability to perform actions on objects and the environment—is organized differently from all other objects. To distinguish among the three questions, a sorting paradigm was employed that required object parts to be organized into categories. The sorting paradigm provides the basis for revealing differences in the cognitive organizational schemes for the parts of different objects.

One parsimonious organizing scheme for the representation of objects and their parts is that all objects are organized in the same manner. A number of object recognition theories posit that part organization relies on low-level visual properties such as the size of the part, the points of natural discontinuity, or the location of parts relative to the object's frame of reference (Biederman, 1987; Hoffman & Richards, 1984; Kosslyn, 1976; Marr & Nishihara, 1992). Such visual-based theories provide several predictions for the processing of human bodies and other objects (Morrison & Tversky, 1997). First, the *image size hypothesis* states that parts with larger surface areas would be encoded faster than smaller parts and thereby would be more salient. Kosslyn (1976) found that when imagery was used to visualize a whole object, larger parts were verified faster than smaller parts. In the present study, the image size hypothesis is relevant because the size of a part may govern part salience in the context of the whole object, regardless of the class of object. Thus, size would be the salient dimension of part similarity and people would group object parts of similar sizes together.

Second, the *contour discontinuity hypothesis* emphasizes the relationships among different object parts. An object is recognized, regardless of viewpoint, based on visual perceptions of the natural divisions of the object and the separation of its parts. Thus, the visual system uses the regularities in nature to divide the object into a hierarchy of parts and transform it from three dimensions into two, thereby promoting recognition (Biederman, 1987; Hoffman & Richards, 1984; Marr & Nishihara, 1992). Biederman (1987) demonstrated that object recognition was more impaired when areas of concavity were deleted than when the regions between concavities were deleted. In the present study, the contour discontinuity hypothesis would predict that participants categorize object parts based on regions defined by the natural concavities in the form's contours and that disconnected parts would be placed into separate categories.

Third, the *environmental axes hypothesis* posits that visual scenes are comprised of objects in relation to the major axes of the environment. If these axes

are critical for object representation, then they may determine object part organization. Some evidence suggests that objects and the human body may be organized at least into top and bottom regions, defined by the horizontal axis. Chambers, McBeath, Schiano, and Metz (1999) found that participants had a generic bias to view the tops of objects as being more salient than the bottoms. Similarly, Reed and Farah (1995) found that movement of the top portion of the human body facilitated memory for the position of another person's top portion of the body, but not the bottom portion and vice versa. In the present study, the environmental axes hypothesis would predict that object parts are grouped in terms of environmental horizontal and vertical axes.

Another possible organizing scheme for object representation is that animate objects differ from inanimate objects in terms of their salient properties (e.g., Freyd, 1992). McBeath et al. (1992) demonstrated a perceptual bias to view the apparent motion of animate objects as moving in the direction they "faced". Neuropsychological studies also support animate vs. inanimate distinctions at more conceptual levels. A number of reported case studies have documented double dissociations between the recognition of living and nonliving categories of objects (e.g., Farah, McMullen, & Meyer, 1991; Kolinsky et al., 2002; Laiacona, Capitani, & Barbarotto, 1997; Powell & Davidoff, 1995; Warrington & Shallice, 1984). Farah and McClelland (1991) have argued that the living versus nonliving distinction is less of a category-specific deficit and reflects more of a difference in the reliance of visual and functional object properties. Living objects are said to be based on visual properties and nonliving objects to be based on those object's functional properties. Caramazza and Shelton (1998) reevaluate this idea to argue that what distinguishes animate from inanimate objects is the relative correlation between sensory/visual and functional properties within each category.

In the present study, if object representations differ in terms of the relative salience of properties for animate and inanimate objects, then the parts of animate objects would tend to be organized more the basis of their visual properties (e.g., colour, shape, size) than their functional properties (e.g., walking, eating). In contrast, inanimate objects would tend to be organized more on the basis of their function (e.g., propulsion, steering) than on their visual properties.

A final organizing scheme for object representation is that the human body is represented differently from all other objects. Evidence for a separate human body representation is found in neurological and psychological literatures. Brain damage can produce dissociations between spatial knowledge of the human body and other objects in the external environment (Babinski, 1918; Bisiach, Perani, Vallar, & Berti, 1986; Denes, 1999; Fredericks, 1985; Guariglia, Piccardi, Puglisi Allegra, & Traballes, 2002). For example, autotopagnosia is a deficit in which patients have a selective difficulty locating human body parts within the context of the human body. This disorder demonstrates that the cognitive representation of the human body can be selectively impaired by brain

damage, leaving intact the representations of other animate and inanimate objects (Buxbaum & Coslett, 2001; Coslett, 1998; Denes, Cappelletti, Zilli, Dalla Porta, & Gallana, 2000; DeRenzi & Faglioni, 1963; DeRenzi & Scotti, 1970; Guariglia et al., 2002; Ogden, 1985; Sirigu, Grafman, Bressler, & Sunderland, 1991).

Evidence of a separate human body representation is also found in studies of healthy adults. Reed and Farah (1995) had participants judge whether the body position of a human model had changed while they made nonrepetitive arm or leg movements. Moving a part of their own body actually facilitated participants' memory for the position of the same part of the model's body. In contrast, in a similar task in which participants judged whether the position of block figures had changed, movement of their own body part did not influence the memory for the position of the block configurations. More recently, Downing, Jiang, Shuman, and Kanwisher (2001) used functional magnetic resonance imaging to demonstrate that a specific brain region in neurologically intact humans, namely a portion of the right hemisphere's lateral occipital area, is selectively activated for the passive perception of human bodies compared to many types of other objects.

Thus, the human body may be represented differently from other objects for several reasons. First, the *cortical representation hypothesis* (i.e., the part significance hypothesis described by Morrison & Tversky, 1997) states that people not only use perceptual salience, but also the size of cortical representation to make cognitive categories. In somatosensory and motor cortices, there is greater cortical representation for the most active and most sensitive body parts (e.g., the fingers or the mouth). Body parts with greater representation in the somatosensory and motor cortices would be more salient and thus, would be more easily differentiated from those parts with less cortical representation. Using a task that asked participants to verify if a named body part was the same as an illustrated body part, Morrison and Tversky found that participants responded fastest to those parts with the greatest cutaneous sensitivity, such as the hands and head. In the present study, the cortical representation hypothesis would predict that areas of greatest somatosensory representation (e.g., fingers, hands) would also be more salient than less sensitive and active parts (e.g., torso).

Second, the human body may be represented differently because of the body's ability to perform functional actions with objects and the environment. The *functional action hypothesis* suggests that the dynamic nature of our bodily experience organizes the body representation in terms of the human body's action properties. Kinsbourne (1995) proposed that the human body representation is "referenced for action" and that human body parts with joints (e.g., fingers, hands) tend to be more salient than larger, nonjointed parts (e.g., back, chest). Unlike the cortical representation hypothesis, body parts such as the hands, arms, legs, and feet would be relatively more salient because they per-

form overt physical actions. Further, these parts do not share the same degree of representation in the somatosensory and motor cortex homunculi. Arms, legs, hands, and feet may be considered similar because they are the effectors for action. The head may not be part of that category because it performs a different type of function.

To distinguish among the three organizing schemes for object representation and their corresponding hypotheses, a sorting paradigm was employed that required object parts to be organized into categories. The instructions were only “to put parts together that went together”. The tasks did not involve any object or part naming in order to avoid any explicit use of language and its organizing influences. Three different line drawings were used to represent each class of object: The human body class was represented by a human male body, animate objects by a bear, and inanimate objects by a bicycle. Multidimensional scaling analyses were conducted on similarity data to reveal the underlying organizational principles for each object and its parts.

## METHODS

### Participants

Thirty-six participants from the University of Denver volunteered to participate in this study for extra course credit in undergraduate psychology courses; thirty participants participated in the major study and an additional six participants participated in the follow-up study.

