Object orientation and levels of identity

by

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Abstract

Naming latencies for objects rotated in the picture plane increase linearly as a function of object orientation for rotations up to 120^0. This systematic effect of orientation is commonly thought to reflect angular normalisation of the image to the upright via the shortest angular distance prior to identification. A pre-identification process of normalisation is logically circular because image orientation is defined by the identity of the object, making the selection of the direction of rotation identity-dependent. Upright picture-name match/mismatch tasks have shown that objects are initially identified at a basic categorical level, while subordinate identification is delayed by further visual processing of the image. A series of studies employing name-rotated picture match/mismatch decisions and rotated object naming are presented in which the level of object identification was manipulated. The latency and accuracy results suggest that basic level identification is orientation invariant, while subordinate identification requires normalisation. Initial invariant access to a basic level identity would provide the object's current and upright orientation, allowing for the selection of the direction of rotation required for subordinate identification. This result challenges several current theories of object recognition concerning when normalisation of orientation occurs during rotated object identification.

List of symbols and abbreviations

DPS	=	degrees per second
ms	=	milliseconds
ms/deg	=	milliseconds per degree
^{o}	=	degrees of rotation
MS_e	=	mean square error
pc	=	percent correct
rt	=	reaction time
SVGA	=	super video graphics array
LTVR	=	long term visual representation

Group labels for Experiments 1 and 2

SB	=	same basic identity
SS	=	same superordinate identity
DS	=	different superordinate identity

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The retinal image produced by an object may be radically different depending on the viewing conditions and physical relationship between the viewer and the object. Despite such arbitrary changes we continue to identify objects readily. This ability to identify objects regardless of these changes is referred to as "object constancy". The processing involved in producing object constancy has been of interest to psychologists for many years (e.g., Dearborn, 1899). If we are to understand the human visual processing system, we must be able to explain how we are able to achieve stable identification from unstable and coincidental viewing information.

At the point of identification, it is presumed that visual processing of a stimulus has contacted a long term representation of the object. Below is a simple schematic showing the sequence described above.

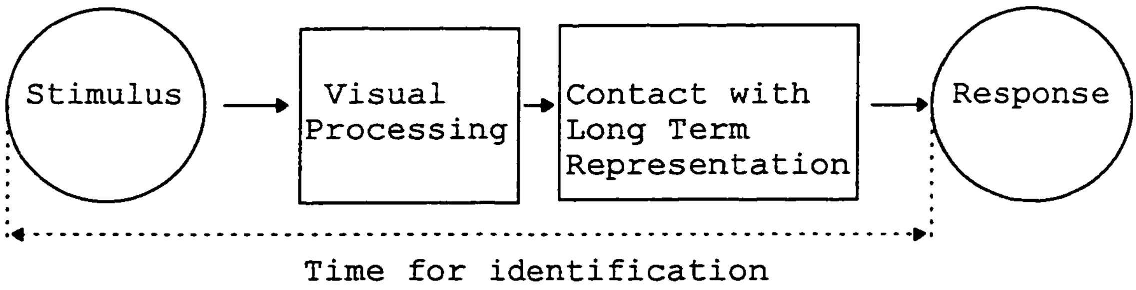

Figure 1: Simple schematic of processing sequence involved in object identification.

As illustrated in Figure 1 above, the time for identification is measured between stimulus onset and the initiation of the response. The nature of the visual processing involved, and the properties of the long term representation, can be inferred from measuring changes in identification time. Visual processing extracts information from the stimulus in order to map it on to an identifying representation. Manipulations which do not affect the processing time, are assumed to be of minor importance to the task of identification.

Canonical Views of objects:

Given the previous general schematic, as a stimulus more closely corresponds to the long term representation, less processing would be required to contact the identifying representation, resulting in shorter response latencies. When asked to identify an object, some views consistently produce faster response times than others (Palmer, Rosch, & Chase, 1981). The view which is commonly found to be recognised most quickly is referred to as the "canonical view" (Palmer et al., 1981). For many common objects, this canonical view is a roughly three-quarter frontal view of the object in its upright orientation (Palmer et al., 1981). When subjects are asked to rate the "goodness" of a view, the canonical view is also rated as the "best" depiction of the object.

The increase in identification time for noncanonical views is thought to reflect delays in the visual processing required to contact long-term identifying representations. One source of a delay in visual processing is the mental transformation process which aligns the visual information extracted from the stimulus with the long term representation. Mental transformation processes are conceptualised as analogue in nature (Bundesen & Larsen, 1975; Jolicoeur, 1985; 1990; Larsen, 1985; Shepard & Cooper, 1986; Shepard & Metzler, 1971), which implies that the increase in identification time will be a systematic function of the magnitude of the required transformation.

When subjects are asked to determine if two stimuli are the same shape, decision latencies are a function of the size ratio between the two stimuli (Bundesen & Larsen, 1975; Larsen, 1985) or a function of the difference in orientation (Larsen, 1985; Shepard & Metzler, 1971; Shepard & Cooper, 1986). These findings support the interpretation that in order to determine a response, one stimulus representation is mentally transformed in size (Bundesen & Larsen, 1975; Larsen, 1985) or in orientation (Larsen, 1985; Shepard & Metzler, 1971; Shepard & Cooper, 1986) to correspond with the second stimulus representation prior to determining a correspondence in shape. However, the time to determine if two stimuli are of the same shape does not necessarily reflect the time to determine if the two stimuli have the same identity (Posner, 1978) and so findings from studies employing the direct comparison of two presented shapes may not reflect the processing involved in object identification. If the long term representation is coded in such a way that it maintains an optimal size or orientation, then similar transformations would be required in order to align the stimulus with the long term representation. In other words, identification latencies of a single stimulus should also increase as a function of the magnitude of the required transformation.

For example, disparities in size ratios produce increases in decision latencies to determine if two shapes are identical (Bundesen & Larsen, 1975; Larsen, 1985; Corcoran & Besner, 1975 in Posner, 1978). However, stimulus size does not show an effect on the time to name an object (Biederman & Cooper, 1992; Fiser & Biederman, 1995; see block 1 data both studies; Corcoran & Besner, 1975 in Posner 1978). This difference in the effect of stimulus size reflects a change in processing required to perform the different tasks of comparison and identification. Comparison of one shape with another requires the comparison of two specific short-term representations which must be equated in size. In contrast object naming requires contact with a long-term representation which, based on the naming findings above, appears to be coded invariant of stimulus size.

Rotating objects in depth away from the canonical view produces a linear increase in naming latencies as an inverse function of its rated canonicalness (Palmer et al, 1981). This finding may be interpreted as reflecting a rotational transformation of the stimulus to correspond with the long-term representation stored in the canonical view.

An alternative explanation of these findings is that the canonical view is the view which displays the most salient information required for identification. Rotations in depth produce changes in the quality or quantity of information contained in the image (Palmer et al., 1981) by obscuring some features and by changing other potentially important information, such as foreshortening the major axis (Humphreys Riddoch, 1984; Marr, 1982; Ullman, 1989). As the magnitude of these changes in stimulus information is a function of the orientation in depth away from the canonical view, interpretation of the increase in naming latencies for depth rotations becomes difficult; does the increase represent a mental transformation in depth or a physical change in stimulus quality The second interpretation is supported in the finding that rotations in depth have not consistently shown effects of orientation on identification when features are not obscured (Biederman & Gerhardstein, 1993).

Unlike rotations in depth, rotations in the picture plane do not change the availability of information contained in the stimulus (Rock, 1973). If the long-term representation is stored such that it maintains the normal upright orientation, then the visual processing of a stimulus that precedes contact with this representation must correct for the angular difference in orientation. However, should the long term representation be coded independent of orientation, then changes in stimulus orientation should produce minimal effects on rotated object identification. This is because picture plane rotations would not change the availability of information due to misorientation (Rock, 1973).

How might orientation-invariant identification occur?

Marr (1982; Marr & Nishihara, 1978) suggested that orientation-invariant identification could be accomplished if the parts of objects are spatially coded in a co-ordinate system that is based on the object rather than the viewer. In such a scheme, when an object is misoriented relative to the viewer, the co-ordinate system is similarly misoriented, effectively producing no change in the identifying representation. Determination of an object's orientation and size is based on detection of a major axis, such as elongation or symmetry, which "defines the extent of the shape context of the model" (Marr & Nishihara, 1978). The construction of the object-centred co-ordinate system, the orientation of which is known based on the above, continues with the parsing of the object at the points of deep concavity of its contours. This parsing results in the object being described by parts, which themselves are described by a volumetric cylinder. The connection of the major axis of elongation or symmetry of these cylinders creates a wire-frame representation of the object and is the basis of Marr's object-centred co-ordinate system, which is termed an "object-centred frame of reference". This object-centred frame of reference is a "distributed co-ordinate system", in which details concerning the individual parts are calculated from the major axis of that part (Marr & Nishihara, 1978).

A similar method of achieving orientation invariance has been offered by Biederman (1987). Biederman suggests that objects are represented by the arrangement of a collection of simple geometric volumes ("geons") which include volumes other than Marr's cylinders. Similar to Marr (1982), geons are defined after segmentation of the object at points of deep concavity of its contours. These geons are themselves orientation-invariant (Biederman, 1987) and provided that the geons are not obscured from view, object identification will proceed uninhibited by misorientation of the object. Because picture plane rotations do not change the availability of geons across views, picture plane rotations should produce no change in the identification process.

Evidence that Object Identification requires Orientation Normalisation:

Jolicoeur (1985) demonstrated that the time to name misoriented line drawings depicting common objects increased linearly as a function of the orientation of the stimulus presentation. Jolicoeur's (1985) finding demonstrated a linear increase in naming latencies for images rotated up to 120° either clockwise or counter clockwise, a finding which has been replicated many times (e.g. Jolicoeur, 1988; Jolicoeur & Milliken, 1989; Maki, 1986; McMullen & Jolicoeur, 1992; McMullen, Hamm, & Jolicoeur, 1995; Murray, 1997). Naming latencies for inverted stimuli were faster than would be expected based on extrapolation of the 0° to 120° data.

One explanation for these effects of orientation on object identification is that rotation in the picture plane affects the assignment of the top and bottom of objects (Rock, 1973; Biederman, 1987). Under this explanation, effects of orientation reflect delays in determining the location of the top of objects (Rock, 1973) or arise due to a "perturbation of the 'top-of' relationship between the geons", (Biederman, 1987) as opposed to a mental transformation of the stimulus image. Support for this interpretation may be found when subjects are asked to determine if a dot is located near the top or bottom pole of a rotated object. This "top-bottom" task shows effects of orientation similar to object naming, including the reduced effect for rotations of 180^0 (McMullen & Jolicoeur, 1992). In conflict with this assignment-of-top explanation, pre-cueing the location of the top with or without the orientation of the top-bottom axis in no way reduced the effects of orientation on naming latencies of rotated stimuli (Gibson & Peterson, 1994; McMullen et al., 1995). The lack of a reduction in the effects of orientation after disambiguating the location of the top with a precue raises questions as to the validity of such an explanation.

Alternatively, Jolicoeur (1990) has suggested a dual-route model of rotated object identification. Jolicoeur (1985; 1990) suggested that the effects of orientation shown during object naming reflect a normalisation of orientation process employed in order to align the stimulus with a long-term identifying representation. This explanation suggests that, unlike stimulus size, long-term representations are coded in a manner which retains information pertaining to a preferred orientation. To explain why the effects of object orientation diminish when the same stimuli are repeated (Jolicoeur, 1990; McMullen & Jolicoeur 1990; 1992) a second, orientation-invariant feature-based route is described. As the subject becomes familiar with the stimuli through repeated presentations, the feature route produces orientation-invariant identification more quickly than the normalisation route reflected in the initial identification latencies. Hence effects of orientation on repeated naming of rotated stimuli are diminished. As an example, if the only object in the stimulus set which contains stripes is a zebra, upon detection of stripes a subject may identify the object as the zebra (Jolicoeur, 1990). Such an identification may only happen after having been exposed to the stimulus set at least once.

Since presentation of new objects restores large effects of orientation (McMullen & Jolicoeur, 1990; 1992), the reduction in the effects of orientation for repeated presentations is not due to a general improvement in the normalisation route.

Jolicoeur's (1990) dual route model expands upon Humphreys & Riddoch's (1984) suggestion that object identification may be achieved either by a wholistic or a feature-based analysis. Jolicoeur postulates that the wholistic identification route employs mental rotation as the orientation normalisation process which aligns the visual information with an upright representation of the object. Operating in parallel with this wholistic route is a feature-based identification system which identifies objects based on relatively orientation-invariant features. Effects of orientation shown during rotated object naming studies reflect the wholistic normalisation route between the orientations of 0^0 and 120^0. The "dip" found for rotations of 180^0 reflects influence of the feature-based identification route which may operate more quickly when the object's top-bottom axis is aligned vertically (Jolicoeur, 1990; however, see Murray, 1997 for an alternate explanation).

The feature-based route itself is not necessarily unaffected by rotations (Jolicoeur, 1990). If it were, one would expect a plateau in object naming latencies indicating the time to perform feature-based identification. However, as the time to name objects rotated 120^0 is longer than the time to name objects rotated 180^0 (Jolicoeur, 1985; 1990), feature-based identification must be faster for 180^0 rotations than for 120^0 rotations, presuming the faster identification times for 180^0 rotations than 120^0 rotations is reflective of feature based identification. Effects of orientation on the feature route, however, do not reflect normalisation but a change in feature quality arising planar rotations. Such changes in quality may include the decrease in the salience of a non-vertical axis of symmetry (Corballis & Roldan, 1975). However, the size of the effect of orientation on the feature route will be much smaller than that shown for the mental rotation, or normalisation route (Jolicoeur, 1990), as demonstrated by the reduction of the effect of orientation for repeated presentations where the feature-based route is thought to be more representative of the naming latencies. If the feature-based identification was equally affected by orientation, then no reduction in the magnitude of the effect would be shown. The possibility that feature extraction is sensitive to orientation is supported by the finding that effects of orientation are found under conditions of brief exposure and masking, which are thought to interfere with the normalisation route and thereby force identification to be based solely on feature analysis (Jolicoeur, 1990).

In contrast to feature identification explaining the reduction in the effects of orientation over multiple presentations, Tarr & Pinker (1989; 1990) have proposed that the reduction is due to the formation and use of orientation-specific templates. Formation of an orientation-specific template during the first presentation of objects reduces the angular disparity between a subsequent rotation of the stimulus and the nearest template, which would account for the reduced effects of orientation on the second viewing. Tarr & Pinker (1989; 1990) trained subjects to identify novel asymmetrical letter-like characters by associating each with a key board response. During training, subjects were presented with the objects at three orientations. Upon completion of the training phase, subjects were presented with the objects in new orientations. Tarr & Pinker (1989; 1990) found that the time to identify the objects in the new orientations was a function of the angular distance to the nearest template presumed to have formed during training. However, the extent to which the effects of orientation diminish with repeated presentations has been shown not to be related to the previously seen rotated views when using line drawings of common objects (Murray, Jolicoeur, McMullen, & Ingleton, 1993). Murray et al.'s (1993) finding suggests that multiple template formation does not occur with familiar objects. McMullen (1995) examined the conditions under which template formation may occur and showed that Tarr & Pinker's finding may be limited to highly visually similar objects.

The departure from linearity when naming objects at 180^0 of rotation has been explored by Murray (1997) and may reflect individual differences in strategies. In naming inverted objects, subjects may rotate the object in the picture-plane or flip the object out of the plane to the upright. Flipping appears to be faster than rotating (Murray, 1997). The resulting identification time for 180^0 rotations will depend on the proportions of "flippers" and "spinners" in the experiment.

Examination of the effects of object orientation for rotations between 0^0 and 120^0 has failed to show any difference in magnitude between object naming latencies and left/right discrimination[1] latencies (McMullen & Jolicoeur, 1992). Left/right discriminations are thought to require mental rotation. Furthermore, there was a correlation between subjects' rate of rotation for naming and rate of rotation for left/right discriminations suggesting the two tasks were mediated by the same underlying process (McMullen & Jolicoeur, 1992). These findings are consistent with the notion that the underlying process which performs the normalisation of orientation during object naming is mental rotation (Jolicoeur, 1985; 1990).

Unlike the normalisation theories of Jolicoeur (1985; 1990), Humphreys and Riddoch (1984), and Tarr and Pinker

[1] Left/right discriminations require subjects to indicate if a rotated object would be facing to the left or the right should they be rotated to the upright.

(1989; 1990), Corballis (1988) argues that normalisation of orientation prior to object identification is logically untenable as object orientation and the canonical upright are both determined by the identity of the object. Given the symmetrical nature of the naming latency function about 180^0 of rotation, normalisation must proceed through the shortest angular distance to the upright . Without some level of identification, determination of the shortest angular distance can not be achieved. Corballis therefore suggests that some level of identification must occur independent of orientation. If object identification is orientation-invariant (Marr, 1982; Biederman, 1987; Corballis, 1988), why do naming latencies for objects show an effect of orientation which suggest the use of mental rotation or some other normalisation procedure (Jolicoeur, 1985; 1990) In order to explain the effects of orientation shown during rotated object naming, Corballis (1988) suggests that normalisation may be employed in order to verify the obtained orientation-invariant identity.

However, the necessity of having some identity information prior to normalisation is arguable. Ullman (1989) suggests that normalisation prior to identification could be achieved after localising three non-colinear points

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[2] A horse race between simultaneous clockwise and counterclockwise normalization would produce these results. Such an explanation is dismissed as implausible in the literature (Jolicoeur, 1990) although, to my knowledge, this explanation has not been directly tested.

or a major axis and one other point off this axis. Major axes, such as elongation or symmetry, have been implicated as being important in object identification (Humphreys & Riddoch, 1984; Marr, 1982; Marr & Nishihara, 1978; Ullman, 1989). Furthermore, the detection of an axis of symmetry is impaired as the axis is rotated away from the vertical (Corballis & Roldan, 1975). If the axis of symmetry is critical in object identification (Marr, 1982), then effects of stimulus orientation on object naming latencies may in part reflect an impairment in locating this critical information. However, the effects of orientation are not affected by the presence or lack of either an axis of elongation or vertical symmetry (Hamm & McMullen, 1995). Note that, when a vertically symmetric object is rotated 60^0 or 240^0, the axis of symmetry lies along the same non-vertical orientation. Detection of the axis of symmetry should therefore be equally impaired for rotations of 60^0 and 120^0 (Corballis & Roldan, 1975; note that 240^0 of rotation is equivalent to 120^0 of rotation in the opposite direction) resulting in a deviation from linearity in the naming of vertically symmetric objects rotated between 0^0 and 120^0. However, the effects of orientation on naming vertically symmetric objects are linear between 0^0 and 120^0 (Hamm & McMullen, 1995), suggesting there is little influence of the effect of orientation shown for object naming arising from the detection of an axis symmetry.

In summary, some theories of rotated object identification postulate a normalisation process prior to a stimulus image accessing a long-term representation (e.g., Jolicoeur, 1990; Tarr & Pinker, 1989; 1990) while others postulate that initial object identification is based on orientation-invariant processes (Biederman, 1987; Corballis, 1988; Marr, 1982) and that a normalisation process is employed after this initial identification. What might be this initial level of orientation-invariant identification?

Levels of object Identification:

So far we have talked only of contacting a long term representation in order to identify an object without concern for the level of specificity of identification. When presented with a picture of a collie, what response must be given to consider this object identified? To indicate that a collie is an animal, a dog, or a collie are all correct and suggest that the stimulus has contacted a long term identifying representation. Rosch, Mervis, Gray, Johnson, & Boyes-Braem (1976) examined the time to identify objects at three levels of specificity. These three levels are referred to as the superordinate, basic, and subordinate. In reference to the collie, the corresponding names are animal, dog, and collie for superordinate, basic, and subordinate, respectively. Potentially, each of these levels of identification may arise from contacting the same long term representation or through contact with different representations.

Rosch et al. (1976) concluded that the first level at which an object is identified corresponds to the basic level. Both superordinate and subordinate identification occurs after access to the basic level identity. Rosch et al (1976) speculated that superordinate identification was based on movement within the semantic system and required no further visual processing while subordinate identification was based on further visual processing of the object. This interpretation suggests that there may be two long term identifying representations, one coding for basic level identification and one, possibly built on the first, which provides subordinate level identification. As superordinate identification is thought to be based on semantic knowledge, there is no need to postulate a visual identifying representation for this level of identification.

Jolicoeur, Gluck, Kosslyn (1984) tested this explanation of Rosch et al. (1976) using an upright picture - word match/mismatch task. Subjects were presented with an object and after a one second delay were presented with a word at one of the three levels of identification and were to respond true or false depending upon the appropriateness of the label in regards to the picture. Support for Rosch et al.'s (1976) explanation was found when it was shown that brief exposure affected only subordinate decisions and not superordinate or basic decisions. Jolicoeur et al. (1984) concluded that object's are first identified at the basic level, semantic processing is required for superordinate identification, and further visual processing is required for subordinate identification. This model is shown schematically below:

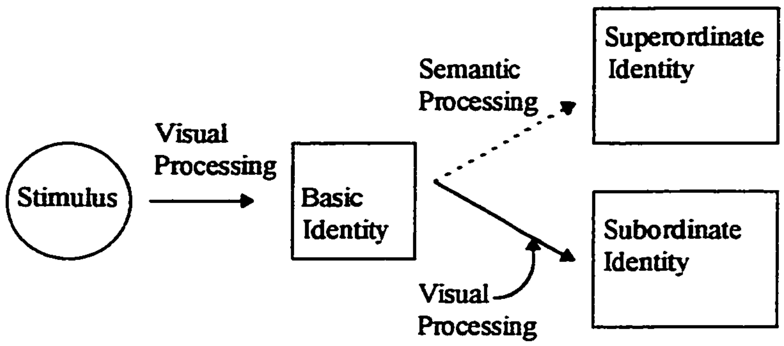


Figure 2: Graphic representation of processing involved in identifying objects at the basic, subordinate, and superordinate levels.

Rosch et al. (1976) noted that members of the same basic identity had a large overlap in physical attributes while objects which shared only superordinate identity had few common attributes. Subjects did not list significantly more physical attributes for subordinate identities than for basic identities. This suggests that the additional visual processing required for subordinate identification may be fine tuning the visual analysis rather than detecting further physical attributes (Marr & Nishihara, 1978).

This commonality in physical appearance for objects sharing basic level identity does not hold for all members. Atypical objects of a given basic level identity will tend to share fewer attributes than the more typical members. Jolicoeur et al. (1984) demonstrated that atypical exemplars are identified more quickly at the subordinate level than at the basic level. They concluded that atypical exemplars are first identified at the subordinate level, with basic identity being retrieved semantically. Jolicoeur et al. (1984) suggest that typical exemplars of a basic category will be identified initially at the basic level while atypical exemplars will initially be identified at the subordinate level.

Further modifications to the assumption that initial identification corresponds to the basic level were provided by Tanaka & Taylor (1991). Tanaka & Taylor asked dog and bird experts to name pictures and make word-picture match/mismatch judgements where some of the stimuli depicted objects corresponding to the subjects' area of expertise. Their findings suggested that experts tend to use subordinate names for items in their area of expertise and are able to identify these objects at the subordinate level as quickly as at the basic level. Furthermore, experts listed more attributes than novices for objects at the subordinate level when dealing with objects of their expertise. Experts' increased knowledge of the subordinate exemplars provides them with more differentiating features among members of the category in which they are expert.

Tanaka & Taylor suggest that the level of identification which is first accessed depends on the ability to differentiate an object from others. Novices differentiate objects at the basic level, while experts are able to more easily differentiate at the subordinate level. This explanation may be rephrased as objects are identified at the basic level, but what constitutes the basic level for an expert corresponds to the subordinate level for novices. The ease of differentiation may also explain the typicality finding of Jolicoeur et al. (1984), because atypical exemplars share fewer attributes with the more typical members of a basic category.

In conjunction, the findings of Jolicoeur et al. (1984) and Tanaka & Taylor (1991) suggest that the level at which an object is initially identified may depend on how well it represents its basic category for the subject.

Implications of the level of identity on rotated object identification:

Jolicoeur (1985) demonstrated that the time to name objects increased linearly as a function of the orientation of the stimulus. The magnitude of the effect of orientation was similar to the effect of orientation shown during a mental rotation task (McMullen & Jolicoeur, 1990). Given the similarity of the effect size, Jolicoeur has suggested that prior to the identification of a visual stimulus, the stimulus is rotated to the upright orientation in order to access a long-term representation. The process which is employed to accomplish this orientation normalisation is suggested to be mental rotation (Jolicoeur, 1985; 1990).

However, if some level of identification occurs that is independent of orientation as suggested by Corballis (1988), to what extent has the object been identified? Rosch et al. (1976) introduced the concept of the basic level of identity and concluded that an object was initially identified at the basic level (i.e., dog) and further processing was required to access a superordinate level of identity (i.e., animal) or the subordinate level of identity (i.e., collie). The additional processing required was speculated to be purely semantic in the case of superordinate identification, while further visual processing of the image was required in subordinate identification. This speculation was tested and supported by Jolicoeur et al. (1984).

If initial identification of rotated objects is independent of orientation, then it follows that this initial level of identification should be the basic level, at least for typical exemplars (Jolicoeur et al., 1984) and non-expert subjects (Tanaka Taylor, 1991). Stimuli employed in many of the object naming studies (McMullen et al, 1995; Jolicoeur, 1985; McMullen Jolicoeur, 1990; 1992; Murray, 1997) have been selected from the Snodgrass Vanderwart (1980) corpus. The Snodgrass Vanderwart (1980) stimulus set contains many different exemplars of the basic category bird, and some level of subordinate identification must be required to differentiate the shirt, blouse, sweater, and jacket. It is therefore suggested that many of the stimuli named in studies employing these items are identified at the subordinate level. The object naming studies may be reflecting effects of orientation required only in the subordinate identification of these stimuli. Subjects are normally given instructions that emphasise both speed and accuracy of response (e.g., Murray, 1997). It is possible that the emphasis on accuracy may encourage the subjects to be specific in their naming response and identify the objects at a subordinate level. Examination of the responses given to stimuli during a free naming study included many names which could be considered the subordinate level (e.g., Polar Bear, Bumblebee, Sparrow; McMullen, 1988). In fact, Jolicoeur (1985; Experiment 1) explicitly instructed subjects to produce as specific a name as possible.

If some level of object identification precedes a normalisation process, then for typical exemplars (Jolicoeur et al., 1984) and non-expert subjects (Tanaka Taylor, 1991), this level of identification should correspond to the basic level (Rosch et al, 1976; Jolicoeur et al, 1984).

The research reported in this thesis is designed to examine the possibility that basic level identification may be achieved via orientation-invariant recognition while subordinate identification may require orientation normalisation. Should the effects of orientation on object identification originate prior to identification, then all levels of identity (basic, superordinate, and subordinate) should show effects of orientation of similar magnitudes. However, if the basic level is accessed independently of orientation, then basic level identification should show minimal effects of object orientation. Similarly, superordinate identification should also show minimal effects of object orientation as this level of identification appears to be based on semantic processing rather than on visual processing (Rosch et al., 1976;

Jolicoeur et al., 1984). In contrast, subordinate identification may require the use of a normalisation process which is guided through the shortest angular distance to the upright by the basic level identification.

Methodological Issues

Throughout the experiments presented in this thesis I am concerned with the processing which maps a stimulus to a long-term identifying representation. Object identification in this thesis is concerned with the ability to make a decision about the identity of a single object and not a visual shape comparison between two simultaneous objects. A stimulus will be considered identified if subjects are able to make a response which requires knowledge of the object's name. Name-based responses may take the form of verbally producing the name of the object (e.g., Jolicoeur, 1985; 1990; McMullen et al., 1995; Murray, 1997), making simple same/different judgements between a word and an object (Rosch et al., 1976; Jolicoeur et al., 1984), or depressing a key corresponding to the identity of the object (Tarr & Pinker, 1989; 1990).

The comparison of simultaneously presented objects may include processing which does not reflect contact with long-term identifying representations (Posner, 1978). For example, size differences between two stimuli may produce latencies which are proportional to the size ratio of the stimuli (Bundesen & Larsen, 1975; Larsen, 1985; Corcoran & Besner, 1975 in Posner, 1978). This effect of size-ratio on the decision latencies reflects the processing necessary to compare one stimulus with another specific instance of a stimulus rather than accessing a long-term identifying representation. If the long term identifying representation was coded to include some optimal size, then one would expect an effect of stimulus size on object identification. Contrary to this prediction, the size of a stimulus shows very little effect in terms of identification time as measured by naming latencies (Biederman & Cooper, 1992; Fiser & Biederman, 1995; see block 1 data both studies; Corcoran & Besner, 1975 in Posner, 1978).

A similar argument can be made for rotations in the picture plane. Determining if a letter is normal or mirror-reversed shows large effects of orientation (e.g., Cooper & Shepard, 1973) whereas letter identification often shows no effect of orientation (Corballis, Macadie, Crottie, & Beale, 1985; Corballis & Nagourney, 1978; Corballis, Zbrodoff, Shetzer, & Butler, 1978; Eley, 1982; Koriat & Norman, 1989; Young, Palef, & Logan, 1980; White, 1980). We must therefore be careful to note differences in methodology between studies which employ evaluation of object shapes with those that employ identification of an object (Posner, 1978).

A further concern lies in the difference between identifying an object as an item previously seen, as in a recognition memory task (e.g., Dearborn, 1899) and identifying an item through contact with a long-term representation. In order to determine that an object is the same object as that previously viewed, the second instance must be compared to a specific representation of the earlier version and not to a long term identifying representation. Rock & Heimer (1957) demonstrated that when the second instance was rotated, identification accuracy decreased, suggesting identification was more difficult. In contrast, when subjects are asked to identify the same items repeatedly, effects of orientation diminish (McMullen & Jolicoeur, 1990; 1992) suggesting identification is easier the second time. Furthermore, the amount of reduction in the effects of orientation for the second viewing is unrelated to the previously seen view (Murray et al., 1993). These apparently conflicting results arise from the fact that the memory task requires contact with a specific representation of the previous view, while the naming task requires contact with a long-term general representation.

The majority of the experiments presented in this thesis employ a word-picture match/mismatch task. Subjects will be presented with a name of an object at one of the previously discussed levels of identification, followed by the presentation of a rotated stimulus. The first benefit of this task is that it requires the subject only to identify the object to the level specified by the verbal label in order to determine a match. Second, the mismatch condition can be manipulated in that mismatch objects may mismatch with the name at various levels of identity, (e.g., share superordinate and basic identity with the verbal label and mismatch only at the subordinate).

A similar match/mismatch task was employed by Jolicoeur et al. (1984) in the investigation of the levels of object identification. However, they presented an upright object followed by a name whereas in the present program of research the name was presented prior to the object. To present the object prior to the name would allow for object processing to reach completion prior to the presentation of the verbal label. As such, any effects of orientation on object identification would not be shown.

The match/mismatch task has benefits over an object naming task. As mentioned previously, the match/mismatch tasks allows for manipulation of the level of identification at which a mismatch judgement may be determined. Furthermore, by presentation of the name, any variance in response production due to word familiarity or other such linguistic effects should be minimized. Finally, in a rotated object naming task, the experimenter does not have as fine a control over the level to which a subject identifies the stimuli.

In order to explore object identification at the superordinate, basic, and subordinate levels, I have gathered a new set of objects. A complete description of this set including the exemplars and their basic level typicality ratings may be found in Appendix A.

In order to compare the findings from the experiments in this thesis and those of the literature, I shall compare the magnitude of the effect of orientation on the identification times. Rotated object naming studies have shown a range of values between 2.5 ms/deg (Jolicoeur, 1985 Experiment 1) and 0.71 ms/deg (Murray, 1995; upright naming group). Throughout this thesis, I shall employ this range of effect sizes as being typical of object naming results.

Finally, analysis of the data for all experiments presented in this thesis are of a common nature. Issues concerning the standard analysis are described in detail in Appendix B.

Summary of General Introduction

The current thesis examines effects of orientation on the time to identify an object. Theories concerning object identification which contain an orientation transformation process prior to identification have been postulated (Jolicoeur, 1990; Tarr and Pinker, 1989) as have theories which predict orientation invariance (Marr, 1982; Corballis, 1988; Biederman, 1987).

Although the time to name rotated objects increases linearly between 0^0 and 120^0, which suggests a mental normalisation to the upright occurs prior to identification of the object (Jolicoeur, 1985; 1990; Tar & Pinker, 1989; 1990), it has been suggested that some level of identification must be obtained in order to guide the normalisation process through the shortest angular distance (Corballis, 1988). Naming studies of rotated objects have allowed subjects freely to identify the objects without regard to the level at which these objects are identified. Examination of acceptable responses suggest that many of the objects are identified at the subordinate level (see Jolicoeur, 1985 Appendix A). Because objects are thought to be identified initially at the basic level, previous findings from naming studies may often reflect subordinate identification and not initial basic level identification. If some level of identification may be obtained independent of orientation, then it is presumed this identification will correspond to the basic level. Furthermore, if the naming studies are reflecting subordinate level identification, then it is predicted that similar effects of orientation will be shown for identification of the same stimuli when determination of the correct response requires access to the subordinate identity.

Experiment 1

Introduction

We have identified three levels of object identification which differ in the amount and type of processing. These three levels are referred to as the superordinate, basic, and subordinate (Rosch et al., 1976; Jolicoeur et al., 1984). Basic level identification is thought to be the initial level at which an object is identified (Rosch et al., 1976) provided the object is not an atypical exemplar (Jolicoeur et al., 1984) nor an object from the subject's area of expertise (Tanaka Taylor, 1991). Superordinate identification is based on semantic knowledge derived from the basic level identity (Rosch et al, 1976; Jolicoeur et al., 1984) while subordinate identification requires additional visual processing of the image beyond that of either the basic or the superordinate.

Experiment 1 is designed to determine if the match/mismatch task can be used to examine effects of orientation on object identification. The corpus of objects from Snodgrass Vanderwart (1980) that have been employed in many naming studies may encourage subordinate identification and not basic level identification. Therefore, if the effects of orientation shown during object naming are reflective of subordinate level identification, we would expect a subordinate level match/mismatch task to show effects of object orientation of a similar magnitude to those shown during rotated object naming.

Jolicoeur (1985; 1990) has suggested that prior to any identification, rotated objects are normalised to the upright canonical view. It follows from this model that normalisation of the stimulus must be completed in order to determine a match between the name and stimulus regardless of the level of the name. Furthermore, in order to determine a mismatch, effects of orientation similar to the match trials will be shown regardless of the correspondence between the name and the presented stimuli.

Contrary to this view of a pre-identification locus of the effects of orientation, Corballis (1988) has argued that some level of object identification must occur prior to any normalisation procedure on the grounds that the symmetrical nature of the naming latency effects about 180^0 indicates the stimulus' orientation and canonical upright have been determined prior to normalisation which allows normalisation to proceed through the shortest angular distance to the upright. As the current stimulus and the upright orientations are defined by the identity of the object, any effects of orientation during object identification must reflect some level of post-identification processing (Corballis, 1988).

Basic level identification is the initial level at which an object is identified. Based on Corballis' argument that effects of orientation are post-(basic level) identification, subordinate match decisions may show large effects of orientation which arise after orientation-invariant identification at the basic level. However, mismatch responses which can be made at a basic level should reflect this orientation-invariant recognition. When mismatch decisions require identification at the subordinate level to distinguish between members of the same basic identity, visual processing beyond the initial basic level identification occurs (Jolicoeur et al., 1984), and effects of orientation will be shown for mismatch judgements.

In order to examine the different predictions which arise from Corballis' (1988) post-identification locus and Jolicoeur's (1990) pre-identification locus for the effects of orientation, subjects were asked to make match/mismatch judgements at the subordinate level. Both Jolicoeur (1990) and Corballis (1988) predict effects of orientation during subordinate match decisions and for mismatch decisions where the name and object share basic level identity. However, Jolicoeur (1990) predicts that mismatch judgements where the name and object do not share basic level identity will continue to show effects of orientation whereas Corballis (1988) predicts these mismatch judgements will reflect orientation-invariant identification at the basic level.

Methods

Subjects:

Eighty subjects between the ages of 17 and 27 voluntarily participated or received 1 credit point towards an introductory psychology course. Eight subjects failed to meet a performance criterion of 60% accuracy in every cell of the design with an overall performance of 70% correct and so were not included in the analysis. The statistics and data presented are based on the remaining 72 subjects (36 male and 36 female). These subjects were equally divided into three groups of 24 subjects (12 males and 12 females per group). No subject performed in any other experiment reported in this thesis.

<u>Apparatus</u>:

The 72 stimuli were black line drawings on a white background as discussed in Appendix A. The average visual angle was between 6 and 7 degrees. Stimuli were presented in the centre of a 15" flat-screen monitor controlled by a 386-33 IBM clone containing a math co-processor. The software which controlled stimulus presentation and data collection was written by the experimenter. Millisecond timing routines were adapted from Crosbie (1989) and the keyboard was monitored as recommended by Brysbaert (1990) in order to obtain millisecond accuracy. Millisecond timing and stimulus onset were synchronised with the video refresh (Heathcote, 1988).

<u>Design</u>:

The 72 stimuli were divided into 36 match and 36 mismatch trials. A match trial consisted of the presentation of the subordinate name of the subsequent object (i.e., the word "Collie" followed by the presentation of a picture of a "Collie"). There were an equal number of match and mismatch trials selected from each of six basic categories. Each object was shown as a match trial twice (once for males and once for females) at each of the six orientations (0^0, 60^0, 120^0, 180^0, 240^0, 300^0) for each group of subjects. The direction of facing when upright (left or right) was reversed over the two match presentations.

The remaining objects were similarly presented twice for mismatch trials. However, the nature of the relationship of the subordinate name to the object was dependant on the experimental group. Group "SB" (Same basic) received mismatch names which described an object from the same basic category as the stimulus (i.e., Word "Irish Setter" followed by a picture of a "Collie", so both are "dogs"). Group "SS" (Same Superordinate) received mismatch names which differed in basic category but shared superordinate categorical membership with the object (i.e., Word "Termite" followed by a picture of a "Collie", a "dog" and a "bug" but both are "animals"). Group "DS" (Different Superordinate) received mismatch names which differed both at the basic and superordinate categorical levels (i.e., Word "Raft" followed by a picture of a "Collie", a "dog" and a "boat" or a "vehicle" and an "animal"). For all groups, mismatch labels were at the subordinate level, and were members of the six basic categories tested (namely "Bird", "Dog", "Bug", "Car", "Boat", and "Aircraft"), but were not names of objects actually used as stimuli. Across subjects, all objects were shown equally often as match and mismatch trials.

For a given subject, the trials were presented in a random order with the constraint that no more than four trials in a row were of the same response or depicted objects at the same orientation.

Procedure:

Before running the experiment, subjects were informed of the six categories of objects that would be presented ("bird", "dog", "bug", "car", "boat", and "aircraft").

A trial began with the presentation of the verbal label in all black capital letters on a white background and centred on the computer monitor. The label remained visible for 1500 ms, and was subsequently replaced by a blank white screen. The blank screen remained for 500 ms, at which point a stimulus was presented in one of the six orientations. Subjects were to depress the "1" key on the number pad of the keyboard if the stimulus matched with the prior verbal label, and to press the "2" key if the stimulus did not match. Subjects were instructed to respond as quickly as they could without making errors. Millisecond timing and stimulus presentation were linked to the beginning of the rastor scan of the monitor (Heathcote, 1988). To ensure accurate timing of responses made on the computer keyboard, the program monitored keypresses as recommended by Brysbaert (1990). A trial terminated with the removal of the stimulus upon the detection of a response or after 4000 ms had elapsed from stimulus presentation. The next trial began after a 2000 ms delay.