### Stimuli

The stimuli were 3 × 5 inch cards depicting line drawings of complete objects, their parts, and their part combinations. For this study, a representative exemplar was selected from each class of objects: A human male to represent the class of human bodies, an American brown bear to represent the class of animate objects, and a touring bicycle to represent the class of inanimate objects. The following criteria were used to select each exemplar: (1) The objects had to be familiar to the participants; (2) objects had to have multiple parts; (3) the parts had to be visually distinguishable from each other; (4) the parts could be segmented from the whole object; and (5) the individual parts had to be identifiable without the context of the whole object. To meet these criteria, each complete object was depicted in its *canonical* or most familiar view (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). The human body, created using Fractal Design Poser software, was a human male figure facing forward in a neutral, standing pose. The bear and the bicycle stimuli, selected from the Snodgrass and Vanderwart (1980) set of drawings, were facing sideways. Within the Snodgrass and Vanderwart familiarity and naming ratings, the bicycle was virtually equivalent to human body parts. Compared to the bicycle and body parts, the bear was ranked

as being less familiar but equivalent in naming ratings. Nonetheless, the bear was similar in familiarity ratings among the other illustrated animate objects from this set, and, more importantly, its illustration met all of the above selection criteria, unlike some of the relatively more familiar animate objects.

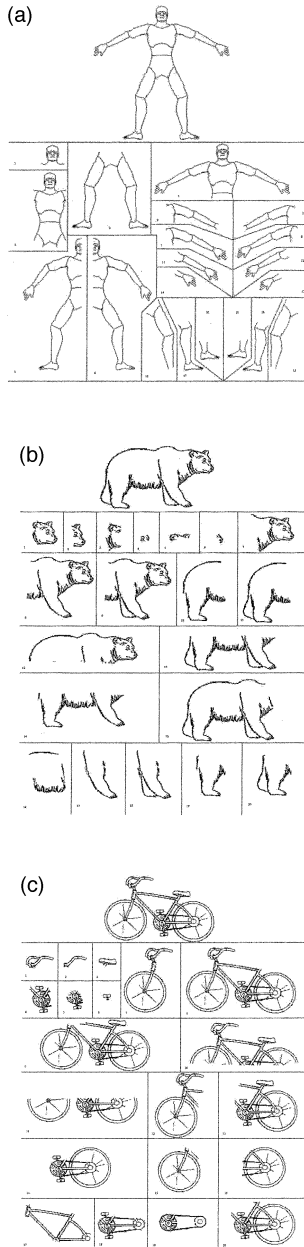
The stimulus cards were constructed to equate the parts of the human body with those for the bear and bicycle as much as possible, while maintaining the images in their canonical viewpoints. Twenty different cards were created from each of the three objects (Figure 1A, 1B, and 1C). The cards depicted identifiable parts and part combinations that permitted the cards to be sorted using similar strategies across objects, despite the individual variation among object parts. The part combinations permitted visual and/or functional strategies for sorting. For example, participants could use a visual strategy to divide all stimuli by major horizontal and vertical axes. Participants could also use a functional strategy to group movable parts.

## Procedure and design

Participants performed categorization tasks that required them to sort a set of object parts into various categories. Each participant performed four sorting tasks: (1) An unrestricted “free” or unlimited category sort; (2) a two-category sort; (3) a three-category sort; and (4) a four-category sort. For each sorting task, participants were instructed to place cards that “went together” into the same category or pile. For the “free” sort, participants were told to make as many piles of similar cards as they needed. For the two-, three-, and four-category sorts, participants were told to make two, three, or four piles respectively. No other instructions or feedback were provided. These sorts were completed for each of the three object types. There were a total of twelve sorts per participant.

Participants were presented with the complete illustration of the object to be sorted and a corresponding set of 20 cards depicting the object’s parts. The unrestricted or “free” sort was always performed first. The purpose of the free sort was to determine the “natural” divisions among object parts. The experimenter recorded which cards were placed in which pile. In addition to the categorization data, overall sorting times were recorded. Using a stopwatch, the experimenter measured sorting time, beginning with the first stimulus presentation and ending with the placement of the last card. At the end of the sort, the experimenter asked participants to provide a verbal label describing each category (e.g., “upper body parts”, “moving parts”).

After the free sort, participants performed three more sorts in which they categorized the object parts into two, three, and four piles. Object type (e.g., human body, bicycle, and bear) and sort type (e.g., two-, three-, and four-pile sorts) were counterbalanced across participants to reduce order and practice effects. The purpose of the restricted category sorts was to determine which dimension or dimensions were most salient and which dimensions could be



**Figure 1.** Three exemplars of human, animate, and inanimate object classes—(A) human body, (B) bicycle, and (C) bear—are displayed in their canonical views. The complete picture was used for reference and was displayed during each sort. The parts and part combinations were constructed so that similar sorting strategies could be used for all objects.

ignored. For instance, the two-pile sort (2-sort) may reveal the more critical organizing dimensions while the three-pile sort (3-sort) and four-pile sort (4-sort) may show auxiliary dimensions. The experimenter shuffled the cards after each sort to reduce card order effects. After all the sorts were completed, participants ranked them in order of difficulty.

## RESULTS AND DISCUSSION

### Overview

Three types of data were analysed: Dissimilarity profiles, mean sorting times, and difficulty rankings. Dissimilarity data were analysed using hierarchical cluster and multidimensional scaling (MDS) analyses to reveal patterns of categorization across the different sort methods. These two types of analyses demonstrate the reliability and consistency of the data patterns. The category labels provided an explicit measure of the organizational scheme used for each sort. Sorting-time data provided a general measure associated with the ease of categorization across sorts and objects. Difficulty-ranking data provided a converging measure of difficulty across sorts.

### Hierarchical clustering, MDS, and category labels

To determine the emergent categorization scheme for each object across participants, hierarchical cluster analyses, ALSCAL MDS analyses, and INDSCAL MDS analyses were conducted using SPSS (version 9.0) statistical software. For each object and sort, a  $20 \times 20$  dissimilarity matrix was constructed with each cell representing the proportion of participants who did *not* put two cards together in the same pile.

Hierarchical cluster analysis methods were performed to construct spatial representations of the mental organizations of each object. The data were standardized using *z*-scores prior to clustering. To avoid extremes of either large or compact clusters, an agglomerative hierarchical procedure of unweighted pair group arithmetic averaging (UPGMA) was used to cluster or group similar object parts. The linked cluster nodes in the resulting dendrogram (see Figures 2, 4, and 6) were based on squared Euclidean distances, where larger distances between object parts represented greater mental differences.

The results are spatially illustrated by the individual dendrograms associated with each sort and object. In each dendrogram, the clusters provide information regarding the judged similarity of parts. As a result, similar parts are listed next to each other along the vertical axis of the dendrogram. The card number column relates the card label on the dendrogram to the card number on the relevant stimulus figure (Figure 1A, B, or C). The horizontal axis on the dendrogram indicates dissimilarity distances. The dendrogram “tree” indicates the priority of the clusters and the relations between clusters. Symbols that connect the



object parts closest to 0 on the dissimilarity scale are the primary clusters and indicate the closest associations among object parts. Symbols that connect these primary clusters are associated with higher dissimilarity numbers, indicating the next level of associations among clusters, and so on.

The ALSCAL and INDSCAL MDS analyses provided additional support for the results found in the hierarchical cluster analysis. The data from each sort were analysed separately and all together. For each procedure, the best fit solution was selected based on a stress value under 0.1 and an  $R^2$  above .90. Given that the two types of MDS analyses revealed similar results, we report only the results of the INDSCAL analyses because they not only provide information about the dimensions, but they also provide information regarding the relative salience of those dimensions.