Results

Name matching latencies at the subordinate level

Mean correct response times were calculated after excluding outlier latencies. To avoid the sample size bias often introduced by outlier rejection procedures, a recursive check with a sliding criterion as recommended by Van Selst and Jolicoeur (1994) was applied. This resulted in rejection of less than 1% of the total correct responses. Figure 3 shows the effects of orientation and response type for each of the three subject groups. (Note that the results shown for 0^0 and 360^0 throughout the article are the same data and are displayed in this way to help judge the degree of symmetry around 180^0. However the analyses only considered the 0^0 data.)

Separate analysis of variances (ANOVA) were performed on data from each group with Orientation (6) and Response (2) as within-subject variables.

Group "SB": (mismatched objects shared basic category with subordinate names)

Response Time: Figure 3a shows the mean correct latencies for each orientation and response type from Group "SB" subjects. As with object naming, orientation affected response time, $F(5,115) = 2.6$, $MS_e = 32158$, $p < 0.05$, showing a linear trend between 0^0 and 180^0 to this effect, $F(1,115) =$

10.7, $p < 0.01$; ms/deg = 0.68 and 0.52 for match and mismatch, respectively. The linear trend remained when responses to objects rotated 180^0 were excluded, $F(1,115) = 10.8$, $p < 0.01$; ms/deg = 0.81 and 0.89 for match and mismatch responses respectively. Match responses (mean = 865.2 ms) were faster than mismatch responses (mean = 943.8 ms), $F(1,23) = 10.2$, $MS_e = 43465$, $p < 0.01$. Orientation did not interact with response ($F(5,115) < 1.0$; $MS_e = 22584$), and furthermore, none of the interaction contrasts reached significance (all $F(1,115) < 1.0$).

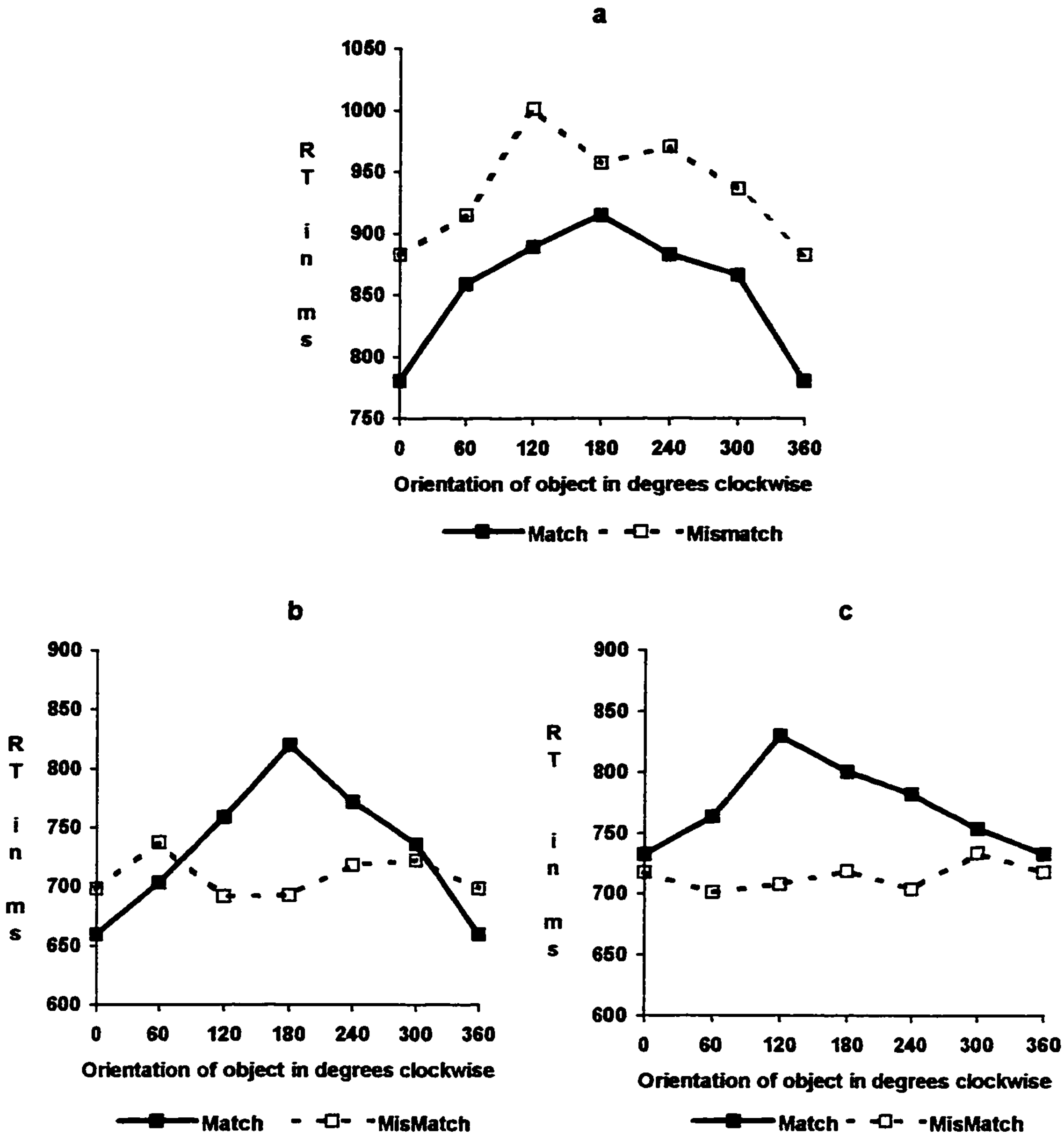


Figure 3: Effects of object orientation on latency to make subordinate level match/mismatch judgements with mismatch word-object relationship a) sharing basic level identity; b) sharing superordinate level identity only; and c) sharing neither superordinate nor basic level identity.

The rates of normalisation between 0^0 and 120^0 shown during this task are within the range of rates cited for rotated object naming (0.71 - 2.50 ms/deg). This range has been calculated from data between 0^0 and 120^0 presented in published studies of rotated object naming.

Percent Correct: The accuracy data may be seen in Figure 4a. None of the main effects, interactions, or contrasts of interest reached significance.

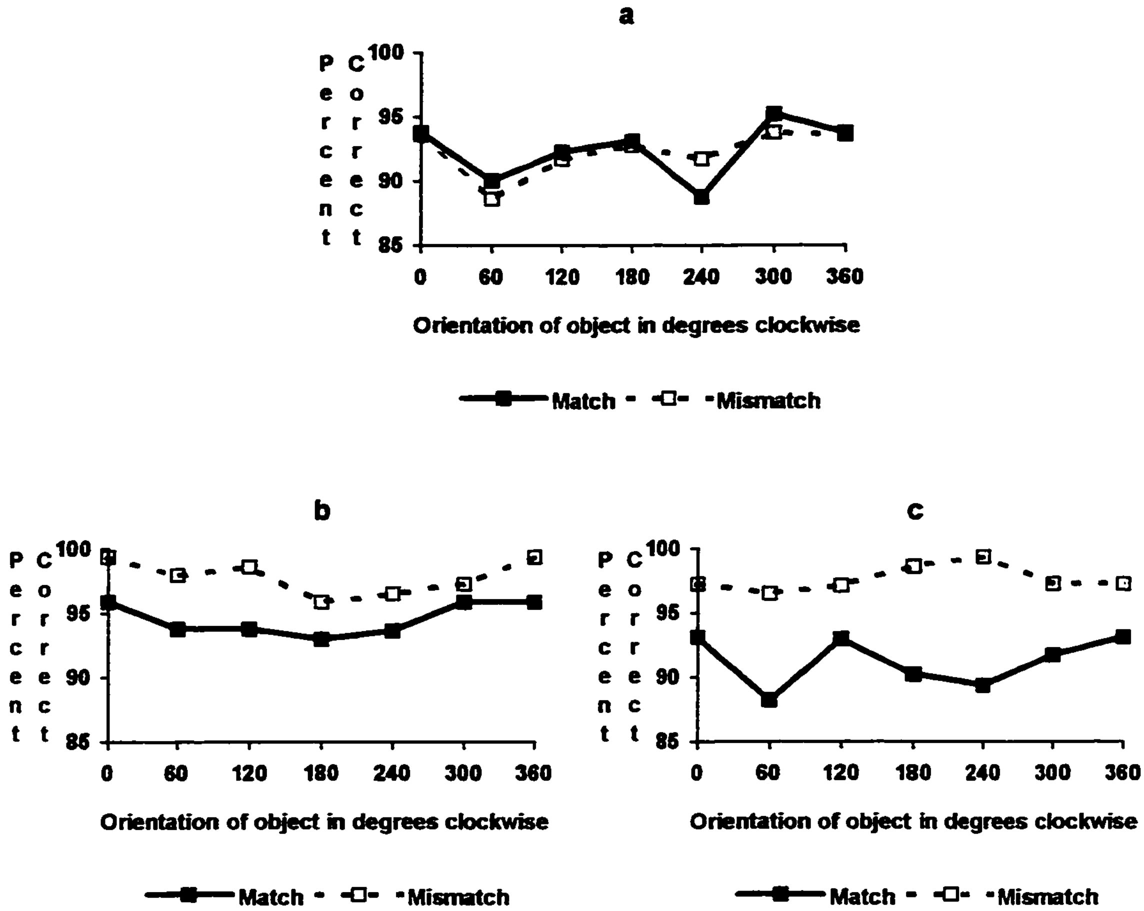


Figure 4: Effects of object orientation on accuracy of subordinate level match/mismatch judgements with mismatch word-object relationship a) sharing basic level identity; b) sharing superordinate level identity only; and c) sharing neither superordinate nor basic level identity.

Group "SS": (mismatched objects differed at the basic level but shared superordinate category with subordinate names)

Response Time: Figure 3b shows the mean correct latencies for each orientation and response type, from Group "SS" subjects. Effects of orientation were found, $F(5,115)$ =

2.8, $MS_e = 11855$, $p < 0.02$, showing a linear trend between 0^0 and 180^0, $F(1,115) = 11.7$, $p < 0.001$, which was again robust when responses to objects rotated 180^0 were excluded, $F(1,115) = 8.4$, $p < 0.01$. In contrast to Group "SB", match responses (mean = 741.4 ms) were slower than mismatch responses (mean = 709.8 ms), $F(1,23)=5.3$, $MS_e = 13630$, $p < 0.05$, and this effect interacted with orientation, $F(5,115) = 3.5$, $MS_e = 13835$, $p < 0.01$. The linear trend analysis confirmed that effects of orientation were larger for match than mismatch responses, $F(1,115) = 16.0$, $p < 0.001$; ms/deg = 0.86 and -0.10 respectively. This interaction was maintained when responses to objects rotated 180^0 were excluded, $F(1,115) = 5.6$, $p < 0.02$; ms/deg = 0.86 and -0.01 match and mismatch responses, respectively. This lack of an effect of orientation on the mismatch responses explains why match responses were slower than mismatch responses.

<u>Percent Correct</u>: The accuracy data may be seen in Figure 4b. Mismatch responses (mean = 97.6%) were more accurate than match responses (mean = 94.3%; $F(1,23) = 9.11$, $p < 0.01$). No other effects reached significance.

<u>Group "DS": (mismatched objects differed at superordinate level from subordinate names)</u>

<u>Response Time</u>: Figure 3c shows the mean correct latency for each orientation and response type, from Group "DS"

subjects. Effects of orientation did not reach significance, $F(5,115) < 1.0$, $MS_e = 14651$. Match responses (mean = 776.4 ms) were slower than mismatch responses (mean = 713.5 ms), $F(1,23) = 9.0$, $MS_e = 31812$, $p < 0.01$, and this effect did not interact with orientation, $F(5,115) = 1.3$, $MS_e = 15089$. However, contrast analyses showed a marginal interaction in the linear trends between 0^0 and 180^0, $F(1,115) = 3.6$, $p = 0.06$, in the direction of a larger effect of orientation for match (ms/deg = 0.45) than mismatch (ms/deg = -0.03) trials. Analysis of this linear trend, excluding responses to objects rotated 180^0, confirmed this interaction at the conventional level of significance, $F(1,115) = 3.8$, $p = 0.05$. However, it remains marginal at the Modified Bonferoni (Keppel, 1982) criterion with $p > 0.04$ explained in Appendix B (ms/deg = 0.63 and -0.12 for match and mismatch respectively). Keppel (1982) suggests that in such cases judgement should be suspended in order to avoid making either a type I or type II error.

Percent Correct: Accuracy data may be seen in Figure 4c. Mismatch responses (mean = 97.7%) were more accurate than match responses (mean = 90.9%; $F(1,23) = 25.02$, $p < 0.01$). No other effects reached significance.

Between-groups analysis of Match and Mismatch

In order to further investigate these findings, the match and mismatch response times were analysed separately in a mixed design analysis of variance, with orientation (6) as the within-subjects factor and group (3) as the between-subjects factor.

Contrasts analysing the group factor compared Groups "SS" and "DS" directly, and then collapsed these together to compare with group "SB". This pairing was chosen because both groups "SS" and "DS" contained mismatch items from a different basic category than the name, while "SB" contained mismatch items from the same basic category as the name. Based on the findings of Rosch et al. (1976) and Jolicoeur et al. (1984), no difference between groups "SS" and "DS" is expected.

Match Responses

The purpose of this analysis was to examine if the nature of the mismatch trials affected performance during subordinate match trials. Examination of the response latencies revealed a main effect of orientation ($\underline{F}(5,345) = 6.74$, $\underline{p} < 0.001$, $MS_e = 19624$) consisting of a significant linear trend between 0^0 and 180^0 ($\underline{F}(1,345) = 32.07$, $\underline{p} < 0.001$; ms/deg = 0.66) which remained robust when the 180^0

point was dropped ($F(1,345) = 21.79$, $p < 0.001$; ms/deg = 0.77). This effect did not interact with group ($F(10,345) < 1.0$), nor did either of the linear trends (all comparisons $F(1,345) < 2.10$, $p > 0.15$).

There was a main effect of group ($F(2,69) = 3.50$, $p < 0.05$; $MS_e = 167574$) in which groups "SS" and "DS" did not differ ($F(1,69) < 1.0$) while group "SB" was significantly slower ($F(1,69) = 125.83$, $p < 0.001$).

These findings suggest that although the nature of the mismatch trials made the discriminations more difficult, thus explaining the slower overall match response times for group "SB", the effect of orientation on the match latencies was not affected suggesting that the subjects from all three groups were performing the match trials in a similar fashion.

Mismatch Responses

Mismatch responses were analysed similarly to the match responses.

Mismatch responses showed no main effect of orientation ($F(5,345) < 1.0$; $MS_e = 17100$). Furthermore, the contrast analysis did not reveal any overall linear trends when collapsed across groups either between 0^0 and 180^0 ($F(1,345) = 1.68$, $p > 0.15$; ms/deg = 0.13) or between 0^0 and 120^0 ($F(1,345) = 2.84$, $p > 0.04$). There was no overall interaction between orientation and group ($F(10,345) = 1.25$, $p > 0.25$). Contrast analysis of the linear trends did not show any difference between groups "SS" and "DS" (all comparisons $F(1,345) < 1.0$). However, there was a significant interaction in the linear trends when group "SB" was compared with groups "SS" and "DS", shown both between 0^0 and 180^0 ($F(1,345) = 6.37$, $p < 0.04$) and between 0^0 and 120^0 ($F(1,345) = 7.03$, $p < 0.01$), with group "SB" showing the larger effect.

As with match responses, there was a main effect of group ($F(2,69) = 11.98$, $p < 0.001$; $MS_e = 2135835$) which indicated group "SB" was slower than groups "SS" and "DS" ($F(1,69) = 116.63$, $p < 0.001$).

These results suggest that effects of orientation on mismatch trials depended on the nature of the basic categorical relationship between the name and the item, with effects only being shown when the name and the object shared basic level identity. Furthermore, taken in conjunction with the analysis of the match responses, we find that groups "SS" and "DS" show no significant differences in either match or mismatch responses. It follows from this that we may now argue that the interaction between match and mismatch responses for which we've suspended judgement in group "DS" should be considered reliable.

Discussion

Large effects of object orientation were shown during word-picture match decisions at the subordinate level (ms/deg = 0.77). The magnitude of this effect of orientation was similar to that shown for rotated object naming (0.71 - 2.5 ms/deg). It is concluded that the same mechanism underlies the effects of orientation during object naming and subordinate name-picture match decisions. Furthermore, mismatch judgements which required subordinate identification also showed large effects of object orientation which did not differ in magnitude from the effect shown during match trials. However, when mismatch judgements could be based on basic level identification, no significant effect of object orientation was shown. These findings are consistent with the notion that basic level object identification may be independent of orientation.

An order of identification beginning with basic level and proceeding to subordinate would explain the similarity in findings between mismatches at the basic level regardless of similarity of superordinate membership (refer to Figures 3b and 3c). Once a basic level mismatch is determined, a mismatch judgement may be executed without requiring the additional processing to the subordinate level. However, when the mismatch decision can not be made based on basic level information, as in the case of a within basic category mismatch shown in Figure 3a, then additional visual processing is required to obtain subordinate level identification. The current results, showing large and equal effects of orientation on subordinate match and within-basic mismatch judgements and no effects of orientation on between basic level mismatches, suggest that the effects of orientation arise during this post-basic level visual processing.

Subordinate identification requires additional visual processing beyond the basic level (Rosch et at., 1976; Jolicoeur et al., 1984). The effects of orientation shown during match decisions would arise if a normalisation procedure was required either prior to basic level identification or during the additional visual processing to achieve subordinate identification. As responses to objects which mismatched with the names at the basic level did not show effects of orientation, it is suggestive that the effects of orientation shown for match responses reflect a normalisation process operating during the additional visual processing after the basic level identification which is required for subordinate identification. This is further supported by the fact that within-basic level mismatch decisions were much slower than between-basic level mismatch decisions for 0^{0} presentations, suggesting additional processing may be occurring.

Although the findings of Experiment 1 suggest that basic level identification may be achieved independent of orientation, an alternative explanation may be found based on dual route models of object recognition (Klein & Starratt, 1980; Humphreys & Riddoch, 1984; Jolicoeur, 1990). Jolicoeur (1990) describes a dual route model of object recognition which expands upon Humphreys & Riddoch's (1984) model and so the discussion will focus on Jolicoeur's (1990) model.

One route employs a transformation process in which a rotated stimulus is normalised to the upright canonical view prior to identification. The other route to object identification is feature-based. Items which share basic level identities have many features in common while items from different basic categories have relatively few features in common (Rosch et al., 1976). The different amount of shared features provides an interpretation of the results of Experiment 1 in terms of Jolicoeur's dual route model. During a match trial, the feature identification route may only conclude a positive decision upon comparison of the set of features present in the stimulus with the set of features which defines the object. As many objects may share features in common (Biederman, 1987; Rosch et al., 1976), the feature identification route would operate relatively slowly during subordinate match trials (Klein & Starratt, 1980; Jolicoeur, 1990) allowing the normalisation route to reach identification on the bulk of the trials. Subordinate match decisions therefore, may be based on the normalisation route which results in the large effects of orientation found for match trials in all three conditions of Experiment 1.

Similarly, during within-basic category mismatches, the feature route would also operate slowly as the mismatch item would contain many features in common with the item described by the name (Rosch et al., 1976). As with the match trials, basic category mismatch trials would also reflect the operation of the normalisation route. This is supported by the finding that the within-basic category mismatch trials showed large effects of orientation which did not differ in magnitude from those of the match trials.