For all of the analyses, the labels of the clusters and dimensions represent our interpretations of part organization schemes in the object recognition system and, to some extent, the specific stimulus depictions. The reliability of the clusters for each object representation, however, can be determined via an analysis of what clusters and dimensions remain constant and least variable across sorts. Further, the “tightness” or similarity distances for these clusters provide information regarding the relative agreement across participants.

### *Human body*

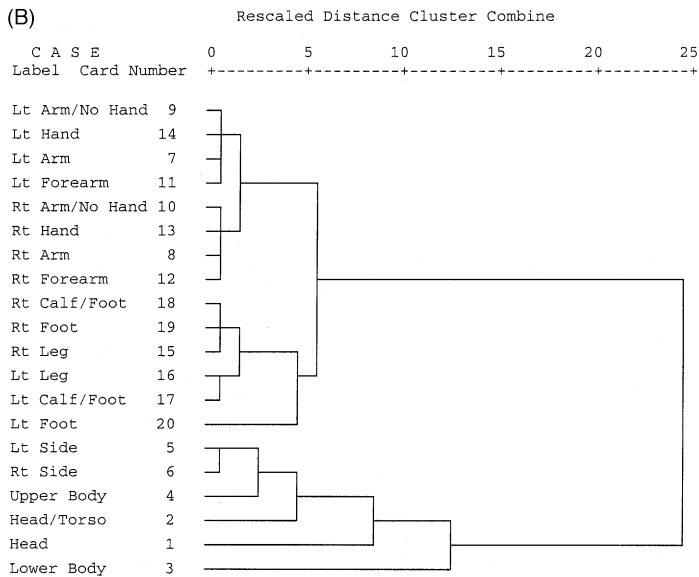
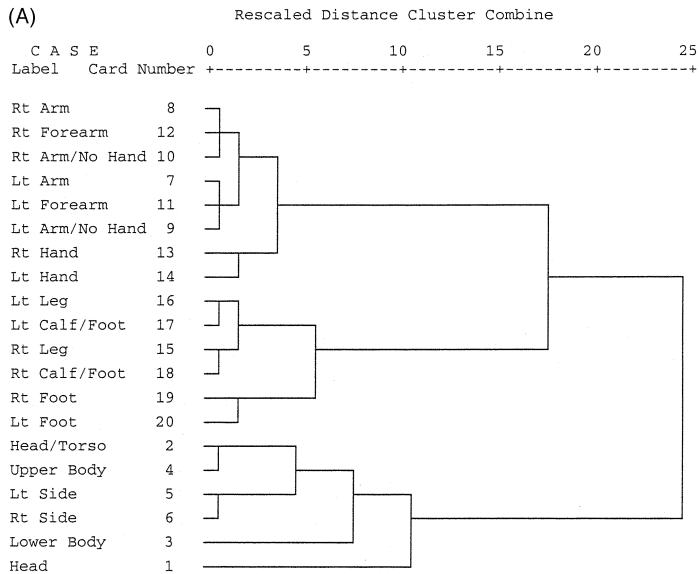
The results of the hierarchical cluster analyses and INDSCAL MDS analyses revealed similar patterns of part organization for the human body. Across all the sorting conditions, the human body was consistently organized by three major clusters: Arms/hands, legs/feet, and head/torso. A fourth cluster representing combinations of body parts varied in its importance across sorts.

*Hierarchical cluster analyses: Dendrograms for free-, 2-, 3-, and 4-sorts.* The purpose of the “free” sort was to determine the unrestricted cognitive associations among human body parts (Figure 2A). As a result, the lower linkages showed variation across participants in terms of small categorical distinctions that put together individual arms, legs, hands, feet, and body combination parts. The first cohesive linkages or clusters that emerged were arms/hands, legs/feet, and body quadrants. The *lower body*<sup>1</sup> and *head* stimuli were then added to the body quadrant cluster make a combination body part cluster. The highest-level linkage put the body together by connecting the arm/leg cluster with the combination body part cluster.

For the 2-sort task (i.e., when participants were forced to sort into two piles), two basic clusters emerged in the dendrogram: Arms/legs and combination body parts (Figure 2B). The combination body parts cluster is more variable and

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<sup>1</sup> Stimulus cards are referred to by their labels in italics.



**Figure 2.** The dendrogram for human body stimuli combined data from all four sorts, (A) free-sort, (B) 2-sort, (C) 3-sort, and (D) 4-sort, and illustrated cluster formations and linkage distances for all 20 human body part stimuli. Clusters forming toward the scale point of 0 are considered more similar and part of the lower linkage node (e.g., more primary clusters or clustering first). Three primary clusters were revealed: Arm/hands, legs/feet, and head/torso.

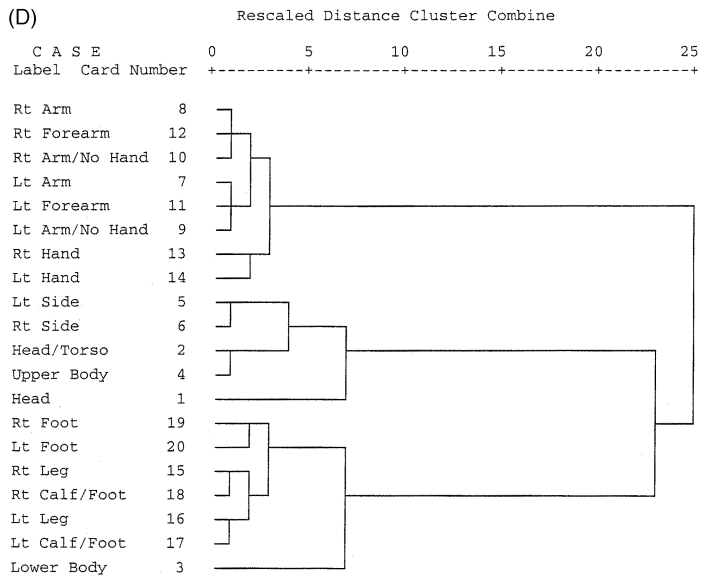
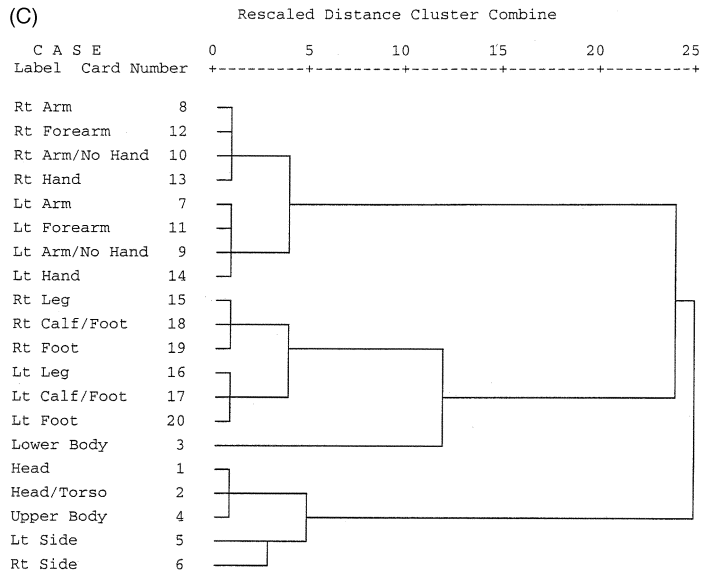


Figure 2. Continued.

groups differently from the free-sort. This suggests that two piles are not sufficient to adequately represent salient distinctions among human body parts.