However, when the name and object mismatched at the basic level, then the object would contain many features which indicate that a match is impossible. Upon detection of a feature in the stimulus which makes a match an impossibility, the feature-based route would immediately be able to conclude a mismatch while the normalisation route is still performing the transformation process. As individual features may be orientation-invariant (Biederman, 1987; Jolicoeur, 1990) the feature route would be unaffected by the orientation of the object. Such a conclusion is supported by the finding that cross-basic category mismatches were unaffected by stimulus orientation.

One implication of the above explanation for the lack of an orientation effect during cross-basic category mismatches is that we can not assert that the mismatch object was identified per se. Although the feature route may be able to determine that a given stimulus is not of a particular identity (i.e., not a dog), this does not mean that the route had completed the identification process to the extent of asserting the object as being a particular identity (i.e., is a bird).

As the lack of an effect of orientation on the cross-basic category mismatches may be explained either by orientation-invariant identification at the basic level, or by the detection of a single feature ruling out a match without identification, we cannot be sure if the effects of orientation shown for the subordinate match and within-basic category mismatches reflect normalisation occurring before or after basic level identification. This difficulty arises because if the cross-basic category mismatches are reflective of the feature-route determining that a match is impossible without actually identifying the object, then we have no evidence of orientation-independent identification. However, we can be certain that the match/mismatch task will show effects of orientation on match decisions even if the name and mismatch objects do not share basic level identity. This is shown in groups SS and DS. As such, the match/mismatch task is a viable methodology to address issues concerning effects of orientation during object identification.

Experiment 2

Introduction

Experiment 2 is designed to examine if basic level identification can be achieved invariant of stimulus orientation. If the finding that cross-basic category mismatches from Experiment 1 is indicative of the detection of a single disconfirming feature rather than of orientation independent identification at the basic level, then when subjects are asked to make match/mismatch judgements concerning basic level identification, the basic level match decisions should reflect normalisation prior to identification (Jolicoeur, 1990) similar to subordinate identification.

In contrast to this prediction, if objects are initially identified independent of orientation (Corballis, 1988) at the basic level, we would expect both match and mismatch trials to show no effect of stimulus orientation when the names are at the basic level of identity.

Orientation-invariant access to a basic level identity would also provide a consistent explanation for the findings of Experiment 1. Mismatch judgements at the basic level would remain unaffected by stimulus orientation for both of these explanations since they may equally be explained by orientation-invariant identification at the basic level (Corballis, 1988) or by the detection of a single disconfirming feature (Jolicoeur, 1990).

In order to examine this question, subjects were asked to make match/mismatch judgements when the name was at the basic level rather than at the subordinate level as in Experiment 1.

Methods

Subjects:

Eighty-two subjects voluntarily participated or received one credit point towards an introductory psychology course. The data from 10 subjects were excluded because of failure of the subjects to meet the accuracy criteria as described in Experiment 1. Data presentation and statistics are based on the remaining 72 subjects (36 males and 36 females). These subjects were divided into two groups of 36, with equal numbers of males and females per group.

Apparatus:

The same apparatus was used as in Experiment 1. However the verbal labels employed were now the 6 basic category names of "Bird", "Dog", "Bug", "Car", "Boat", and "Aircraft".

Design:

Similar counterbalancing of stimuli, orientation, response, gender and upright direction of facing was performed as in Experiment 1. Match trials employed the presentation of the corresponding basic label (i.e., Word "Dog" followed by a picture of a "Collie"). The two groups of subjects differed in the nature of the relationship of the mismatch names to the presented stimulus. Group "SS" received a basic level name of the same superordinate category (I.e., Word "Bird" followed by a picture of a "Collie") while group "DS" received a verbal label of the other superordinate category (I.e., Word "Car" followed by a picture of a "Collie").

Procedure:

The procedure employed was identical to that in Experiment 1, with the exception that the names employed now corresponded to the basic level rather than the subordinate level.

Results

Name matching latencies at the basic level

Separate ANOVAs were performed on data from each of the two groups with Orientation (6) and Response (2) as within-subject variables.

Group "SS": (mismatched objects shared superordinate category with basic names)

Response Time: Figure 5a shows the mean correct latencies for each orientation and response type, from Group "SS" subjects.

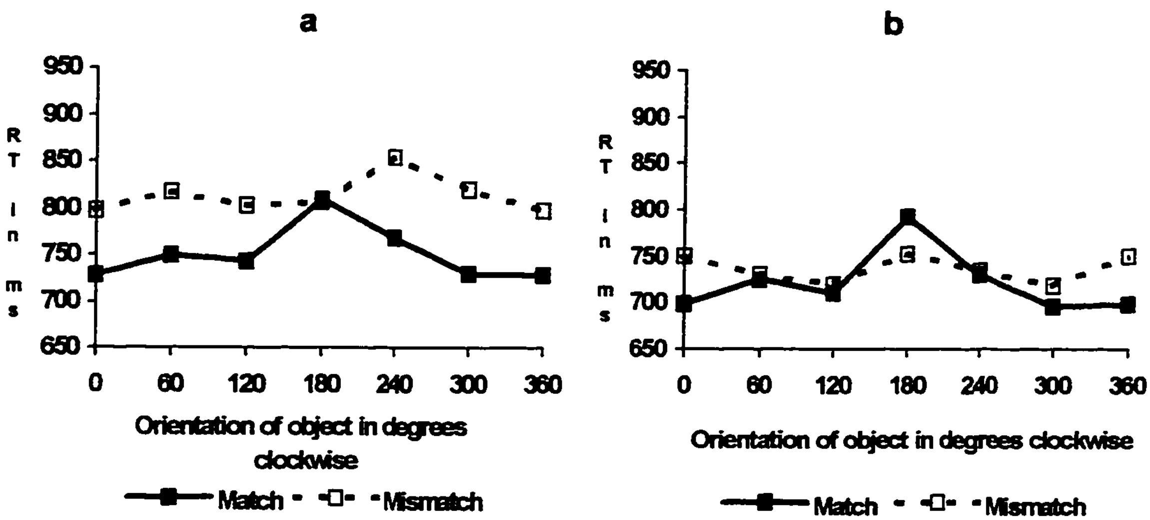


Figure 5: Effects of object orientation on latency to make basic level match/mismatch judgements with mismatch word-object relationship of a) sharing superordinate identity; and b) not sharing superordinate identity.

Effects of orientation were not reliable, $F(5,175) = 1.9$, $MS_e = 14641$, $p = 0.09$. However, contrast analyses revealed a significant linear trend was present between 0^{0} and 180^{0}, $F(1,175) = 5.8$, $p < 0.02$, which was due to inclusion of responses to objects rotated 180^{0}. Deletion of these times failed to reveal linear effects of orientation, $F(1,175) = 2.7$, $p = 0.1$. Match responses (mean = 753.8 ms) were faster than mismatch responses (mean = 816.0 ms), $F(1,35) = 22.7$, $MS_e = 18342$, $p < 0.001$; an effect which did not interact with orientation, $F(5,175) = 1.4$, $MS_e = 14773$. Consistent with this result, contrast analyses failed to show a reliable interaction in the linear trends between match (ms/deg = 0.41 and 0.23 including and excluding 180^{0} respectively) and mismatch (ms/deg = 0.07 and 0.25 including and excluding 180^{0} respectively) responses, $F(1,175) = 2.8$, $p = 0.09$.

Percent Correct: The accuracy data may be seen in Figure 6a. No significant effects were found.

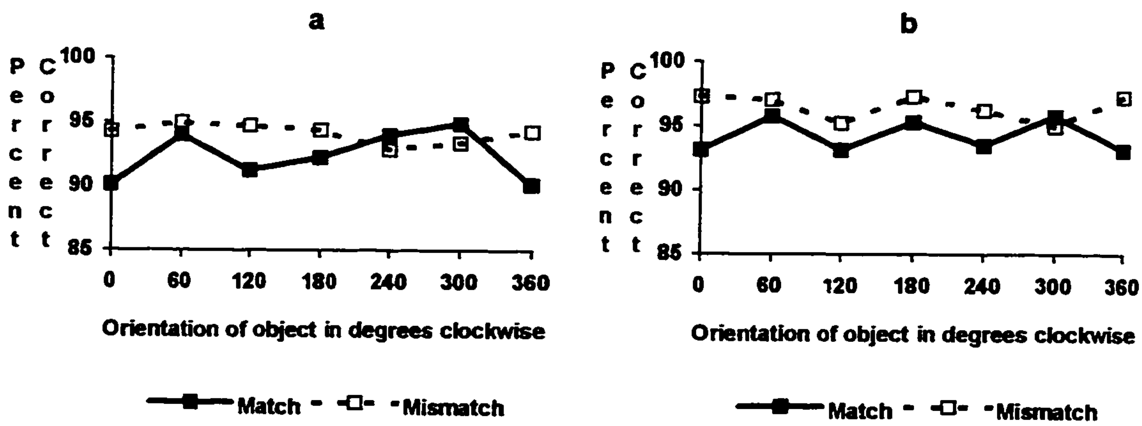


Figure 6: Effects of object orientation on accuracy of basic level match/mismatch judgements with mismatch word-object relationship of a) sharing superordinate identity; and b) not sharing superordinate identity.

<u>Group "DS": (mismatched objects differed at the superordinate level from basic names)</u>

<u>Response Time</u>: Figure 5b shows the mean correct latencies for each orientation and response type, from Group "DS" subjects. A main effect of orientation was found, $F(5,175) = 2.5$, $MS_e = 15147$, $p < 0.05$, which contained a linear trend between 0^0 and 180^0, $F(1,175) = 5.4$, $p < 0.02$. However, these linear effects of orientation again disappeared when the 180^0 response times were excluded from the analysis, $F(1,175) < 1.0$. The time to make match responses (mean = 724.7 ms) did not differ from the time to make mismatch responses (mean = 733.8 ms), $F(1,35) < 1.0$, $MS_e = 23404$, nor did this (non)effect interact with orientation, $F(5,175) = 1.4$, $MS_e = 11640$. Contrast analyses confirmed an interaction in the linear trends between match and mismatch trials, $F(1,175) = 5.9$, $p < 0.02$; ms/deg = 0.46 and 0.02 for match and mismatch responses respectively), indicating a larger effect of orientation for match than mismatch responses. However, this interaction was again due to inclusion of response times to objects presented at 180^0. It disappeared when the analysis excluded these responses, $F(1,175) = 2.1$, $p = 0.1$; ms/deg = 0.18 and -0.16 for match and mismatch responses respectively.

Percent Correct: The accuracy data are shown in Figure 6b. Mismatch responses (mean = 96.3%) were slightly more accurate than match (mean = 94.8%) responses ($\underline{F}(1,35)$ = 5.36, $\underline{p} < 0.04$). No other effects reached significance.

Simple Effects Analysis

In order to be consistent with the analysis of the data from Experiment 1, the match and mismatch responses were analysed separately in a two factor between-groups analysis of variance with orientation (6) as a within-subjects factor and groups (2; "SS" "DS") as a between-groups factor. Although no significant effects of orientation were found between 0^{0} and 120^{0} for either group, by combining the groups we will increase the power to detect any effects should they exist.

Match responses

Match responses showed an overall effect of orientation ($\underline{F}(5,350) = 4.40$, $\underline{p} < 0.01$, $MS_e = 17279$) due primarily to significant linear and quadratic trends between 0^{0} and 180^{0} ($\underline{F}(1,350) = 14.80$, $\underline{p} < 0.001$ and $\underline{F}(1,350) = 3.85$, $\underline{p} < 0.05$ for the linear and quadratic trend, respectively). However, neither trend maintained significance after the exclusion of the 180^{0} data (both $\underline{F}(1,350) < 1.46$, $\underline{p} > 0.20$). There was no effect of group ($\underline{F}(1,70) = 1.62$, $\underline{p} > 0.20$, $MS_e = 222068$;

means = 770 and 712 for "SS" and "DS", respectively), nor was there an interaction between orientation and group ($F(5,350) < 1.0$). Finally, none of the orientation by group contrasts reached significance (all $F(1,350) < 1.0$).

Mismatch Responses

Apart from a significant difference between groups ($F(1,70) = 8.15$, $p < 0.01$, $MS_e = 160240$) with "SS" slower than "DS" (means = 832 ms and 722 ms, respectively) and a significant interaction in the quadratic trends between 0^0 and 180^0 ($F(1,350) = 5.28$, $p < 0.04$, $MS_e = 17279$), none of the effects or contrasts reached significance (all p's > 0.09). Note, when the 180^0 data were excluded from the analysis, the interaction in the quadratic trends was not apparent ($F(1,350) < 1.0$).

These analyses show that the lack of a significant effect of orientation for basic level match/mismatch decisions was not due to insufficient power.

Discussion

Unlike subordinate match/mismatch judgements, basic level decisions did not show significant effects of object orientation for either match or mismatch judgements. Furthermore, calculation of the magnitude of the effect (<0.25 ms/deg for both match and mismatch) shows that any effect which may exist is well outside of the range (0.71 - 2.50 ms/deg) normally found for rotated object naming. These findings are consistent with the notion that basic level identification is achieved independent of orientation. Invariant basic level identification followed by a normalisation process to achieve subordinate level identity is consistent with the findings of both Experiments 1 and 2.

However, before asserting this conclusion too confidently we must examine an alternative explanation. It has been shown that effects of orientation diminish with repeated presentation of the same stimuli in different orientations (Jolicoeur, 1985; 1990; McMullen Jolicoeur, 1990; 1992; Murray, 1995b). Although the current experiments do not repeat the same stimuli, multiple exemplars of the same basic identity are repeated as objects. If presentation of multiple exemplars is sufficient to produce a reduction in the effects of orientation, then by collapsing across exemplar presentation, the current results of Experiment 2 may average out an effect which was initially present but which diminished over the course of the experiment.

I shall address the possibility that effects of orientation diminished over the course of the experiment as a result of the presentation of multiple exemplars in several ways. First I shall suggest that the repetition of exemplars is not a sufficient explanation by demonstrating that repetition of exemplars occurs in many of the naming experiments which do show large effects of orientation on the first block (e.g., Jolicoeur, 1985; McMullen and Jolicoeur, 1990; 1992; McMullen et al., 1990; Murray, 1995a; 1995b; 1997). I shall also address the methodological difference between Experiment 1 and Experiment 2 involving the number of repetitions of the employed names. In Experiment 1 where large effects of orientation were found, a given name was only employed once, whereas in Experiment 2, there were twelve repetitions of each label; 6 for match trials and 6 for mismatch. Finally, I shall present the results of a post-hoc analysis of the first trial where a member of a basic category was presented.

The first concern involves the repetition of exemplars. A common stimulus set employed in studies of rotated object naming is selected from Snodgrass and Vanderwart (1980). Of the 250 stimuli which comprise this set, a selection of 120 objects which are deemed to have distinct tops and bottoms are employed regularly (Jolicoeur, 1985; McMullen and Jolicoeur, 1990; 1992; McMullen et al., 1995; Murray, 1997). Large effects of orientation on naming latencies are shown for the first block of presentation of these stimuli.

In this set of 120 objects, as has been mentioned earlier, there are many exemplars of objects from the same basic category. The set of birds used in the current experiments, for example, is comprised of many stimuli selected from the Snodgrass and Vanderwart set. Similarly many of the bugs were also selected from Snodgrass and Vanderwart (1980). Overall, 21 of the current 72 stimuli have been chosen from this commonly used set. Furthermore, items in the Snodgrass and Vanderwart set such as the dress shirt, blouse, sweater, and possibly the jacket, vest, and overcoat, could be all be considered members of the same basic category of shirt, or at least being two categories of shirt and jacket. Because the Snodgrass and Vanderwart set, which itself contains multiple exemplars from the same basic categories, shows large effects of orientation on the first presentation of these objects, it seems reasonable to assume that the employment of multiple exemplars in the current experiment would not wash out the effect.

Moreover, Jolicoeur (1985) demonstrated that the reduction in the orientation effect due to repetition of stimuli across blocks is specific to the stimuli employed and does not generalise to new items. Therefore the use of multiple exemplars should not produce a reduction in the effects of orientation as each exemplar is a new stimulus. Finally, as we can see from the findings of Experiment 1 which employed the same set of stimuli as Experiment 2, large effects of orientation are shown with these items even though the same repetition of exemplars occurs. The difference between Experiment 1 and Experiment 2 lies in the level to which the objects required identification. As the names given to the items selected from Snodgrass & Vanderwart (1980) during a rotated object naming study are the subordinate level identities used in Experiment 1 (i.e., duck and grasshopper), it appears that previous naming studies are showing results arising from subordinate level object identification and not basic level identification.

It was suggested that the repetition of the verbal labels may have reduced the effects of orientation during basic level decisions. However, this does not explain the lack of an effect of orientation during subordinate verification on trials which mismatched at the basic level. In these conditions, there was no repetition of the verbal labels and yet no effect of orientation was found.

I shall now empirically address the possibility that effects of orientation had diminished over the course of the experiment due to the repetition of exemplars within a basic category. The assumption that basic level identification showed effects of orientation which diminished predicts that on the first presentation of an exemplar from a basic category, a large effect of orientation would appear. In order to examine this finding, the response times from the first trial in which an exemplar from each of the six basic categories was shown were examined[3]. Because orientation did not interact with response, this first trial analysis combines match and mismatch trials. This analysis results in a maximum of 6 trials from a given subject. Because this is a post-hoc analysis, these trials will not be evenly distributed across orientations. In order to remove variation which would be introduced by the unequal representation of the subjects across orientation, each subject's overall mean was subtracted from their response times to produce a "difference rt". Although z-scoring the data under such circumstances is common (Keppel, 1982), to do so would change the scale of the dependent measure and make it difficult to compare the magnitude of the overall effect of orientation to the magnitude of the effect of orientation on the first trial. Because it may be expected that only the match trials would show an effect of orientation, (as in Experiment 1 groups "SS" and "DS") a separate analysis was performed which only included response times for the first presentation of a basic category exemplar if it was a match trials. The resulting data from both the combined match/mismatch and match trial only analysis are shown in Figure 7.

[3] Thanks to Ray Klein and Pierre Jolicoeur for independently suggesting this analysis.

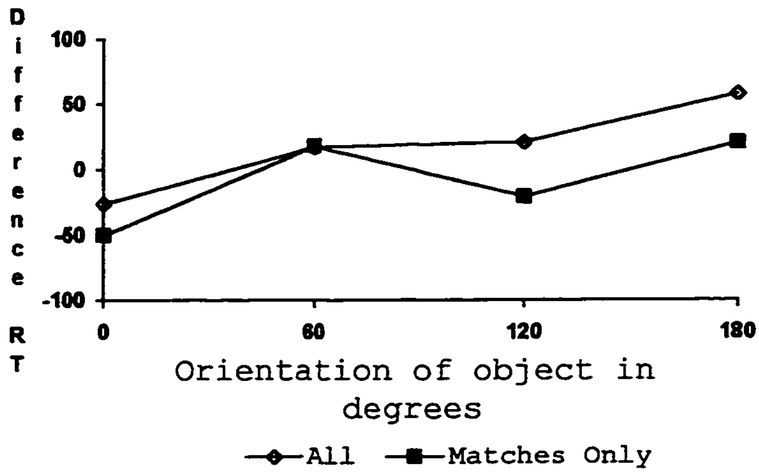


Figure 7: Effects of orientation from the first presentation of a basic category exemplar.

Examination of the magnitude of the effect of orientation for these trials does not suggest that there was an effect of orientation which diminished for the match and mismatch trials combined (ms/deg = 0.40 and 0.35 including and excluding the 180^0 point respectively) nor for the match trials in isolation (ms/deg = 0.20 and 0.12 including and excluding the 180^0 point respectively).

The findings of this post-hoc analysis fail to support the notion that the non-significant effects of orientation during basic level matches are due to diminished effects over the course of the experiment because there was not an original effect to diminish. In contrast, a similar analysis of the first presentation of an exemplar of a basic category from Experiment 1 (match trials only) resulted in ms/deg of 1.07 and 0.62 including and excluding the 180^0

point. As the overall effect size on the subordinate matches when all trials were included were 0.66 and 0.77 ms/deg including and excluding 180^0, it appears that this post-hoc analysis is capable of detecting effects of orientation when they are present on the first trial.