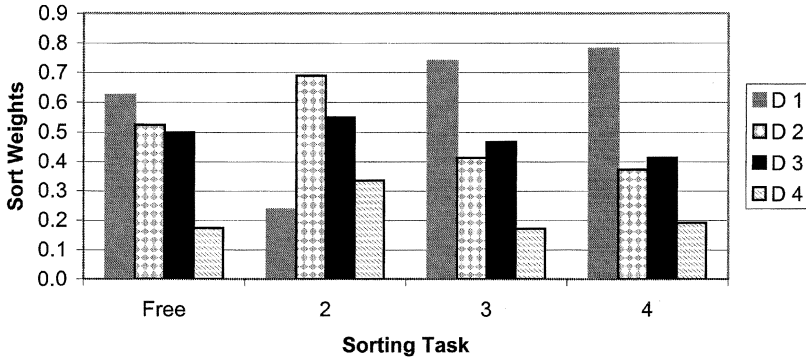
For the 3-sort task, the dendrogram revealed three clear clusters: Arms, legs, and head/torso (Figure 2C). The *lower quadrant* combination stimuli were included with the leg cluster and the *upper body quadrant* and *left/right sides* stimuli were included with the head/torso cluster. The tightness of these clusters suggests high participant agreement and indicates that the body may best be grouped into three categories.

For the 4-sort task, the dendrogram showed a different profile from the other sorts, but still indicated an arms/hand cluster, lower body cluster, and a combination body quadrant cluster (Figure 2D). Higher level linkages indicated two basic conceptual divisions: Arms/hands and combination body parts that included the legs. The different ordering and grouping of the parts compared to the other sorts suggests that the human body is not best represented by four categories.

*Human body combined INDSCAL MDS.* The INDSCAL MDS analysis revealed commonalities among the various sorts by combining the data from all four sorts. A solution with four dimensions best fit the data ( $S = 0.087$ ,  $R^2 = .952$ ). Dimension 1 distinguished arms and hands from all other body parts; Dimension 2 separated arms, hands, legs, and feet from combined body parts (e.g., *left side of body*, *upper body*, *right side of body*); Dimension 3 emphasized body-part combinations, and Dimension 4 specified distinctions along the body's vertical axis. To compare the relative importance of the different dimensions for each sort, salience measures were calculated from the weights obtained in the overall INDSCAL analysis (Figure 3). This analysis indicated that for the free-, 3- and 4-sorts, Dimensions 1–3 were most important for categorization. However, only Dimensions 2 and 3 were salient for the 2-sort, suggesting that two categories do not adequately represent the human body.

In summary, dimensions that consistently emerged across the human body sorts included arms, legs, head/torso, and combination parts. Divisions of the body along body quadrants or environmental axes were often compromised or varied across sorts. In support, the 3-sort dendrogram exhibited the cleanest and tightest clusters for all the sorts. These were consistent with the salience dimensions as well. Parts of the human body that perform actions in the world, namely the head/torso, arms, and legs, tend to be distinguished. These divisions were confirmed by participants' labels for their piles or categories in the various sorts. Overall, the human body data supported a functional action hypothesis more than a part significance hypothesis because legs and feet were categorized together, as were arms and hands. The cortical representation hypothesis was not supported because hands were grouped with arms. An image size hypothesis was not supported because hands and feet were not grouped together. Also, the environmental axes hypothesis was not fully supported. Left/right distinctions

### Body Part Dimensional Saliency 4D



**Figure 3.** Results of dimension saliency among sort conditions for the human body stimuli using weights obtained for four dimensions as determined by the INDSCAL procedure. Dimension 1 (D1) distinguished arms and hands from all other human body parts; Dimension 2 (D2) separated arms, hands, legs, and feet from combined body parts; Dimension 3 (D3) emphasized body-part combinations, and Dimension 4 (D4) specified distinctions along the human body's vertical axis.

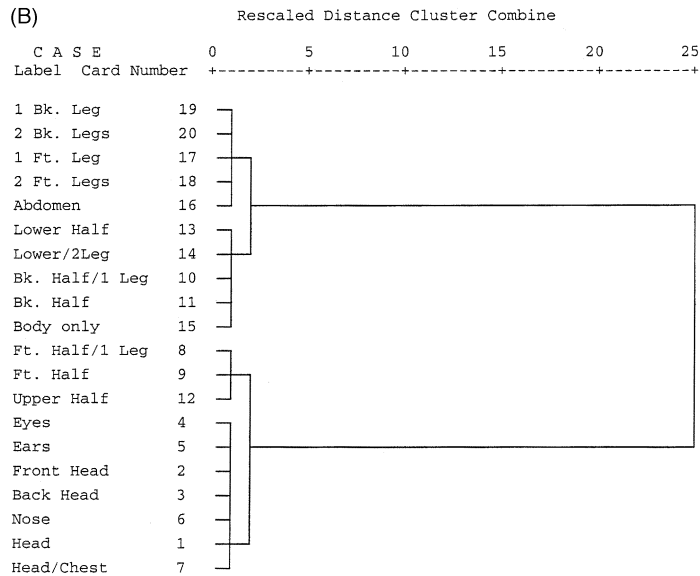
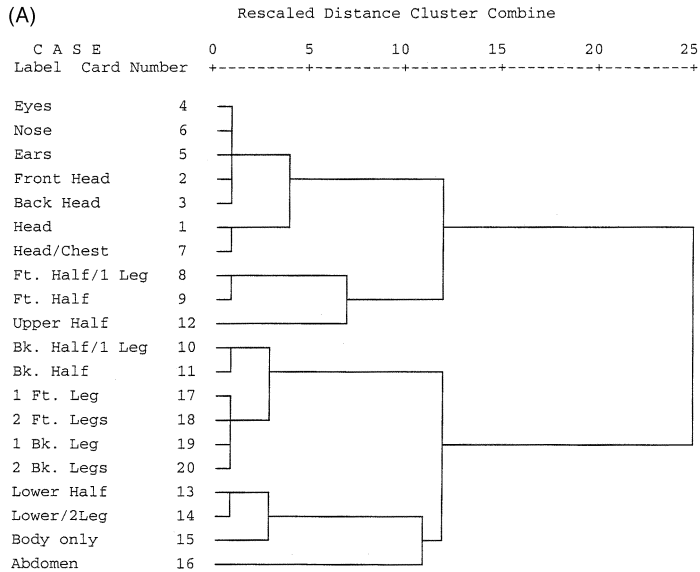
were not consistent across the whole body, in that left and right arms and legs were distinguished but not when combined with other parts of the body. Further, upper and lower portions of the body were placed in different groups of parts across sorts.

#### *Animate object: Bear*

The results of the hierarchical cluster analyses and INDSCAL MDS analyses revealed similar patterns of part organization for the bear. Across all the sorting conditions, the bear was consistently organized by environmental axes.

*Dendrograms for free-, 2-, 3-, and 4-sorts.* The free-sort dendrogram for the bear stimulus indicated four clusters: Head/front, front/upper, all legs, and lower body (Figure 4A). The lowest linkages divided the bear into multiple small clusters. The first group included parts of the bear head. The next groups distinguished the front of the bear, the back of the bear, and the legs. The last group included the lower portion of the bear. The higher linkage nodes showed a clear distinction of the head/upper/front portions of the bear from the lower/back portions of the bear. These basically indicate divisions along environmental axes.

The 2-sort dendrogram revealed similar distinctions as the free-sort, but with much less variability as seen in the greater similarity distances and tightness of the clusters (Figure 4B). Two major clusters emerged distinguishing the lower/back portions of the bear from the upper/front/head portions of the bear. Note



**Figure 4.** The dendrogram for bear stimuli combined data from overall all four sorts, (A) free-sort, (B) 2-sort, (C) 3-sort, and (D) 4-sort, and illustrated cluster formations and linkage distances for all 20 bear part stimuli. Clusters forming toward the scale point of 0 are considered more similar and part of the lower linkage node. Across all the sorting conditions, the bear was consistently organized by environmental axes: Head/front/upper body vs. legs/rear/lower body.

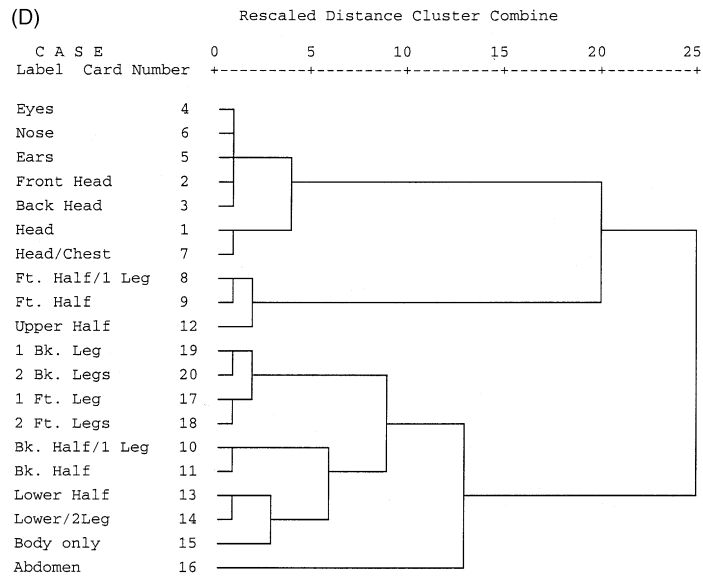
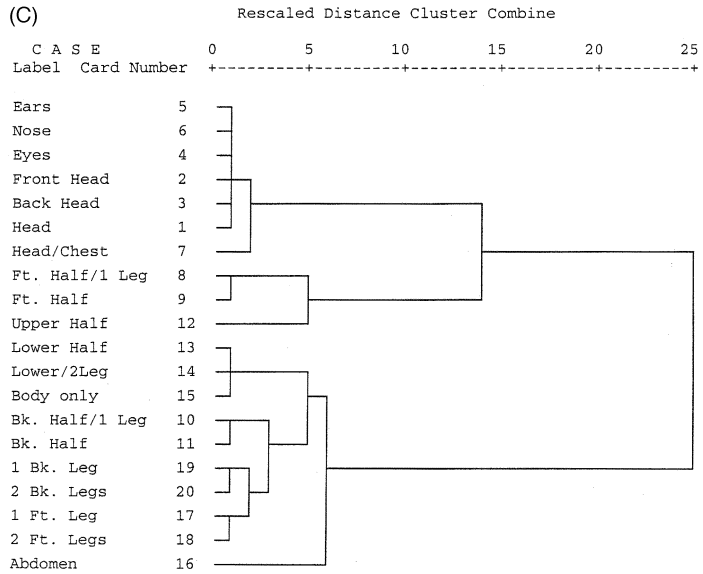


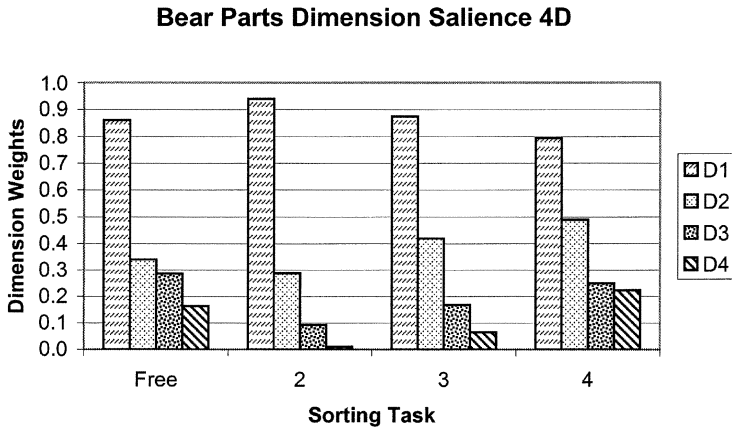
Figure 4. Continued.

that image size could not account for these clusters because the legs were highly distinguished from the head. These results indicated that two categories represent the natural divisions among bear parts.

The 3-sort dendrogram revealed more variability in the groupings than the 2-sort, but ultimately indicated the same two major clusters: Front/upper and lower/back portions of the bear (Figure 4C). The lower linkages showed a clustering of head parts and upper bear parts. In contrast to previous sorts, the front legs were grouped with other leg parts rather than the front/upper cluster.

The 4-sort dendrogram displayed even more variability, but again, ultimately ended up distinguishing front/upper from lower/back portions (Figure 4D). Again, head parts clustered into a tight grouping. However, the 4-sort was different because the leg stimuli were distinguished from the lower back portions of the bear.

*Bear combined INDSCAL MDS.* INDSCAL MDS analysis was performed that combined the bear data from all four sorts. A solution with four dimensions fit the data best ( $S = 0.067$ ,  $R^2 = .973$ ): Dimension 1 represented the head and face parts, Dimension 2 represented horizontal and vertical axes, Dimension 3 represented a vertical axis grouping in which front and back were separated, and Dimension 4 represented a group in which parts that did not fit into the first three dimensions were placed. The “catch-all” nature of Dimension 4 is reflected in the low saliency scores below. For all sorts, Dimension 1, which



**Figure 5.** Results of dimension saliency among sort conditions for the bear stimuli using weights obtained for four dimensions as determined by the INDSCAL procedure. Dimension 1 (D1) represented the head and face parts, Dimension 2 (D2) represented horizontal and vertical axes, Dimension 3 (D3) represented a vertical axis grouping in which front and back were separated, and Dimension 4 (D4) represented a group in which parts that did not fit into the first three dimensions were placed.



grouped the head and face parts separately from the rest of the bear, was the most salient. Dimension 4 contributed very little and did not greatly shift the level of salience across the other dimensions when it was removed. Thus, when all the sorts were combined the overall strategy was to divide the bear into front and back regions with the greatest emphasis on the head.

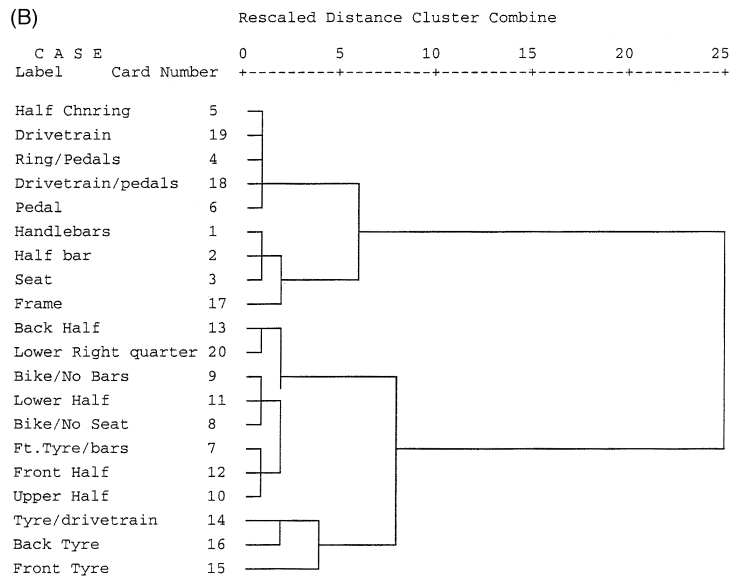
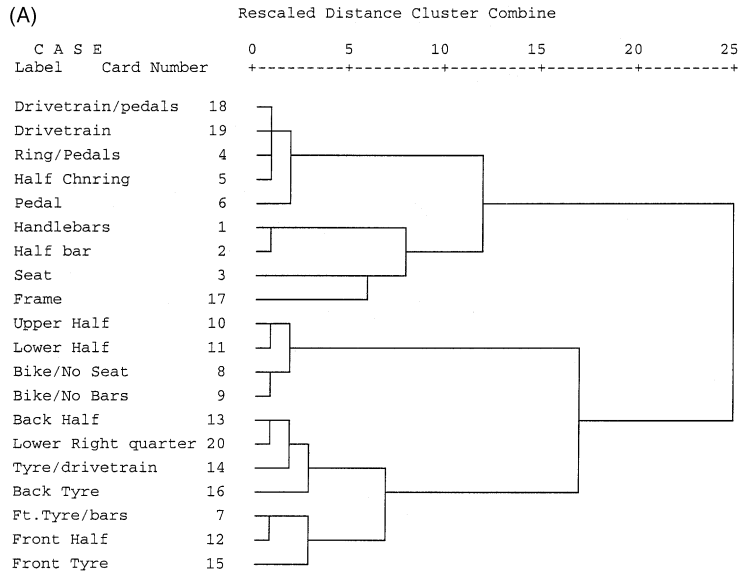
In summary, dimensions that consistently emerged across the bear sorts include the head/front/upper, and back/lower. In support, the 2-sort dendrogram exhibited the cleanest and tightest clusters for all the sorts. In other words, the most salient and persistent natural divisions among bear parts were along environmental axes. The emphasis on the head may be attributable to both cognitive representations and our stimulus depictions. Divisions of the bear between the legs, lower portions, and abdomen were often compromised or varied across sorts. These were consistent with the salience dimensions as well. The labels for the various sorts of bear stimuli generally agreed with these dimensional interpretations. Nonetheless, the variability across sorts suggests that participants used several different strategies to categorize the stimuli.