In conclusion, based on the overall findings and these post-hoc analyses, it appears that basic level identification can be invariant of object orientation.

Experiment 3

Introduction

Experiments 1 and 2 examined the effects of orientation on match/mismatch judgements at subordinate and basic levels of identification. The findings have been consistent with basic level identity being accessed independent of orientation. Because subordinate identification is thought to require additional visual processing of the image after identification at the basic level, the current experiments suggest that this additional visual processing may include an orientation normalisation process which has been shown during rotated object naming studies. Furthermore, it has been suggested that rotated object naming studies may reflect subordinate identification rather than the initial basic level identification.

Like subordinate identification, superordinate level identification also requires processing beyond the basic level (Rosch et al., 1976; Jolicoeur et al., 1984). However, unlike the additional visual processing required by subordinate level identification, superordinate identification requires additional semantic processing (Rosch et al., 1976; Jolicoeur et al., 1984). If orientation normalisation is a process contained within the additional visual processing required for subordinate identification, then match/mismatch judgements at the superordinate level should not show effects of orientation, similar to basic level decisions. Subjects were therefore asked to make match/mismatch judgements at the superordinate level.

Methods

Subjects:

Seventy-four subjects voluntarily participated or received one credit point towards an introductory psychology course. Data from two subjects were discarded due to high error rates as described in Experiment 1. The remaining 72 subjects comprised one group containing an equal number of males and females.

Apparatus:

The same apparatus and stimuli were employed as in Experiments 1 and 2 with the exception that the names were the superordinate category names of "Animal" and "Vehicle".

Design:

Similar counterbalancing of stimuli, orientation, response, gender and upright direction of facing was performed as in Experiments 1 and 2. Match trials employed the presentation of the corresponding superordinate label, while mismatch trials presented the non-corresponding superordinate label.

Procedure:

The procedure was the same as that employed in Experiments 1 and 2.

Results

Name matching latencies at the superordinate level

An analysis of variance (ANOVA) was performed on the mean correct response times to match superordinate level names using Orientation (0°, 60°, 120°, 180°, 240°, and 300°) and Response type (match and mismatch) as within-subject variables. Less than 1% of the total correct responses were rejected as outliers. Figure 8 shows the effects of orientation and response type.

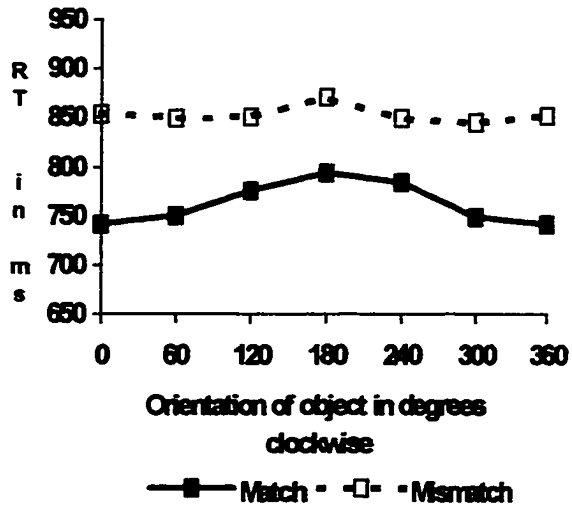


Figure 8: Effects of object orientation on latency to make superordinate level match/mismatch judgements.

Response Time: Effects of orientation were unreliable, $\underline{F}(5,355) = 1.7$, $\underline{p} > 0.10$, $MS_e = 16635$. However, contrast analyses revealed the presence of a linear trend, $\underline{F}(1,355) = 7.7$, $\underline{p} < 0.01$. Once again, this trend was due to inclusion of responses to objects presented at 180^0. Analysis of responses to objects between 0^0 and 120^0 only failed to reveal this linear trend, $\underline{F}(1,355) = 1.8$, $\underline{p} > 0.15$. Match responses were faster than mismatch responses (765 ms vs. 853 ms, respectively), $\underline{F}(1,71) = 93.1$, $MS_e = 18018$, $\underline{p} < 0.001$, and this effect did not interact with orientation $\underline{F}(5,355) < 1.0$, $MS_e = 16558$.

For rotations up to 120^0, slopes were 0.35 ms/deg for matches and -0.01 ms/deg for mismatches. For rotations up to 180^0, slopes were 0.33 ms/deg for matches and 0.09 ms/deg for mismatches.

Percent Correct: The accuracy data may be seen in Figure 9. Match responses (mean = 94.8%) were slightly less accurate than mismatch responses (mean = 95.9%), $F(1,71) = 3.9$, $p = 0.05$. No other effects reached significance in this analysis.

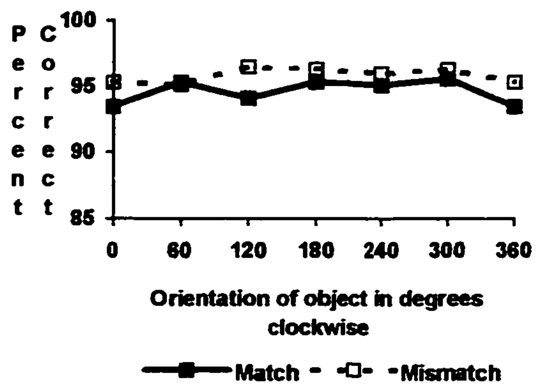


Figure 9: Effects of object orientation on accuracy of superordinate level match/mismatch judgements.

Discussion

As with basic level decisions, superordinate match/mismatch judgements were not significantly affected by object orientation. This finding was supported by a similar post-hoc analysis of first trials performed on the basic level data. When match and mismatch trials were combined, the effect size of orientation on the first presentation of an exemplar from a basic category was 0.19 and 0.14 ms/deg including and excluding the 180^0 point respectively. Looking only at the match trials similarly resulted in effects of orientation much smaller than is suggestive of a normalisation process; ms/deg = -0.11 and 0.22 when including and excluding the 180^0 point respectively.

Taken in conjunction with the findings of Experiment 1 and 2, it appears that effects of orientation are shown only when additional visual processing is required beyond that necessary for basic level identification.

Experiment 4

Introduction

Experiments 1 through 3 investigated object identification using a match/mismatch procedure in which the level of identification necessary to perform the task was varied. Large effects of object orientation were found only when subordinate identification was required. It has been suggested in this thesis that the effects of orientation shown for rotated object naming may also reflect subordinate identification.

Experiment 4 examines whether the difference in the effects of orientation shown during subordinate and basic level match/mismatch would be replicated in an object naming task. Because theories of rotated-object identification have been derived primarily on interpretation of naming latencies, it is important to demonstrate that the minimal effects of orientation shown for basic level identification are not limited to the match/mismatch procedure. Object naming may be considered a more direct measure of object identification. As previously noted, we must be careful in our interpretation of the naming latencies and ensure that any effects shown are not due to linguistic influences. If basic level identification may be achieved independent of object orientation, then when subjects are instructed to name objects at the basic level minimal effects of orientation should be shown. Furthermore, if orientation normalisation is required for subordinate identification, then when subjects are instructed to name the same objects at the subordinate level, large effects of orientation should be found. As the effects of orientation are known to diminish on the second presentation of stimuli (Jolicoeur, 1990; McMullen & Jolicoeur, 1990; 1992), all subjects were asked to name the objects at the basic level (i.e., dog) for the first presentation. On the second block, subjects were asked to identify the object at the subordinate level (i.e., collie). This order of naming ensures that any reduced effects shown for basic level naming are not confounded with the known finding of diminished effects for repeated presentation of the same stimuli.

Two groups of twenty-four subjects were asked to name rotated objects at the basic and subordinate level. The first group performed the naming task under standard viewing conditions; i.e., the stimulus remained visible until named. The second group was briefly presented with the stimuli, which were then masked. If basic level identification does not require normalisation, brief presentation and masking should show minimal effects on basic level naming as these manipulations are thought to interfere with the function of the normalisation route (Jolicoeur, 1990). In contrast, since subordinate level naming appears to require normalisation, brief presentation and masking should interfere with subordinate level naming (Jolicoeur et al., 1984). Furthermore, as basic level identification is thought to precede subordinate level identification, the effects of brief presentation and masking should be primarily to increase the number of within-basic category errors during subordinate naming.

If the effects of orientation are primarily after basic level identification, then effects of orientation on the second block of naming (subordinate level naming) should be larger than those shown on the initial block (basic level naming). Additionally, any effect of orientation on basic level naming should fall outside of the upper bound normally attributed to normalisation procedures (0.71 - 2.5 ms/deg; Jolicoeur, 1985) while the effect of orientation of subordinate identification should be within this range.

Methods

Subjects:

The subjects were 24 males and 24 females between the ages of 18 and 48 (mean 23.3) with normal or corrected-to-normal vision. All reported English as their first language. Participation was in return for 1 credit point towards an introductory psychology course.

Apparatus:

The experiment was controlled by a Pentium 75 running software written by the experimenter. Millisecond timing routines were adapted from Crosbie (1989). Stimuli were presented on a 14 inch SVGA monitor with a video resolution of 800 x 600. The seventy-two stimuli employed in Experiments 1 through 3 were again used in this experiment. Verbal responses were monitored by a microphone which tripped a voice key and stopped the millisecond timers. The experimenter coded each response in terms of accuracy, and recorded the utterance via the keyboard.

Procedure:

Subjects were randomly assigned to one of two conditions with the constraint that there be equal number of males and females in each group. Group 1 was the short exposure condition and Group 2 was the long exposure condition. Subjects in both conditions ran two blocks of 72 trials, with no stimuli repeated within a block. In the first block of trials, subjects were to name the category to which the stimuli belonged (i.e., dog) and were familiarised with the names of the 6 basic categories prior to naming. During the second block, subjects were instructed to give as specific an identity as possible (i.e., Collie). Millisecond timing for responses began upon presentation of the stimuli. The onset of both the millisecond timing and stimulus presentation were synchronised with the beginning of a video refresh cycle (Heathcote, 1988). Timing ended when the subject's response tripped a voice key or 4000 milliseconds had elapsed from stimulus presentation. For the short exposure condition, the stimulus was removed after 75 milliseconds, and replaced by a mask consisting of a 40 x 30 grid with 50% of the cells filled solid black. The mask duration was 75 milliseconds, after which the screen was left blank. For the long exposure condition, the stimulus remained visible on the screen until a response was made or the trial timed out. If a response was made within 4000 milliseconds, the word "OK" appeared in green, otherwise the words "TOO LONG" appeared in red. Subject's were informed that the positive feedback was not connected to the accuracy of their responses.

Stimulus Randomisation:

For a block of trials, 2 stimuli from each category were shown at each of the six orientations (0 to 300 degrees in 60 degree steps clockwise). For the second block of trials, all stimuli were shown in an orientation other than the one employed during block one. Collapsed across the 24 subjects of a given exposure duration, for both basic and subordinate naming, all stimuli were shown at each orientation 4 times. Two of these presentations would result in the object facing left when rotated upright, and two presentations facing right. Stimulus presentation was random, with the constraint that no more than four successive trials employed the same orientation or members from the same basic category.

Results

Naming Latencies:

As naming latencies may reflect occasional use of normalisation in order to verify an object's identity

(Corballis, 1988), median naming latencies were calculated rather than the mean latency. The median should not be influenced by such occasional noise provided their occurrence is less than 50%. Note, however, that none of the findings presented here change upon examination of the mean naming latencies. Median naming latencies for correct responses were calculated as suggested by Van Selst and Jolicoeur (unpublished manuscript[4]) to avoid the median bias reported by Miller (1988). The corrected median latencies, hereafter simply referred to as the median latencies, were analysed in a mixed factor analysis of variance (ANOVA) with orientation (6) and level of naming (2) as within-subjects factors and exposure duration (2) as a between-subjects factor. The mean of median latencies may be seen in Figure 10.

[4] Jolicoeur and Van Selst replicated the median bias shown by Miller (1988). When they calculated the medians in the manner to be described, they were able to eliminate the sample size bias. For an odd number of data points, take the middle score, which normally would be the median, and multiply it by 0.742, then add the next lower score (middle - 1) multiplied by 0.258. The resulting weighted average is the corrected median. For even number of data points, find the two middle scores which are normally averaged to produce the median. Take the weighted average of these scores using the weights of 0.238 for the larger value and 0.762 for the smaller value. The simulations used were replicated in this lab and both the bias for the noncorrected median and the elimination of this bias using the corrected median were reproduced.

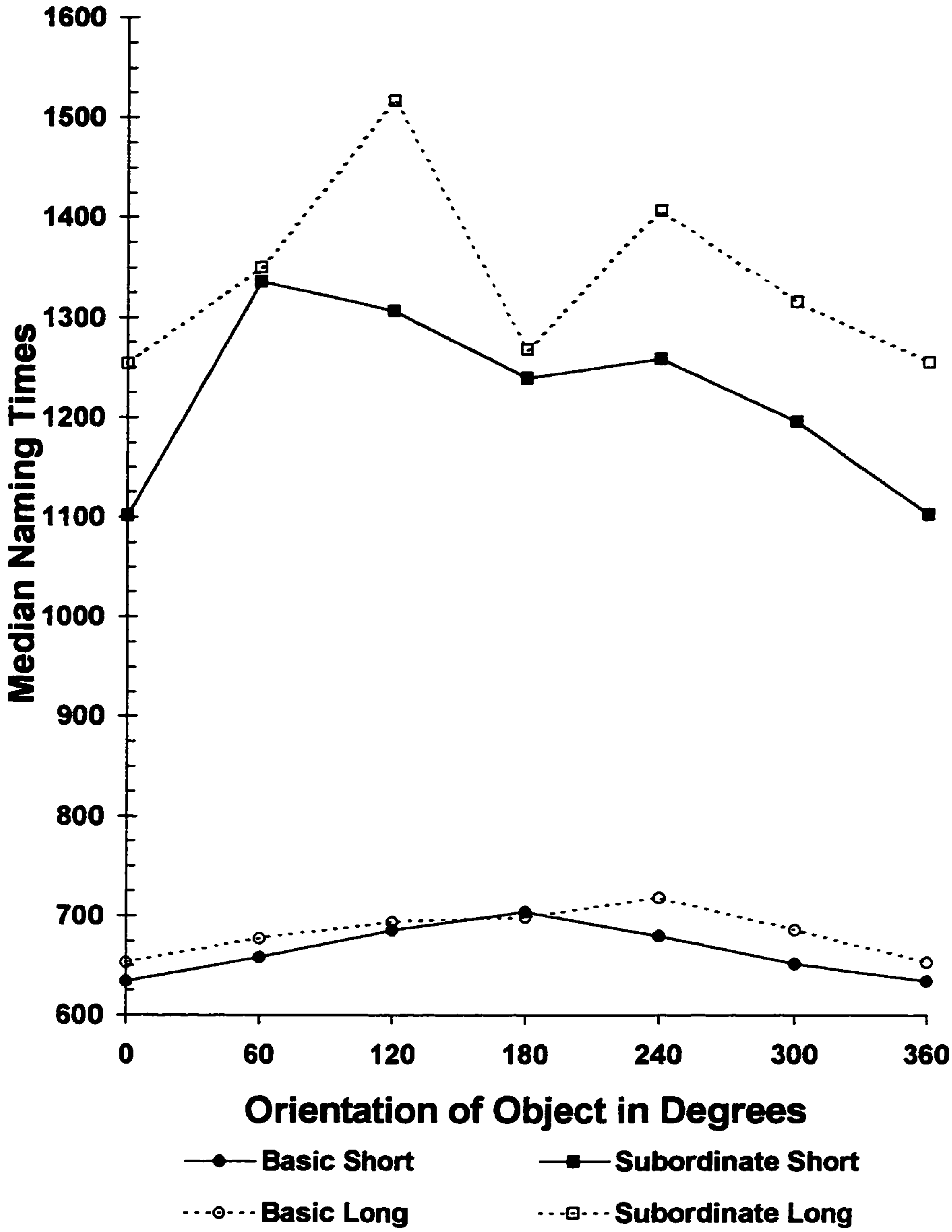


Figure 10: Effects of object orientation on the naming latencies for basic and subordinate level identification under conditions of brief and prolonged exposure.

There was no main effect of exposure duration ($F(1,46) = 3.02$, $p > 0.05$, $MS_e = 204114$; means 954 ms and 1019 ms for short and long exposure, respectively). There was a marginal interaction between exposure duration and level of identification when collapsed across orientation ($F(1,46) = 3.76$, $p = 0.06$, $MS_e = 83571$). However, none of the interactions involving exposure duration and orientation reached significance (all $F(5,230) < 1.49$, $p > 0.15$) and so the data were re-analysed in a two-way ANOVA collapsing across exposure duration with orientation and level of identification as within-subjects factors.

There was an overall effect of orientation ($F(5,235) = 8.12$, $p < 0.001$, $MS_e = 27719$) which was due primarily to linear ($F(1,235) = 13.94$, $p < 0.001$; ms/deg = 0.45) and quadratic ($F(1,235) = 19.00$, $p < 0.001$) trends when tested between 0 and 180 degrees. When trends between 0 and 120 degrees were tested, only the linear trend reached significance ($F(1,235) = 34.35$, $p < 0.001$; ms/deg = 0.99), suggesting the previous quadratic trend was due to the dip at 180^{0} (Jolicoeur, 1990; Murray, 1996).

There was a main effect of level of naming ($F(1,47) = 619.27$, $p < 0.001$, $MS_e = 88480$) with basic naming being faster than subordinate (678 ms vs. 1295 ms respectively).

Finally, the interaction between orientation and level of naming was significant ($F(5,235) = 4.62$, $p < 0.001$, MS_e =

27544). Although this was primarily due to an interaction in the quadratic trends ($F(1,235) = 14.20$, $\underline{p} < 0.001$) when measured between 0 and 180 degrees, when trends were calculated between 0 and 120 degrees, the interaction was shown to be between the linear trends with the larger effect shown for subordinate naming ($F(1,235) = 11.81$, $\underline{p} < 0.001$; ms/deg = 0.42 and 1.55 for Basic and Subordinate naming, respectively). Analysis of the basic level naming alone showed that the linear trend was significant ($F(1,235) = 29.94$, $\underline{p} < 0.001$; $MS_e = 2744$). This effect will be discussed at some length in the discussion.