Thus, categorization strategies for the bear emphasized visual features such as environmental axes. These strategies were very different from those used for the human body. The image size hypothesis was not supported because small head parts were not grouped near individual leg parts. The contour discontinuity hypothesis was not supported because there are no lines to separate the front from back of the bear. The cortical representation hypothesis was not relevant. Last, the functional action hypothesis that classified the categorization of the human body was not supported because action-producing parts were not consistently grouped together. For these stimuli, animate objects do not share the same organizational scheme.

### *Inanimate object: Bicycle*

The results of the hierarchical cluster analyses and INDSCAL MDS analyses revealed similar patterns of part organization for the bicycle. Across all the sorting conditions, the bicycle was consistently organized by two major clusters: Parts a rider touches when riding a bicycle and visual environmental axes.

*Dendrograms for free-, 2-, 3-, and 4-sorts.* The free-sort dendrogram for the bicycle produced two major clusters of steering and propulsion parts and all other parts, but there was considerable variability (Figure 6A). At lowest linkages, the first cluster grouped the drive train and pedals; the second cluster grouped the handlebars, frame, and seat; the third cluster joined the upper and lower parts of the bicycle, excluding the seat and handlebars; and the last cluster grouped parts with wheels. In the higher linkages, the



**Figure 6.** The dendrogram for bicycle stimuli combined data from overall all four sorts, (A) free-sort, (B) 2-sort, (C) 3-sort, and (D) 4-sort, and illustrated cluster formations and linkage distances for all 20 bicycle part stimuli. Clusters forming toward the scale point of 0 are considered more similar and part of the lower linkage node. Across sorts, the bicycle consistently organized by two major clusters: Parts a rider touches when riding a bicycle, and visual environmental axes.

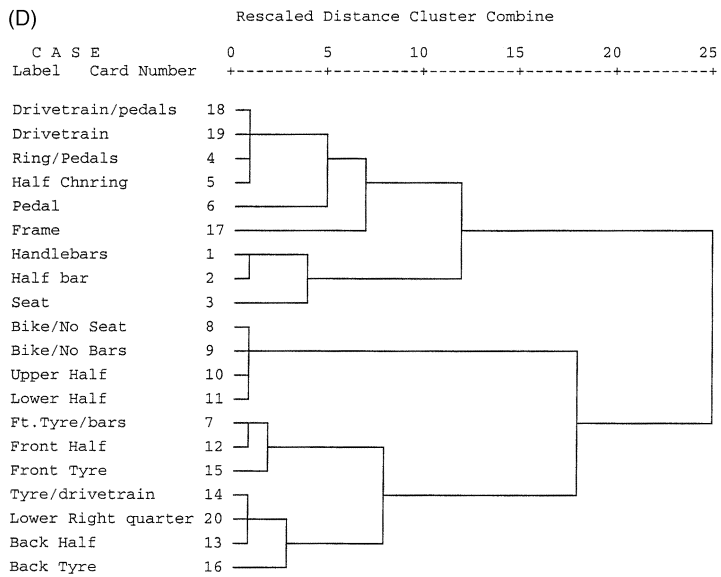
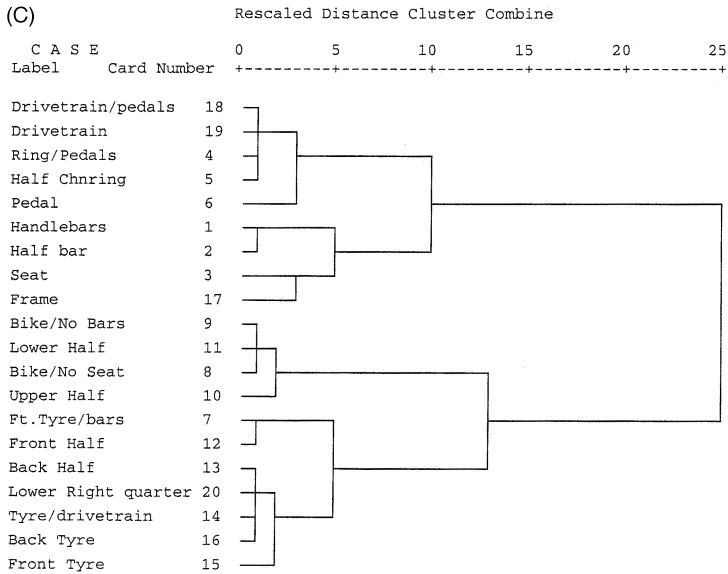


Figure 6. Continued.

propulsion and steering parts were separated from larger parts groupings based on environmental axes and parts including tyres. The propulsion and steering parts may also be categorized as parts that a rider comes in contact with when riding a bicycle.

For the 2-sort dendrogram, tighter clusters emerged (Figure 6B). Lowest linkages revealed four clusters of propulsion parts, structural parts, environmental axes parts, and tyre parts. The next level linkage again showed two major clusters distinguishing parts a rider is touching when riding/seated on a bicycle and divisions based upon visual environmental axes distinctions. The clean groupings of the 2-sort suggest that these two clusters may be a natural division among bicycle parts.

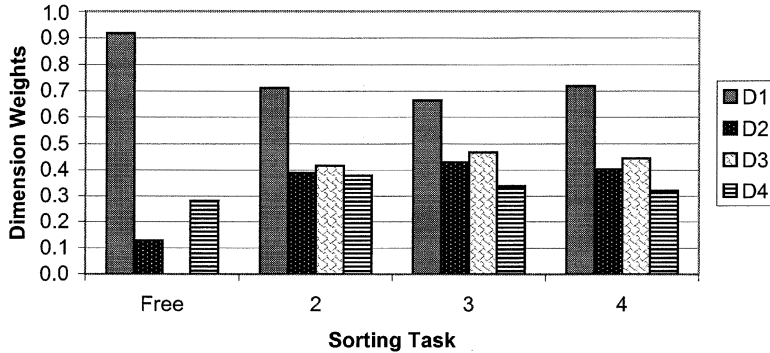
The 3-sort dendrogram was similar to the 2-sort (Figure 6C). The same four clusters emerged at the lowest linkages: Parts, structural parts, environmental axes parts, and tyre parts. However, there was more variability at the next level linkage in which upper/lower combination bicycle parts are distinguished from the front/back and tyre combination parts.

The 4-sort dendrogram revealed the greatest variability and dissimilarity distances among the clusters, suggesting that the bicycle was not as easily divided into four categories (Figure 6D). The biggest difference from the 3-sort dendrogram at the lower linkages was that the front tyres were now distinguished from the back tyres. Nonetheless, for all the sorts, the final clusters distinguished functional parts that a rider touches while riding on a bicycle from visual environmental axes distinctions.