Percent Correct:

Accuracy was analysed in the same 3-way mixed ANOVA as naming latencies. The accuracy data are shown in Figure 11. There was a main effect of orientation ($F(5,230) = 6.48$, $\underline{p} < 0.001$), $MS_e = 100$, due primarily to a linear trend between 0^0 and 180^0 ($F(1,230) = 31.49$, $\underline{p} < 0.001$) which remained significant when tested between 0^0 and 120^0 ($F(1,230) = 11.88$, $\underline{p} < 0.001$). There was a main effect of level of identification ($F(1,46) = 230.11$, $\underline{p} < 0.001$, $MS_e = 225$) with basic naming being more accurate than subordinate naming (means = 95% and 76%, respectively). There was a main effect of exposure duration ($F(1,46) = 17.42$, $\underline{p} < 0.001$, MS_e

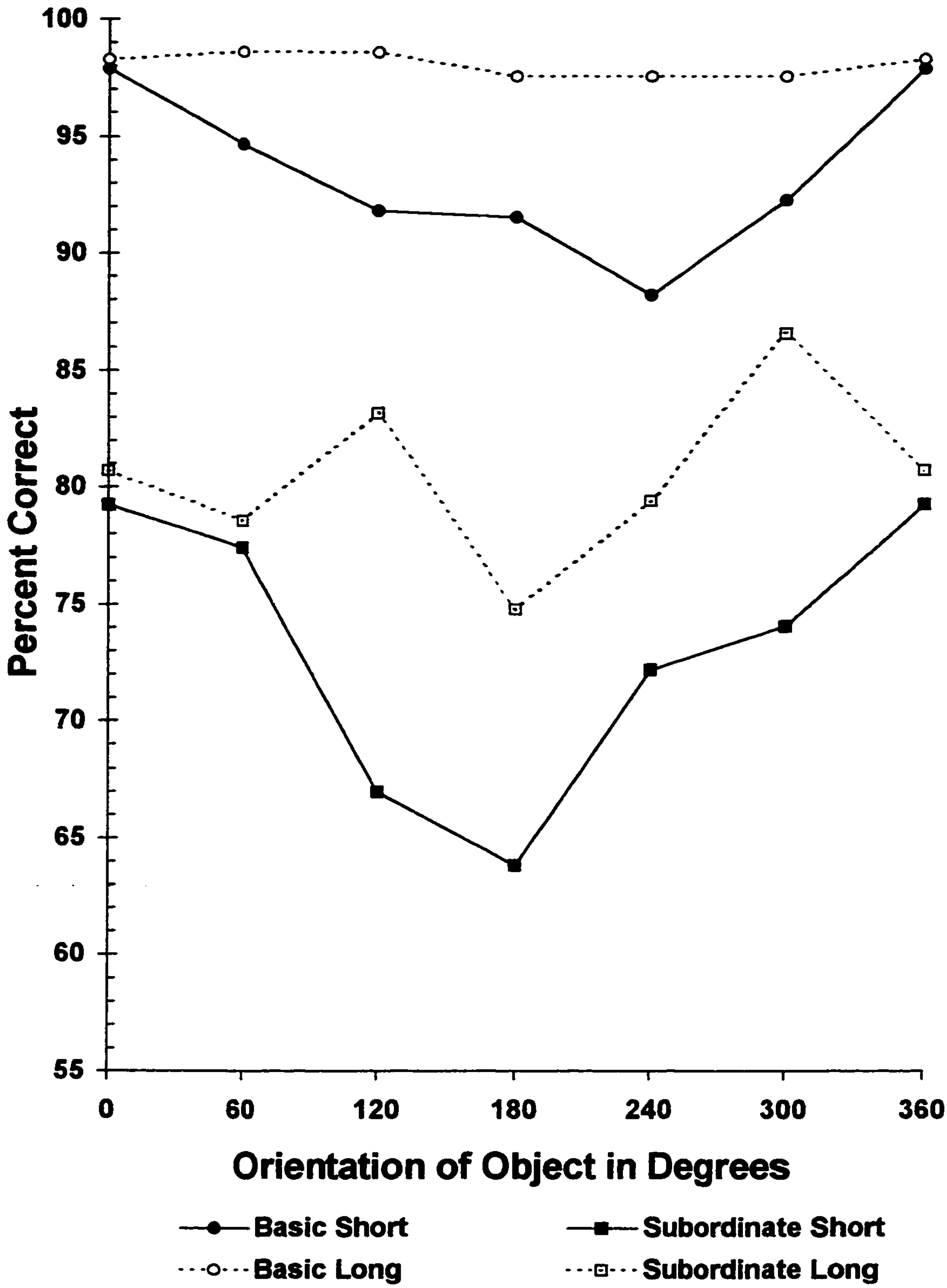


Figure 11: Effects of object orientation on naming accuracy for basic and subordinate level identification under conditions of brief and prolonged exposure.

= 378) with the long exposure promoting more accurate responses than the short exposure (means = 89% and 82%, respectively).

There was a significant interaction between orientation and level of identification ($F(5,230) = 2.53$, $p < 0.05$, MS_e 122) due primarily to a significant interaction in the linear trends ($F(1,230) = 5.77$, $p < 0.04$) and the quadratic trends ($F(1,230) = 4.31$, $p < 0.04$) between 0^0 and 180^0. However, neither of these interactions was significant when measured between 0^0 and 120^0 (both F's < 1.0), suggesting the interactions are due to differences in the 180^0 point alone.

There was an interaction between orientation and exposure duration ($F(5,230) = 4.07$, $p < 0.01$, $MS_e = 100$) due to an interaction in the linear trends ($F(1,230) = 10.54$, $p < 0.01$) between 0^0 and 180^0 which was maintained between 0^0 and 120^0 ($F(1,230) = 12.95$, $p < 0.001$) where the short exposure and mask condition showed a larger decrease in naming accuracy as compared to the long exposure condition. There was also a significant interaction in the symmetry check between 60^0 and 300^0 and exposure duration ($F(1,230) = 4.92$, $p < 0.04$ with the short exposure showing better performance at 60^0 than 300^0 (means = 86% vs. 83%, respectively) and the reverse pattern shown for the long exposure (means = 89% vs. 92%, respectively). Given the similarity in the effect size, 3% in both cases, and given that 60^0 and 300^0 are thought to be perceptually similar, this interaction is considered theoretically uninteresting and will not be discussed further.

No other interaction or interaction contrast reached significance, the closest being a three-way interaction in the symmetry check between 120^0 and 240^0 ($F(1,230) = 3.24$, $p > 0.07$, $MS_e = 122$). All other p's were > 0.10.

The similar decrease in naming accuracies for basic and subordinate naming under conditions of short exposure and masking suggest the possibility that these manipulations interfered with basic level identification since subordinate level naming is thought to require initial identification at the basic level. If the decrease in naming accuracies during subordinate level naming reflects a failure to identify the object at the basic level, then the decrease in accuracy should reflect cross-basic category errors (i.e., naming a collie as something other than a dog).

Modified Subordinate Scoring

Incorrect responses during subordinate naming which identified a stimulus within its proper basic category (i.e., naming a Collie as a German Shepard) were coded as correct for both the short and long exposure conditions. This rescoring of the responses was performed in order to make comparisons between the naming accuracies while controlling for the level at which identification was required. If the decrease in the subordinate naming accuracies with object orientation shown under the conditions of brief exposure and masking reflect failure to identify the object at the basic level, then this effect should be maintained under the new scoring system. The modified naming latencies are examined primarily to determine if the inclusion of these error trials reflect involvement of the same processes as the correct subordinate naming latencies. Both the naming latencies and accuracies were reanalysed in a 2-way mixed ANOVA with orientation (6) as within-subjects factor and exposure duration (2) as a between-subjects factor.

Modified Naming Latencies:

The mean of median naming latencies for the modified coding of correct responses can be seen in Figure 12. There was a main effect of orientation ($F(5,230) = 6.89$, $p < 0.001$) due primarily to significant linear ($F(1,46) = 18.34$, $p < 0.001$) and quadratic ($F(1,46) = 10.62$, $p < 0.01$) trends between 0 and 180 degrees. When the 180^0 point was removed from the analysis, the linear trend remained significant ($F(1,46) = 27.13$, $p < 0.001$) while the previously marginal quadratic trend disappeared entirely ($F(1,46) = 1.12$, $p >$

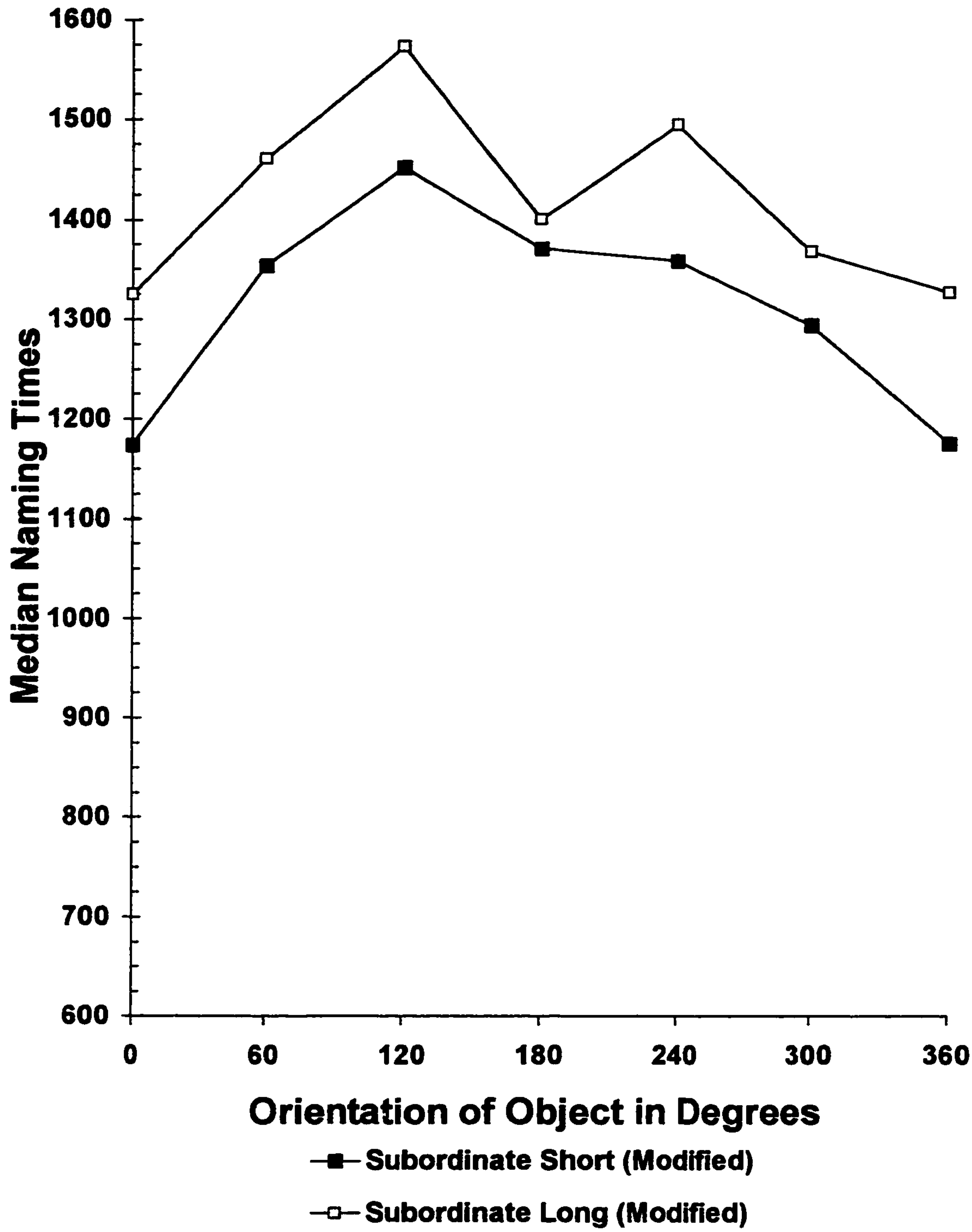


Figure 12: Effects of object orientation on subordinate naming latency when any response indicating correct basic level identity is coded as correct.

0.20). There was no significant effect of exposure duration ($F(1,46) = 2.60$, $p > 0.10$; means = 1333 ms and 1436 ms for short and long exposure, respectively).

The interaction between orientation and exposure duration was not significant ($F(5,230) < 1.0$). Interactions in linear and quadratic trends were not significant whether measured between 0^0 and 180^0 or 0^0 and 120^0 (All $F(1,46) < 1.03$, $p > 0.30$). Effect sizes were 0.67 ms/deg and 0.70 ms/deg between 0^0 and 180^0 for short and long exposure, respectively. Between 0^0 and 120^0, effect sizes were 1.32 ms/deg and 1.77 ms/deg for short and long exposure, respectively. Given the similarity of the pattern of effects shown for the modified subordinate naming latencies and the previously presented subordinate naming latencies, it does not appear that the inclusion of these error trials will create complications in interpretation.

Modified Accuracies:

The modified accuracies were analysed in a 2-way mixed ANOVA similar to that used for the modified naming latencies. The modified accuracies may be seen in Figure 13. The main effect of orientation was not significant ($F(5,230) < 1.0$, $MS_e = 22$). Neither were the linear and quadratic trends between 0^0 and 180^0 (both $F(1,230) < 1.0$). There was no significant linear or quadratic trend between

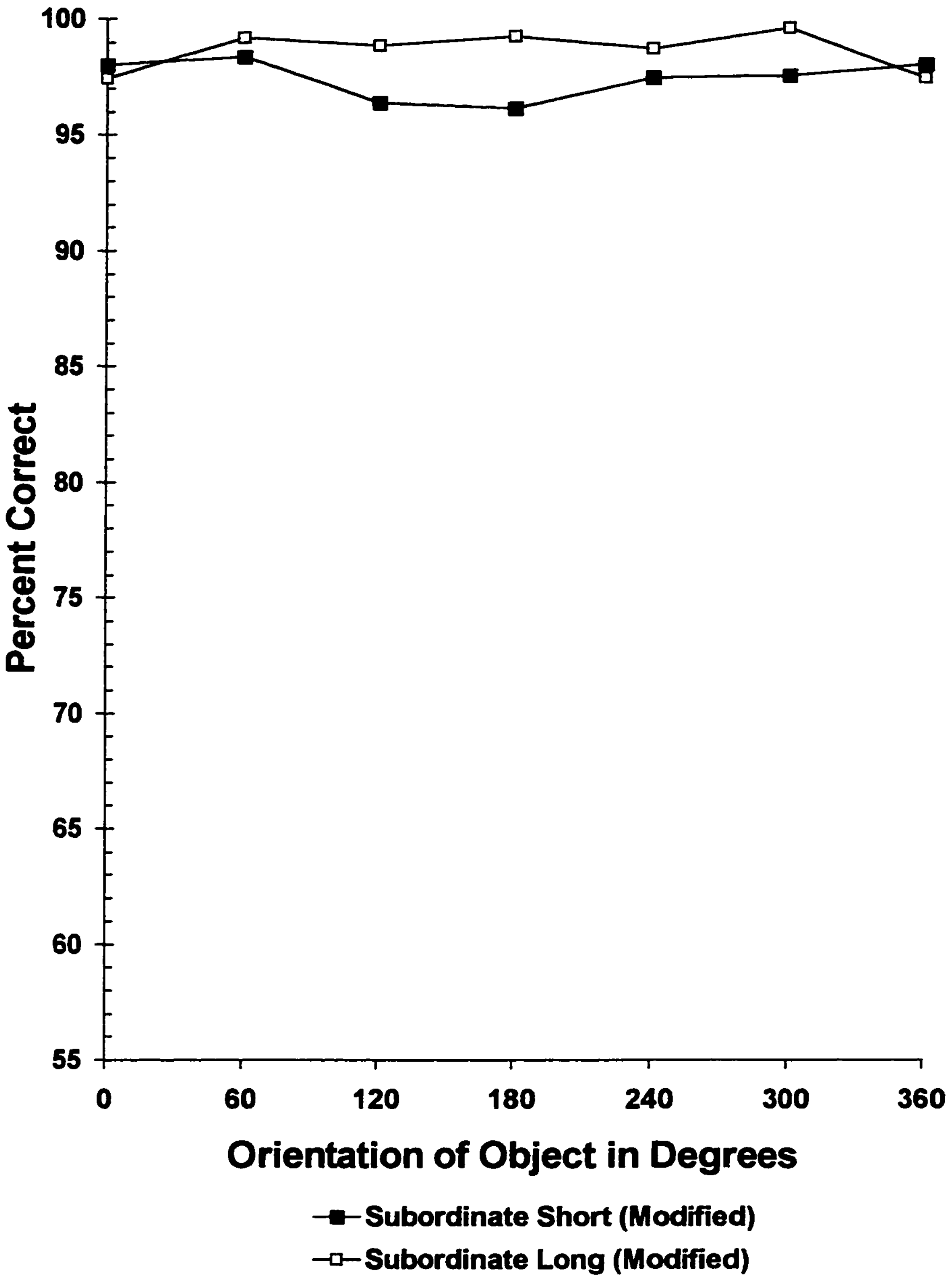


Figure 13: Effects of object orientation on subordinate naming accuracy when any response indicating correct basic level identity is coded as correct.

0^0 and 120^0 (F(1,230) 1.0 and F(1,230) = 2.04, p 0.15 respectively). There was a main effect of exposure duration (F(1,46) = 5.61, p 0.05, MS = 30) with long exposure being more accurate than short exposure (means = 99% and 97%, respectively).

There was no significant overall interaction between orientation and exposure duration (F(5,230) 1.0, MS = 22). However, there was a marginal interaction in the linear trends when measured between 0^0 and 180^0 (F(1,230) = 3.62, p = 0.06) which was not shown between 0^0 and 120^0 (F(1,46) 1.0), suggesting any possible difference was only in the 180^0 point.

The results of the analysis of the modified accuracies suggests that the increase in errors as a function of orientation under the condition of short exposure and masking during subordinate naming were not failures to correctly identify the object at the basic level but were errors in identification only at the subordinate level.

Discussion

Minimal effects of orientation were found for basic level naming of rotated objects (0.42 ms/deg). When this set of objects was named a second time at the subordinate level, large effects of object orientation were shown (1.55

ms/deg) which is within the range of typical naming studies (0.71 - 2.50 ms/deg). These effects of orientation on subordinate naming were larger than those shown for basic level naming despite the fact that naming stimuli for a second time has been shown to reduce the effects of orientation on object naming (Jolicoeur, 1985). These findings suggest that normalisation is not required for basic level naming whereas subordinate level naming does require orientation normalisation.

In order to rule out the possibility that the minimal effects of orientation shown during basic level naming are reflective of large effects which have diminished through the repetition of multiple exemplars of the same basic categories, a post-hoc analysis similar to that employed in Experiment 2 was performed on the first presentation of a basic level exemplar. In order to reduce the noise introduced by subject variability, the subject's mean naming latency was subtracted from these individual data points. The resulting effect size of orientation for this first presentation was < 0 ms/deg suggesting that the initial basic level naming was performed independent of stimulus orientation!

Clearly the minimal effect of orientation shown for basic level naming was not the result of reduction through exemplar repetition as there was no effect of orientation to reduce. As the post-hoc analysis of subordinate match decisions from Experiment 1 demonstrated that this form of analysis is capable of detecting the effects of orientation when present (see discussion Experiment 2), the current post-hoc analysis suggests that the significant linear trend shown for basic level naming in Experiment 4 is not reflective of initial object identification. Additionally, it should be noted that the magnitude of the orientation effect during basic level naming (ms/deg = 0.42) was much smaller than is typically found in rotated object naming studies (ms/deg = 0.71 - 2.5).

The possibility remains, however, that the first trial analysis may be insensitive to the diminutive effect of orientation shown during basic level naming. In order to increase power of this analysis, the first half of each subject's data was analysed. If the effects of orientation shown during basic naming reflect early use of a normalisation process which has been reduced through repeated presentation of exemplars then the effect of orientation during the first half of the experiment should be larger than the overall effect. The resulting linear trend between 0^0 and 120^0 did not reach significance although it was marginal ($F(1,235) = 3.65$, $p = 0.05$; $MS_e = 8700$; ms/deg = 0.29). This first half analysis is consistent with the analysis of the first presentation and suggests that the effect of orientation shown during basic level naming did not reduce over the course of the experiment. Furthermore, given the pattern of these post-hoc results and the overall analysis where the magnitude of the effect of orientation gets larger with the addition of more trials (ms/deg < 0, ms/deg = 0.29, ms/deg = 0.42 for the analysis of first trial, first half, first block, respectively) it appears that the effects of orientation increased over the course of basic level naming rather than diminished. As such, basic level naming appears to have been initially orientation-invariant. Although not necessary in order to perform the task, subjects may have identified objects in a more subordinate fashion as the experiment progressed. As subjects were instructed to respond with a specific set of names, there is no way to determine if subjects were indeed processing the stimuli beyond the basic level prior to responding during the basic naming task. We shall return to examine this possibility further during the general discussion.

In contrast to the minimal effects of orientation shown for basic level naming, subordinate level naming resulted in effects of orientation suggestive of normalisation (ms/deg = 1.47) which was within the range of previous rotated object naming studies (0.71 - 2.50 ms/deg). When subjects named the stimuli at the subordinate level, they had already been exposed to this stimulus set during the basic level identification. Because naming the same stimuli a second time has been shown to reduce the effects of orientation during rotated object naming (Jolicoeur, 1990; McMullen & Jolicoeur, 1990; 1992), this larger effect of orientation from the second presentation provides particularly compelling support for the view that normalisation is required only for subordinate level identification. Taken in conjunction with the finding that initial identification at the basic level is independent of orientation, this large effect of orientation for subordinate naming is consistent with the argument that in previous naming studies, use of the Snodgrass & Vanderwart (1980) stimulus set may have promoted a portion of the stimuli to be named at the subordinate rather than at the basic level.

Examination of the accuracy data showed a systematic decrease in naming accuracy with orientation for both basic and subordinate level identification, but only under the condition of brief exposure and masking. The lack of an interaction between orientation and level of naming in this accuracy effect suggests the possibility that the effect during subordinate identification arose from an inability to obtain the basic level identification. However, the modified scoring of subordinate responses demonstrated that this interpretation was unfounded. The modified subordinate scoring of accuracy, where responses were considered correct if a subordinate response identified the object as a member of the correct basic category, demonstrated that the errors in the subordinate naming were within-basic category errors. The increase in within-basic errors as a function of orientation shown during the unmodified subordinate coding, is consistent with the interpretation that brief exposure and masking interferes with the normalisation route provided normalisation is required for subordinate identification (Jolicoeur, 1990). Furthermore, as the modified coding of the subordinate responses suggested that basic level identification was not interfered with, it follows that basic level identification does not employ normalisation.

However, for the initial basic level naming, errors were by definition, a failure to identify at the basic level. Although the difference in basic naming accuracies between 0° and 120° was 10% under conditions of short exposure and masking, this only translates to an increase in failure to identify of 0.96 more items. A systematic removal of each stimulus item and recalculation of accuracies, however, did not suggest that this effect was due to any one particular stimulus.

The decrease in accuracy as a function of object orientation during basic level naming suggests that brief exposure and masking interfered with the extraction of some critical information necessary to achieve basic level identification. Additionally, this information may be sensitive to orientation. With continuous exposure, this decrease in basic level naming accuracy disappears, with no resulting effect on basic level naming latencies, suggesting that normalisation is not required to correct for the misorientation. If normalisation were required for basic level naming, we would expect a main effect of exposure duration on basic level naming latencies and an increase in the effects of orientation under continuous exposure which were not found. These predictions arise from the following argument. The brief exposure and mask would terminate processing of items which are identified more slowly than the time provided by the exposure duration and mask. If the items responded to more slowly are identified at the relatively upright orientations, which the accuracy data suggest, then they would be included in the calculation of the naming latency at these orientations. However, as they would fail to be identified at the more extreme orientations due to the interference produced by the mask, the more extreme orientations would reflect only the more quickly identified items. Under continued exposure, all orientations would include the naming latencies for the more slowly identified items, and hence we would find both a main effect and an interaction between exposure condition and orientation. Examination of the basic level naming latencies showed neither a main effect nor an interaction between exposure duration and orientation. As such, normalisation does not appear to be required for basic level naming, although some aspect of basic level identification may be sensitive to stimulus orientation.

Although this failure to identify at the basic level was not replicated in the modified coding of the subordinate responses, the subjects had been exposed to the stimuli before naming at the subordinate level. Prior exposure is known to reduce the effects of orientation on object identification latencies (Jolicoeur, 1985; 1990; McMullen & Jolicoeur, 1990; 1992) and therefore, could potentially show a parallel result for naming accuracies.

However, explaining the reduction in the effects of orientation on naming accuracies based on familiarity with the specific stimuli does not follow from Jolicoeur & Landau (1984). Jolicoeur & Landau (1984) employed a brief exposure and mask manipulation during the naming of alpha-numeric stimuli and found no reduction on the effects of orientation for naming accuracy even after 12 repetitions of the same items. Jolicoeur has some unpublished data which replicated this finding using stimuli from Snodgrass and Vanderwart (See Jolicoeur & Humphrey, in press). When my subjects named the objects at the subordinate level, they had only been exposed to the stimuli once during basic level naming.

Effects of orientation on identification accuracies which are shown only under conditions of brief exposure and masking (Jolicoeur & Landau, 1984) have been interpreted as reflecting disturbances in "feature extraction" rather than employment of a normalisation process. Furthermore, brief exposure and masking is thought to disrupt the visual information upon which the normalisation process operates (Jolicoeur, 1990). Since the increase in errors as a function of orientation during subordinate naming does not suggest there was a corresponding increase in errors to identify the objects at the basic level, based on the modified coding of the subordinate responses, it appears that the information which was interfered with was sufficient for orientation-invariant basic level identification and the interference occurred during the normalisation required to achieve subordinate identification.

What might be this information which allows for orientation-invariant basic level identification and requires normalisation in order to achieve subordinate level identification? We would like to suggest the overall global shape of the object as a possible candidate. Rosch et al. (1976) pointed out that members from the same basic category share more overlap in shape than members from differing basic categories. Boucart & Humphreys (1992) demonstrated that semantic information is accessed automatically when attending to the global shape of an object. Earhard & Walker (1985) suggested that object processing may proceed from the outside to in, which would allow for determination of global shape prior to internal details. Such a processing strategy might account for initial identification at the basic level. The possible importance of global shape information will be discussed further in the general discussion.

The findings from basic and subordinate naming of rotated stimuli support the view that basic level identification may be independent of orientation while subordinate level identification requires a normalisation process. The effect of orientation on basic level naming latencies appears to have emerged over the course of the experiment rather than to have diminished with repeated exposure. This finding suggests that the repetition of exemplars (Jolicoeur, 1985; 1990; McMullen & Jolicoeur, 1990; 1992; Murray, 1997) is not responsible for the diminutive size of the effects of orientation. Although basic level naming accuracies reduced as a function of orientation during brief exposure and masking, this finding was not replicated in the modified scoring of the subordinate naming accuracies. Because effects on naming accuracies through brief exposure and masking have not been shown to reduce with repeated presentations (Jolicoeur & Landau, 1984), this failure to replicate the finding coupled with the observation that the difference in accuracy between 0^{0} and 120^{0} reflects an increase in error of identification of less than 1 item, suggests caution in the interpretation of this effect. Regardless, should the effect be reliably replicated suggesting that basic level identification may rely on information which is sensitive to misorientation, the basic naming latencies do not suggest that a normalisation process is employed to correct this information during basic level naming.

Experiment 5

Introduction

From the previous series of match/mismatch and naming studies we have shown evidence that basic level identification may be achieved via orientation-invariant processing. In contrast, subordinate identification appears to require orientation normalisation of this basic level representation.

The results of the experiments so far have been consistent with the explanation that the effects of orientation on object identification occur after basic level identification (Corballis, 1988) rather than prior to any level of object identification (Jolicoeur, 1985; 1990). As a final test, Experiment 5 examines the effect of stimulus degradation on the effects of orientation during object identification. Stimulus degradation is thought to operate at the encoding stage (Sternberg, 1969). If the effects of orientation are prior to any level of object identification (Jolicoeur, 1985; 1990), then it seems reasonable to assume these effects lie in the encoding stage of the object. Based on Sternberg's additive factors logic (1969), degraded stimuli should show larger effects of orientation than non-degraded stimuli. However, if, as suggested by the findings of Experiment 1 through 4, the effects of orientation reflect a normalisation process operating on visual information encoded sufficiently to produce orientation-invariant basic level recognition, then stimulus degradation should be additive with orientation.

In order to test these two hypotheses, subjects were asked to make subordinate level match/mismatch decisions where the mismatch items shared basic level identity with the presented verbal label. This condition was chosen as both match and mismatch decisions show large and equal effects of object orientation (see Experiment 1 group "SB") and would allow the collapsing over response to increase the stability of the resulting data which should operate in favour of detecting any interactions if they are present. Half of the stimuli for both responses were degraded while the remaining were presented intact.

Methods

Subjects:

58 subjects (28 male, 30 female) between the ages of 18 and 27 years participated voluntarily or received 1 credit point towards an Introductory Psychology course. Data from 10 subjects were dropped from the analysis for failing to meet the selection criterion of an overall performance of 80% correct, with a minimum of 75% accuracy at each orientation when collapsed across response for both intact and degraded stimuli. Analysis is based on the data from 24 males and 24 females. No subjects had participated in any other experiment reported in this thesis.

Apparatus:

The same apparatus and stimulus set was used as in the previous four experiments with the following exceptions. Two new basic categories containing 12 stimuli each were added, resulting in 96 different stimuli. These were the categories "fish" and "chair"; three of the chairs were selected from Snodgrass & Vanderwart (1980). Because new stimuli were being added, (fish and chairs) the opportunity was also taken to replace 13 of the exemplars from Snodgrass and Vanderwart (1980) from the other six categories. Because items in the current stimulus set were scanned from photographs, they tend to be more detailed images than those found in Snodgrass and Vanderwart (1980). These substitutions were made to replace some of the less detailed stimuli. All but two of these replacements employed a new exemplar of the same object (i.e., a new penguin) while the "peacock" and "cockroach" were replaced with a "vulture" and "beetle", respectively. Finally, the hot air balloon was replaced with a new exemplar for the same reasons. Half of the stimuli in each category were degraded by randomly turning off 50% of the pixels comprising the image. The stimuli which were degraded were counterbalanced across subjects.

Design:

Across all subjects, every object was shown twice at every orientation in both the normal and degraded state, once as a match and once as a mismatch.

Procedure:

The procedure was identical to that of Experiment 1 group "SB", where the mismatch names were members of the same basic category as the stimuli. Mismatch names were never names of items which appeared as objects.

Results

Response Time:

Based on the findings from Experiment 1, group "SB", it was expected that response (match/mismatch) and orientation would not interact. This was confirmed in a preliminary within-subjects ANOVA where Orientation (6), response (2), and stimulus degradation (2) were entered as factors. There was a main effect of response ($F(1,47) = 9.14$, $p < 0.01$; $MS_e = 106277$) with match responses being faster than mismatch responses (944 ms vs. 1002 ms respectively which was also shown in Experiment 1). Apart from an interaction in the symmetry check between 120^0 and 240^0 ($F(1,235) = 14.33$, $p < 0.001$), none of the interaction contrasts involving response and any other variable reached significance (all $F(1,235) < 2.95$, $p > 0.09$). The data were recollapsed and analysed in a within-subjects two-way ANOVA with Orientation (6) and stimulus degradation (2) as factors. The results of this procedure may be seen in Figure 14.

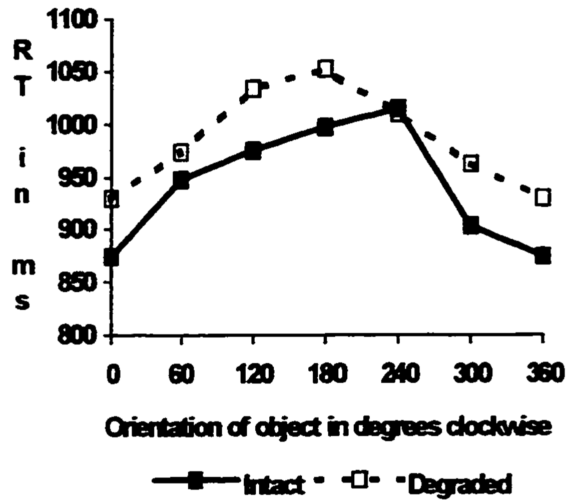


Figure 14: Effects of object orientation on latency to make subordinate level match/mismatch judgements to intact and degraded stimuli with the mismatch word-object relationship of sharing basic level identity.

There was a main effect of orientation ($F(1,235) = 8.58$, $\underline{p} < 0.001$; $MS_e = 26829$) due primarily to a linear trend between 0^0 and 180^0 ($F(1,235) = 39.23$, $\underline{p} < 0.001$; ms/deg = 0.74) which remained significant between 0^0 and 120^0 ($F(1,235) = 26.81$, $\underline{p} < 0.001$; ms/deg = 1.04). There was a main effect of stimulus degradation ($F(1,47) = 8.60$, $\underline{p} < 0.01$; $MS_e = 29183$) showing faster responses to non-degraded stimuli as compared to degraded stimuli (952 ms vs. 993 ms, respectively). The effect of orientation did not interact with stimulus degradation ($F(5,235) < 1.0$; $MS_e = 24097$) and more importantly, there was no interaction in the linear trends between 0^0 and 180^0 ($F(1,235) < 1.0$; ms/deg = 0.77 and 0.72 for non-degraded and degraded stimuli respectively). Nor was there an interaction in the linear trends between 0^0 and 120^0 ($F(1,235) < 1.0$; ms/deg = 0.83 and 1.19 for non-degraded and degraded stimuli respectively).

Percent Correct:

The accuracy data were collapsed over response and analysed in a similar fashion to the reaction time data. The data appear in Figure 15.

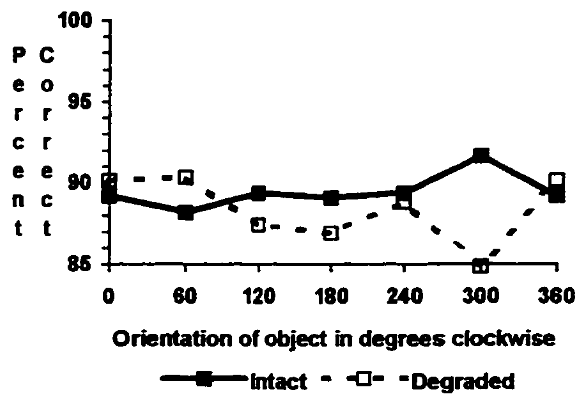


Figure 15: Effects of object orientation on the accuracy of subordinate level match/mismatch judgements to intact and degraded stimuli with the mismatch word-picture relationship of sharing basic level identity.

Apart from a marginal effect of stimulus degradation ($F(1,47) = 3.55$, $p = 0.06$; $MS_e = 78.25$) and a significant interaction in the symmetry check between 60^0 and 300^0 across stimulus degradation ($F(1,235) = 7.52$, $p < 0.01$), no effects reached significance.

Discussion

Degraded stimuli were responded to more slowly than intact stimuli during subordinate level match/mismatch decisions. However, stimulus degradation was additive with object orientation. The current findings are consistent with effects of orientation occurring after the encoding of the object in order to achieve a basic level identification. This basic level identity may be employed to guide a normalisation process to the upright for subordinate level identification. Similar findings of additivity between stimulus degradation and identification have been shown by Sternberg (1969).

Sternberg (1969) demonstrated that stimulus-response compatibility interacted with the size of the potential stimulus set and concluded that these factors were operating after the encoding stage and during the "translation and response organisation" stage. Requiring subjects to name the objects at the subordinate level effectively increases the number of potential responses (e.g., dog vs. collie, German Shepard, poodle, etc.). The interaction between orientation and level of identification may therefore be considered an interaction between orientation and response set size. This interpretation further supports the notion that the effects of orientation are operating late in visual processing, during the determination of the subordinate level identity.

The normalisation process appears to be employed in order to distinguish between members of the same basic category. Phrased another way, this amounts to a method for selecting the appropriate subordinate name through further visual processing of the stimulus (Rosch et al., 1976; Jolicoeur et al., 1984). For example, if subjects were aware that the only dog employed in the experiment were a collie, then upon determining an item were a dog they would be able to respond "collie" without having to perform the necessary normalisation process. However, as found in this thesis, when there are multiple exemplars competing for subordinate identification, large effects of orientation are found in identification latencies. These speculated results of s single exemplar study would result in an interaction between number of alternative responses (i.e., only "collie" or "many dogs") and orientation. However, the explanation for this interaction is the same as that which has been put forth in this thesis; that basic level identification is achieved independent of orientation and would be sufficient to produce the response "collie" in the case of the single exemplar. To access the identifying representation which differentiates "collies" from "other dogs", further visual processing is required, during which orientation normalisation is employed in order to select the correct subordinate identity.

General Discussion

Throughout this thesis I have examined when effects of orientation arise during rotated object identification. Consistently, support has been shown for the interpretation that initial basic-level object identification proceeds independent of orientation, with a normalisation process required for subordinate level identification of the object. These findings do not support models of object recognition which postulate normalisation prior to any level of object identification (Jolicoeur, 1985; 1990). I shall give an overview of the major findings of the experiments presented in this thesis and the implications of these findings for current theory. Following this discussion, I shall present the model of object identification which was tested and shown to be inadequate. Using the tested model as a base, I shall suggest modifications which incorporate the findings of this thesis in order to present a new model of object recognition which combines aspects of orientation-invariant and orientation normalisation theories.

Summary of Major Findings

In Experiment 1, subordinate level object identification was measured using a subordinate name - rotated picture match/mismatch task. For match decisions, reaction times increased linearly as a function of object orientation up to 120^0 from upright. Reaction time to objects rotated 180^0 was less than would be predicted by extrapolating the data from the less rotated conditions, paralleling the effects seen in latencies for rotated object naming (e.g., Jolicoeur, 1985; 1990; McMullen & Jolicoeur, 1990; 1992; McMullen et al., 1995; Murray, 1997). This indicates that subordinate matching probably relies on the same mechanisms as rotated object naming. Furthermore, the effect of misorientation was present when data from the first presentation of an item from each basic category was examined. The size of the orientation effect as measured by this first item analysis was similar to the overall orientation effect, demonstrating that the repeated presentation of exemplars did not reduce the magnitude of the effects of orientation (Jolicoeur, 1985; 1990; McMullen & Jolicoeur, 1990; 1992; Murray, 1995a; 1995b). This concern about repetition of exemplars becomes more of an issue with Experiments 2, 3, and 4.

The pattern described above for match trials was found with the mismatch responses when the subordinate name and the presented object were members of the same basic category. The magnitude and nature of the effect of orientation were similar to those found in rctated object naming studies (e.g., Jolicoeur, 1985; 1990; McMullen & Jolicoeur, 1990; 1992; McMullen et al, 1995; Murray, 1995a; 1995b; 1997), indicating the same mechanisms may underlie within-basic category subordinate mismatch decisions as rotated object naming.

In contrast, when the subordinate name and rotated object were members of different basic categories, no effect of orientation was shown on mismatch judgements. One explanation for this finding is that basic level identification is independent of orientation (Corballis, 1988). Alternatively, mismatch judgements in this condition may reflect the detection of a single feature which ruled out the match possibility without actually identifying the object.

In order to determine if basic level identification is independent of orientation, a second match/mismatch experiment was conducted in which basic level names replaced the subordinate names of Experiment 1. Again, mismatch trials, which by definition cross basic categories, showed no effect of orientation. Unlike Experiment 1, basic level match decisions did not show a significant effect of orientation between the important orientations of 0° and

120^0 (Jolicoeur, 1990). Furthermore, examination of the first instance of a basic category did not show an effect of object orientation and therefore the lack of an effect was not due to repeated presentation of exemplars within a basic category (Jolicoeur, 1985; 1990; McMullen Jolicoeur, 1990; 1992; Murray, 1995). The insensitivity to orientation shown for basic level positive identifications suggests that basic level identification may be achieved independent of orientation (Marr, 1982; Biederman, 1987, Corballis, 1988).

Subordinate level identification requires further visual processing beyond the basic level, while superordinate identification requires further semantic processing beyond the basic (Rosch et al., 1976; Jolicoeur et al., 1984). If further processing alone is sufficient to produce effects of orientation then superordinate match/mismatch judgements should show effects of orientation. However, if further visual processing is required, then superordinate judgements should also be independent of orientation whereas subordinate decisions would show effects of orientation. Subordinate decisions have been show to be sensitive to object misorientation, and the results from Experiment 3 further supported these second hypotheses. Analysis of the first presentation of each basic category in Experiment 3 did not suggest superordinate decisions initially were affected by object orientation, and that this effect diminished with repeated presentations of exemplars.