*Bicycle combined INDSCAL MDS.* The four-dimensional solution fit the combined bicycle data best ( $S = 0.08$ ,  $R^2 = .96$ ). Dimension 1 corresponded to the propulsion and structural parts. If one were seated on a bicycle, one would have contact with these parts and use them to steer and propel the bicycle. Dimension 2 partitioned the bicycle stimuli based on vertical or horizontal axes. Dimension 3 distinguished parts that propel the bicycle (e.g., *drive train, pedals*) and parts that permit it to move (e.g., *tyres*). Dimension 4 distinguished the front parts from the back parts of the bicycle. Over all the sorts, the most salient dimension for the four-dimensional solution was dimension 1 (Figure 7). The remaining dimensions were approximately equal in saliency. The one exception was the free-sort in that it placed no weight on Dimension 3.

In summary, dimensions that consistently emerged across the bicycle sorts included a combination of functional and visual distinctions: Propulsion parts, structural parts, parts divided along environmental axes, and tyre parts. Higher level distinctions emerged consistently across sorts between parts a rider touches when riding a bicycle and visual environmental axes. In support, the 2-sort dendrogram exhibited the cleanest and tightest clusters for all the sorts. In other words, the most salient and persistent natural divisions among bicycle parts were along both functional and visual dimensions. Further, both participants' labels

## Bicycle Sort Dimension Saliency 4D



**Figure 7.** Results of dimension saliency among sort conditions for the bicycle stimuli using weights obtained for four dimensions as determined by the INDSCAL procedure. Dimension 1 (D1) distinguished propulsion and structural parts (i.e., parts that a rider touches when riding a bicycle) and all others; Dimension 2 (D2) distinguished vertical or horizontal axes; Dimension 3 (D3) distinguished parts that propel the bicycle and parts that permit it to move; and Dimension 4 (D4) distinguished the front from the back parts.

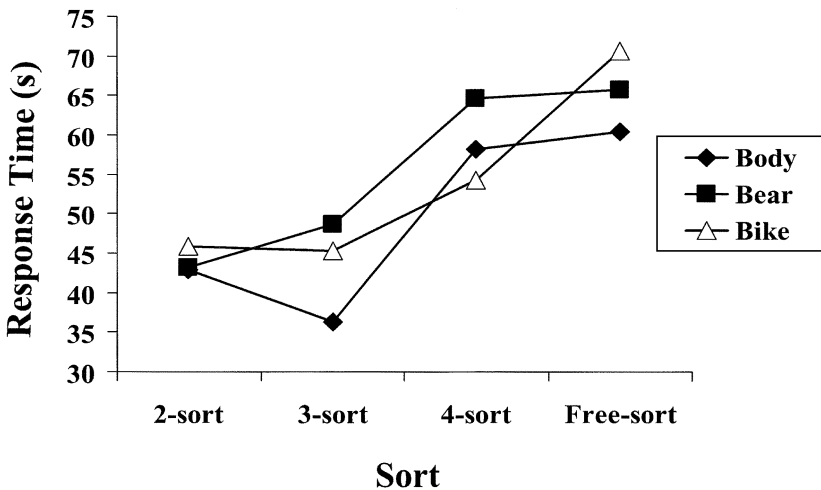
and saliency dimensions supported these interpretations. Divisions that were compromised across sorts distinguished tyre parts from upper/lower/front/back parts. Generally, these divisions were more similar to those for the human body than for the bear. Both separated parts that performed actions from those that did not. However, environmental axes played a relatively greater role in the categorization scheme used for the bicycle than for the body.

Thus, the bicycle was categorized using both visual and functional organizing schemes. The image size hypothesis was not supported because small propulsion parts were not grouped near tyre parts and the large frame was separate from other large combination parts. The contour discontinuity hypothesis was less supported because the tyres would be grouped with other distinguishable parts such as the propulsion parts and there were few visual breaks dividing upper, lower, front, and back portions of the bicycle. The cortical representation hypothesis was not relevant. Last, the functional action hypothesis was supported in that action-producing parts tended to be grouped with other parts performing similar actions (e.g., propulsion parts or tyre parts). However, object function was not the best classifier of bicycle parts. For example, tyres were not grouped with propulsion parts. Instead, the best classifier of bicycle parts was more of an embodiment hypothesis in that parts were groups in terms of the way the human body interacts with the bicycle! Parts that a rider touches when riding a bicycle (e.g., *pedals, frame, seat, handle bars*) were distinguished from other parts.

### Categorization-time data for all objects

Categorization time data for each sort and object was analysed to provide converging measures for the sorting data. The assumption was that faster sorting times reflected more natural object divisions and part categories. A within-subjects Object  $\times$  Sort analysis of variance (ANOVA) was conducted. No main effect was found for Object,  $F(2, 58) < 1$ . This result suggests that the categorization of the three objects and their parts was similar. The significant sort effect,  $F(3, 87) = 30.62, p < .0001$ , indicated that the 2- (mean = 39.19 s) and 3-sorts (mean = 43.40 s) were faster than the 4- (mean = 58.98 s) and free-pile sorts (mean = 65.58 s). Not surprisingly, sorting into more categories takes more time. The significant Object  $\times$  Sort interaction,  $F(6, 174) = 2.15, p < .05$ , indicated that the 3-sort for the human body was faster than all the others and suggested that the human body is naturally divided into three categories (Figure 8).

Second, object (human body, bear, bicycle) ANOVAs were conducted for each of the sorts to determine whether there were differences among particular objects in terms of the ease of categorization in the various sorting conditions. Only the 3-sort indicated significant sorting time differences among objects: 3-sort,  $F(2, 58) = 5.29, p < .008$ ; 2-sort,  $F(2, 58) = 1.29, p > .05$ ; 4-sort,  $F(2, 58) < 1$ ; free-sort,  $F(2, 58) < 1$ . The human body stimuli (mean = 36.27 s) were faster to sort into three categories than either the bear (mean = 48.70 s) or the bicycle (mean = 45.23 s). Not only does this analysis suggest that human body parts may be optimally divided into three categories, but also that the human body may



**Figure 8.** Object  $\times$  Sort interaction for categorization-time data. The 3-sort condition for sorting human body stimuli is faster than the rest, even the 2-pile sorts.

represented differently from the other objects. Post-hoc comparisons revealed significant differences between the human body and the bicycle conditions,  $F(1, 58) = 5.16, p < .03$ , and between the human body and the bear conditions,  $F(1, 58) = 9.93, p < .003$ , but not between the bicycle and bear conditions,  $F(1, 58) < 1$ . In sum, unlike the bicycle and the bear, the human body appears to be categorized into three salient categories.

### Difficulty rating data

Difficulty rating data on the restricted sorts provided a second converging measure of category saliency. Lower ratings reflected more natural object divisions and part organizations. Except for the human body stimuli (40%), the majority of participants rated the 2-sort as being the easiest for the bear (69%) and for the bicycle (83%). Participants also ranked the free-sort and the 2-sort as being equally difficult for the bear, suggesting that the bear stimulus was optimally divided into two categories. Consistent with the two major clusters found in the MDS analyses for the bear and the bicycle, sorting times tended to be fastest for the 2-sort. Consistent with the categorization-time data and the MDS data, the 3-sort for the human body was rated as being the easiest (90%). This difficulty rating data supports the MDS data that the human body is optimally divided into three categories.

## GENERAL DISCUSSION

This study investigated potential differences in the cognitive organization of different classes of objects. It examined (1) whether all objects and their parts were organized similarly, (2) whether animate objects and their parts were organized differently from inanimate objects and their parts, or (3) whether the human body—by virtue of its unique ability to perform actions on objects and the environment—was organized differently from all other objects. To examine differences in the mental organization of different classes of objects—human bodies, animate objects, and inanimate objects, the relationships among the parts of three exemplar objects were examined: a human body, a bear, and a bicycle. Stimulus cards illustrated various part and part combinations of these objects. The stimuli were constructed so that similar sorting strategies could be used for all objects. Participants performed a series of sorting tasks in which they placed “parts that were similar into the same category.” Classification consistencies and differences across free-, 2-, 3-, and 4-pile sorts permitted an analysis of what groupings were essential (i.e., were consistent across sorts) and which groupings could be compromised (i.e., changed across sorts). The dissimilarity data were analysed using multidimensional scaling techniques. The present results indicated that all objects were not organized the same way and that categorization did not follow the animate–inanimate distinction. Instead, the human body was organized based on its ability to perform actions. Further, the factor that dif-

ferentiated sorting performance among the objects was the extent of functional experience people had with the particular objects.

Specifically, our results demonstrated that the human body was organized primarily by functional properties or by action-generating parts. Clusters that consistently emerged across the human body sorts included arms, legs, and head/torso. Divisions of the body along body quadrants or environmental axes were often compromised or varied across sorts. Overall, the human body data supported the functional action hypothesis more than the part significance hypothesis because legs and feet were categorized together, as were arms and hands. Participants' labels provided support for the functional significance of the categories, representing parts that perform specific actions. These labels also argued against organization based on visual contour discontinuity. The cortical representation hypothesis was not supported because hands were grouped with arms. The image size hypothesis was not supported because the smallest parts (hands and feet) were not grouped together. Also, the environmental axes hypothesis was not fully supported in that left and right arms and legs were distinguished but not when combined with other parts of the body. Further, upper and lower portions of the body were placed in different groups of parts across sorts. In sum, the results of the human body data were different from the living-nonliving semantic object representation conclusion that living objects were represented primarily by their visual characteristics (Farah & McClelland, 1991). Instead, it appears that the human body is a separate representation in which its parts are organized primarily by their capacity to perform functional actions.

The categorization strategies used for the bear were very different from those used for the human body. It appears that all animate objects do not share the same organizational scheme. Dimensions that consistently emerged across the bear sorts included head/front/upper, and back/lower. Divisions of the bear between the legs, lower portions, and abdomen varied across sorts. The labels for the various sorts of bear stimuli generally agreed with these dimensional interpretations. Thus, categorization strategies for the bear emphasized visual features such as environmental axes. Categories showed strong right-left distinctions separating the left side of the bear (i.e., head side) from the right side (i.e., rear side) as well as front-back distinctions separating the head from the rest of the body. In addition, parts from the bottom of the bear (i.e., abdominal side) were distinguished from the top of the bear (i.e., spine side). The image size hypothesis was not supported because the feet and other small parts were not included in the head category, nor was the contour discontinuity hypothesis supported because there were no visual cues for the abdominal-front versus spine-back distinction. Last, the functional action hypothesis that classified the categorization of the human body was not supported because action producing parts (e.g., head and legs) were never grouped together.



The bicycle was categorized using both functional and visual organizing schemes. Across the sorts, the bicycle was consistently organized by two major clusters: Parts a rider touches when riding a bicycle and visual environmental axes. The image size hypothesis was not supported because small propulsion parts were not grouped near tyre parts and the large frame was separate from other large combination parts. The contour discontinuity hypothesis was less supported because the tyres were not grouped with other separable parts (e.g., propulsion parts) and there were few visual breaks dividing upper, lower, front, and back portions of the bicycle. In contrast, support was found for the environmental axis hypothesis. Categories were defined by upper and lower portions of the bicycle, as well as defined by front and rear portions of the bicycle. In addition, the functional action hypothesis was supported in that action producing parts were consistently grouped together (e.g., propulsion parts or tyre parts).

Thus, for the bicycle, the living–nonliving distinction of nonliving objects being represented by their functions was upheld to some extent. However, *object* function was not the best classifier of bicycle parts. For example, tyres were not grouped with propulsion parts for a transportation dimension. Instead, human body function appeared to influence the classification of bicycle parts. Bicycle parts were organized by the way the human body interacts with the bicycle! Parts that a rider touches when riding a bicycle were distinguished from other parts.

Together, the present results provide evidence that the representations of body parts are organized differently from other animate or inanimate objects. The extensive and unique experience each of us has using our own bodies as we act upon our environment distinguishes the human body representation from other classes of objects. Thus, the mechanism underlying the human body's special status may be the degree to which we functionally interact with them, which in turn shapes our experience and mental organization. In other words, functional experience is used as an organizing principle for object representation. Empirical support for this expertise idea is provided by behavioural studies demonstrating expert or “configural” processing for the human body in untrained viewers (e.g., Reed, Stone, Bozova, & Tanaka, 2003).

Although human bodies may be “special” because of people's disproportionate functional experience with them relative to other objects, the present results suggest more than that. They indicate that the representations of objects *in general* may be governed by the way the human body interacts with them. Human experience with objects shapes the object representation. Most people have some experience riding a bicycle. As a result, the organization of bicycle parts was governed by the way people ride bicycles. In contrast, most people have little “hands on” interaction with bears and thus, the organization of bear parts was governed more by the specific visual characteristics of the bear stimulus. Such results are consistent with theories of embodiment that propose

that the human body and its actions influence representations from perceptual to higher level cognitive representations of objects and concepts (Barsalou, 2003).

One issue regarding the present study is the fact the different orientations of the stimulus objects may have influenced the categorization results. In this study, objects and their parts were illustrated from their canonical, or most common, view rather than from a shared facing orientation (i.e., all facing to the left). The use of canonical orientations of everyday objects provided four advantages: (1) Greatest object recognizability, (2) greatest part visibility, (3) greatest visual part familiarity, and (4) fewest mental processes required to reorient objects to their most familiar view. However, the use of canonical stimulus orientations introduced differences across the depicted views of the stimuli: The human body was viewed from the front, but the bicycle and the bear were viewed from the side. However, two findings suggest that orientation did not strongly influence the study's results. First, participants categorized object parts based on an internal object representation that was at least partially separate from the visually presented object illustration (e.g., riding a bicycle). Second, a follow-up experiment ( $n = 6$ ) was conducted to determine if object orientation made a difference in the cognitive categorization of the human body. The stimulus was a left side-standing portrayal of the human body to match the sideways orientation of the bear and bicycle. The body was depicted with the arms and legs spread in the picture plane to ensure body part visibility and the parts were divided in the same manner as the forward facing human body. The new sorting results were virtually identical for the left-facing human body stimuli as for the front-facing stimuli. The same three major clusters emerged: Arms/hands, legs/feet, and head/torso. As a result, differences between the human body and the bicycle and bear cannot be fully attributed to orientation differences across stimuli. Nonetheless, our study provides the basis for further research.

In conclusion, the human body representation appears to be "special". Although it shares many features with other types of objects such as the bear and the bicycle (e.g., an articulated visual hierarchical structure, a canonical orientation, and the capability to be manipulated to perform multiple functions), it appears to be represented differently from other objects. The cognitive categories for the human body displayed the tightest, most reliable clusters of all the objects (i.e., parts were perceived to be most similar to each other by most participants). Of interest is why human bodies may be represented differently relative to other objects in the human cognitive system. In addition to evolutionary (Wilson, 2002), behavioural (Reed & Farah, 1995; Reed et al., 2003), and neuropsychological (Buxbaum & Coslett, 2001; Ogden, 1985; Sirigu et al., 1991) arguments for separate body representations, another plausible rationale is that humans receive extensive experience performing functional actions with their own bodies and viewing other humans performing actions. The experience humans have using objects may be what

distinguishes the cognitive organization of various objects and their parts. Thus, the extent to which humans interact with *any* object shapes the mental representations of that object. This “embodied” object representation should lead to facilitated perception and action.

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