Experiments 1 through 3, show that basic level identification may be achieved invariant of object orientation. In order to determine if the same findings are found with the object naming paradigm, subjects were asked to name objects at the basic and subordinate levels. As repeated presentation of the same stimuli would be expected to reduce the effects of orientation for the second viewing (Jolicoeur, 1985; 1990; McMullen & Jolicoeur, 1990; 1992; Murray, 1995a; 1995b; 1997), subjects named the stimuli at the basic level on the first block and at the subordinate level on the second block.

The effects of orientation on naming latencies were not affected by the exposure duration. Larger effects of orientation were found for subordinate naming latencies than for basic naming latencies, suggesting that different underlying processes are operating during basic and subordinate levels of identification. The magnitude of the orientation effect on subordinate naming (1.5 ms/deg) was within the range found for other rotated object naming studies (0.71 - 2.5 ms/deg) which would support the argument that the effects of orientation on object identification latencies shown in the literature may be more reflective of subordinate identification than of initial basic level identification.

The small effects of orientation sometimes shown on basic level naming latencies may reflect an occasional verification via a post identification orientation normalisation process (Corballis, 1988). However, because the dependent measure was median naming latency, the finding of these effects suggest that "occasional" must represent a percentage of at least 50% of the trials. Analysis of the first exemplar of a basic category resulted in no indication of normalisation (< 0 ms/deg); analysis of the first half of the trials showed no significant effects of orientation though the magnitude of the effect seemed to be increasing (0.29 ms/deg); and finally when all of the trials were included, a significant effect of orientation was found, although it was much smaller (0.42 ms/deg) than effects typically found for rotated object naming (0.71 - 2.5 ms/deg). This pattern suggests that as the experiment progressed, basic level naming switched from orientation-invariant processing to orientation-dependant processing. A simple explanation for this finding is that subjects began to process some objects beyond the basic level prior to responding with the instructed basic name. This is a possibility we will return to.

Effects of orientation were shown in identification latency and accuracy for both basic and subordinate naming when stimuli were briefly exposed and masked. Under long exposure, effects of orientation were only shown for identification latencies. These findings parallel other studies in which brief exposure and masking interacted with identification accuracy but not identification latency of rotated alpha-numeric stimuli (Jolicoeur & Landau, 1984). The decrease in accuracy with rotation from upright was similar for both basic and subordinate naming between 0^0 and 120^0 of misorientation. As subordinate identification is thought to build upon a basic level identification (Rosch et al., 1976; Jolicoeur et al., 1984), the similar decrease in performance for basic and subordinate identification suggests that the brief exposure and mask may have interfered with basic level identification in both tasks.

The possibility that brief exposure and masking interfered with basic level identification for both basic and subordinate naming was not supported by a modified coding of subordinate naming responses in which any response indicating that a correct basic level identity had been achieved was scored as correct. This modified coding resulted in the elimination of the effects of orientation in the subordinate naming data. As such, it appears that the similarity of the effects on accuracy are coincidental and do not reflect an inability to extract basic level identity. Since repetition of the same stimuli has not been shown to reduce the effects of brief exposure and masking on the effects of orientation on identification accuracies (Jolicoeur & Landau, 1984), and since the accuracy data during basic level naming reflected a difference of less than 1 more error between the most and least accurate orientations, the effect may be due to the lack of practice trials to familiarise the subjects with the timing of the display.

In Experiment 5 the effects of stimulus degradation on rotated object identification were examined during subordinate match/mismatch judgements where mismatch objects shared basic level identity with the name. It was predicted that if the effects of orientation are prior to object identification during encoding of the stimulus (Jolicoeur, 1985; 1990), then stimulus degradation would interact with orientation (Sternberg, 1969). However, if the effects of orientation are after the object has been encoded and identified at the basic level (Corballis, 1988), then orientation and stimulus degradation should be additive (Sternberg, 1969). The results replicated the findings of Experiment 1 in that large and equivalent effects of orientation were found for both match and mismatch responses. Furthermore, the effects of orientation were additive with stimulus degradation. Consistent with the findings throughout this thesis, these results support theories which suggest that objects may be identified, at least at the basic level, independent of orientation (Biederman, 1987; Corballis, 1988; Marr, 1982), with normalisation required only for subordinate level identification.

Hummel & Biederman (1992) have proposed an alternative to the view that effects of orientation during rotated object naming arise through the use of a normalisation process. Hummel & Biederman (1992) have suggested that misorientation degrades critical information concerning the spatial arrangements of the geons and this degradation results in the effects of orientation on object identification latency. They present a computational model, JIM (John and Irv's Model) which produces a pattern of effects of orientation which is similar to rotated object naming. JIM was presented to explain the effects of orientation found in the literature which were thought to reflect basic level identification (Jolicoeur, 1990). However, as I have argued throughout this thesis, the effects of orientation found in the literature appear to correspond more with subordinate level identification than with basic level identification. As such, I will address

Hummel & Biederman's computational model based on results from subordinate level identification experiments.

Hummel & Biederman (1992) suggest that effects of orientation result from a degradation of information concerning the encoding of the spatial relations amongst the geons. As in Jolicoeur's (1990) model in which he postulates a normalisation process during the encoding stage, Hummel & Biederman's JIM would predict an interaction between orientation and stimulus degradation. As previously mentioned, the effects of stimulus degradation were additive with orientation and did not significantly interact with object orientation. This lack of an interaction on the magnitude of the orientation effect suggests that the effects of orientation do not arise during the encoding of the stimulus (Sternberg, 1969), contrary to the explanation put forth by Hummel & Biederman (1992).

Furthermore, the JIM model predicts that precueing orientation information should produce a reduction in the effect of orientation by disambiguating the alignment of the object and therefore the relative spatial relations of the geons. Precueing of orientation has not been shown to reduce the effects of orientation on rotated object naming (McMullen et al, 1995). Similarly, precueing of orientation is additive with orientation in a left/right discrimination task (Cooper & Shepard, 1973). The left/right discrimination task is thought to employ mental rotation. Because precueing of orientation did not interact with object orientation during rotated object naming (McMullen et al., 1995), the effects of orientation during subordinate identification may reflect a normalisation process, which itself may be mental rotation.

Towards a unification of orientation-invariant and orientation-dependent models of rotated object identification

For the next section of the Discussion, I will describe a model of object recognition which is derived from a combination of models presented in the literature. The core structure of this model is based on dual route models of rotated object recognition (Humphreys & Riddoch, 1984; Jolicoeur, 1990) coupled with the order of identification findings of Rosch et al. (1976), and Jolicoeur et al. (1984). As modifications to the model are required, I shall describe the resulting implications. I shall continue this gradual process of model building and modification until the end of the discussion.

To begin, dual route models of object recognition postulate that wholistic and feature-based processing operate in parallel and may each result in the identification of an object (Humphreys & Riddoch, 1984;

Jolicoeur, 1990). Jolicoeur (1990) has suggested that the wholistic route employs orientation normalisation in order to achieve identification. Furthermore, Jolicoeur (1990) has suggested that the influence of the feature-based identification route is not apparent on the first presentation of a stimulus unless the object is presented at, or near, 180^0 because the feature-based route operates much more slowly than the normalisation route. However, identification resulting from the feature-based route increases in speed with repeated presentation of the stimuli because the identification becomes based upon orientation-invariant features which are stimulus-specific and do not aid in the initial identification (Jolicoeur, 1990). Jolicoeur's 1990 dual route model is shown in Figure 16.

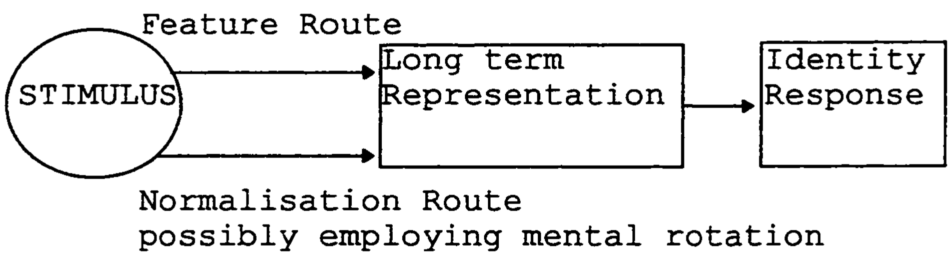


Figure 16: Depiction of Jolicoeur's dual route model of object identification.

If we combine the above model with that of Rosch et al. (1976) and Jolicoeur et al., (1984) we would obtain the model shown in Figure 17 of basic level identification for typical exemplars. In this diagram, I have not included the superordinate identity within the area depicting the long term representation because superordinate identification is thought to be semantically derived from contact with the basic level representation and therefore may be fundamentally different from a visual-based representation (Posner, 1978).

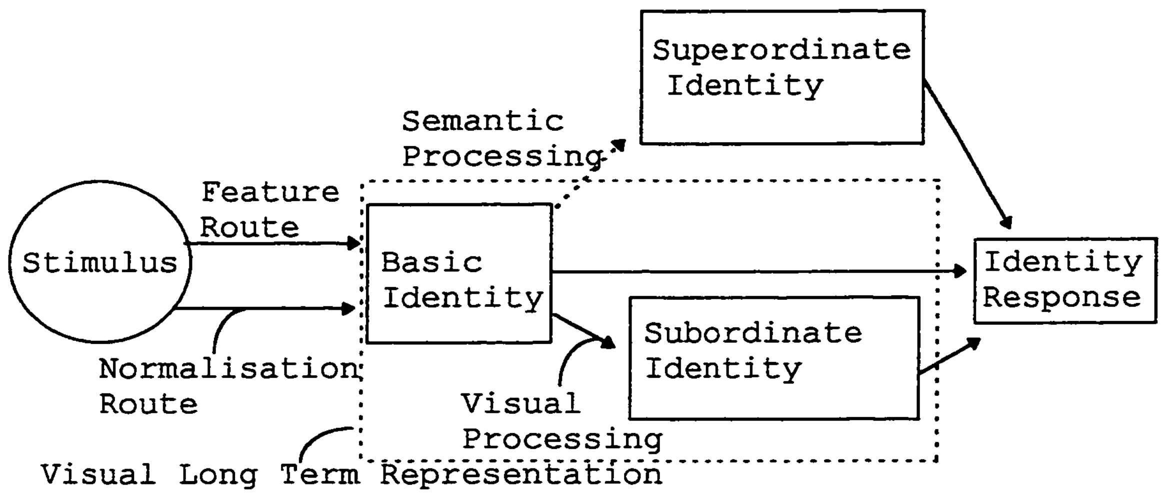


Figure 17: Graphic representation of Jolicoeur's dual route model and order of identification model (Rosch et al., 1976; Jolicoeur et al., 1984)

The model represented in Figure 17 was tested throughout the experiments presented in this thesis. The predictions from this model as presented above were 1) that large effects of orientation would be found for all levels of identity as initial identification of a stimulus relies primarily on the normalisation route (Jolicoeur, 1990) and 2) that stimulus degradation would interact with orientation as the normalisation process is thought to operate during the encoding of the object (Hummel & Biederman, 1992; Jolicoeur, 1990). Feature-based identification requires familiarity with the specific stimuli and would not play a large role in identification on the initial presentation, save perhaps during 180^0 rotations (Jolicoeur, 1990). The above predictions were not confirmed, because only the subordinate level identification was shown to be affected by stimulus orientation in a manner suggestive of normalisation, and this effect did not interact with stimulus degradation. The lack of an effect of orientation on basic and superordinate level identification negates the necessity to postulate a normalisation route prior to access of the basic level identity. However, as large effects of orientation are found for subordinate identification, a normalisation route may be included between basic level identification and subordinate level identification suggesting that orientation normalisation may be part of the visual processing required for subordinate identification (Rosch et al., 1976; Jolicoeur et al., 1984). As Jolicoeur postulates a feature-based route in order to explain the reduction of the effects of orientation, I will place this feature-based route as operating between the basic and subordinate levels of identification where it would continue to diminish the effects of orientation. By moving both the feature and normalisation routes, I must include a new route between the stimulus and basic level identity. For now, I shall simply refer to this route as "an orientation-invariant route". I will return later to a discussion of this route.

A further modification will be made to the model depicted in Figure 17. This modification deals with the distinction between a basic level name and what I shall refer to as a basic level visual class. I have argued that the object set presented in Snodgrass & Vanderwart (1980) contains many items which may be considered members of the same basic category, such as birds. Furthermore, it seems likely that the same processing which is required to differentiate between breeds of dogs would be required to differentiate between shirts and jackets, even though dog, shirt, and jacket may each be considered a basic level name.

In order to name an object, the visual processing system must contact a language-based semantic network. We must be careful, when examining questions concerning visual object identification, to ensure that the effects we find are not due to some aspect or limitation of the semantic system. As an example, I have suggested that in order to name an object which could either be a shirt or a jacket, which have been argued to be basic level names (Jolicoeur, 1985; 1990; Snodgrass & Vanderwart, 1980), that the visual system will operate in a fashion similar to that used in subordinate identification of different dogs. The reason for this is that there is no word which corresponds to the basic visual class of shirts/jackets; we don't call them "torso covers", whereas Collies and German Shepards share the same visual class which is nameable as "dog". The importance of separating visual information and name-based information has been pointed out by various researchers (i.e. Miller, 1970; Pavio, 1975; Posner, 1978).

In this regard, the final modification to the model presented in Figure 17 is to change the terms for the basic and subordinate identities in the long term representation to general and specific visual class respectively, and to connect these representations to verbal semantics, defined below. A similar separation into general and specific representations is shown by Marr & Nishihara (1978; see Figure 8). I am using the term "verbal semantics" in order to distinguish language-based semantic knowledge from non-verbal semantic information (i.e., appropriate motor movements involved in the use of an object; Rosch et al., 1976). It is this aspect of semantic knowledge which is thought to be involved in the determination of the superordinate identity (Rosch et al., 1976; Jolicoeur et al., 1984).

The modified model is shown below in Figure 18, I have labelled the area representing the "long term visual representation" simply as LTVR.

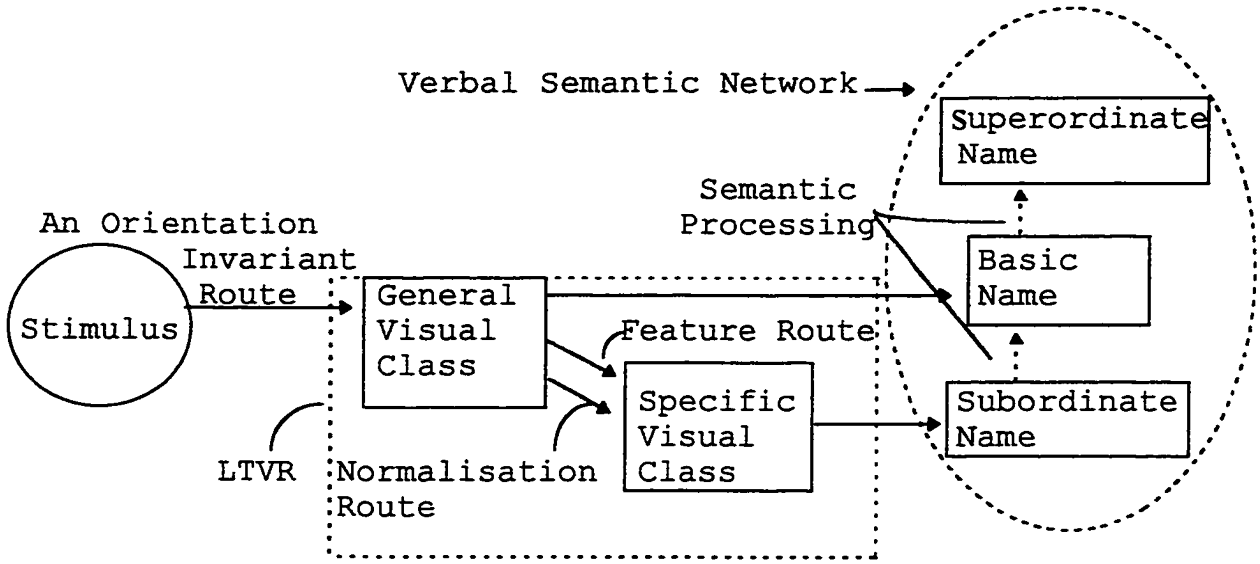


Figure 18: Graphic representation of a modified version of Jolicoeur's dual route model and order of identification model (Rosch et al., 1976; Jolicoeur et al., 1984)

The connections between the visual classes and semantics as represented in Figure 18 correspond to the findings of the experiments presented in this thesis. Each of the basic categories employed were visually distinct and would access different "general visual classes". Each of these "general visual classes" map on to a basic level name (e.g., "dog"). In order to differentiate members of the same "visual class", normalisation is employed which accesses a "specific visual class" representation which then maps onto the subordinate name (i.e., "Collie"). Items from the Snodgrass & Vanderwart set, such as the shirt, blouse, sweat shirt, jacket, vest, overcoat, would also access a common "general visual class". However for this class there is no connection into semantics (i.e., there is no "torso cover"). As such, in order to name these items, visual processing would have to proceed in order to access the "specific visual class" representation before an entry into semantics could be found.

This model is useful in describing why effects shown for studies which compare one stimulus to another may show effects of orientation, such as left/right judgements of objects (McMullen & Jolicoeur, 1990; 1992), when identification of these objects may not, as shown in this thesis. In order to compare two simultaneous stimuli, or to decide if a stimulus was seen before, we are comparing specific representations and not general visual classes.

The reduction of the effects of orientation upon repeated naming is thought to arise from increased employment of the feature-route between the general and specific visual classes. There is, however, another possibility. Once the subject has become familiar with the stimulus set, some items may be identified at the specific level when the general visual class has been determined. For example, if the only "shirt/jacket" item in the stimulus set were the sweatshirt, then upon second presentation when this general visual class becomes active then the response "sweatshirt" may be given.

Another possibility is that until the subject has been exposed to the stimulus set, the number of possible responses at the subordinate level for a given visual class is far greater than after the subject has named the items once. There are far more than twelve breeds of dogs. Sternberg (1969) has shown that the number of alternative responses operates on the selection of the response. Normalisation appears to be necessary to select a specific response. Once a subject has been exposed to the stimulus set, we have effectively reduced the number of possible responses.

The notion that normalisation is required to differentiate items which access the same "general visual class" is supported by the finding that larger effects of orientation are found when determining that a polygon is not a target when the non-target item is of a highly similar shape to the target as compared to a less similar shape (Folk & Luce, 1987). The Folk & Luce (1987) study employs a paradigm involving recognition of a specific item previously seen before, which I've argued may not reflect the same processing required for object identification. However, the model presented in Figure 18 accounts for why these paradigms both show large effects of orientation and why they may not predict effects on naming. Again, effects of orientation arise through the need to access the "specific visual class" regardless of whether or not the object could be named after access to the "general visual class". The more similar the items, the more difficult the discrimination, and hence the greater need for normalisation.

The above model may incorporate the findings of Tanaka & Taylor (1991) who found that experts name objects from their area of expertise at the subordinate level as quickly as at the basic level. Additionally, experts listed more defining features for objects in their expertise at the subordinate level as compared to novices. Both of these findings suggest that the subordinate level for experts was represented in a manner which is similar to the basic level for novices. With increasing knowledge and experience, objects in an area of expertise may develop their own "general visual class". For dog experts[5] "setters" and "retrievers" will each map onto their own "general visual class" representations which are linked to semantics at the subordinate name level. Upon presentation of a "setter", both the general visual class of "dog" and "setter" will activate and the response will depend on which representation produces a response first. As such, both the

[5] Dog experts tend to have areas of expertise, such as sporting dogs, terriers, non-sporting dogs and toys, so the above example would only apply to experts of sporting dogs.

"basic" and "subordinate" names will produce equal naming latencies and should be produced equally often. Both of these predictions were confirmed by Tanaka & Taylor (1991).

Additionally, the model provides two possible explanations for the finding that atypical exemplars are identified more quickly at the subordinate level as compared to the basic level (Jolicoeur et al., 1984). The first is based on the visual differences between atypical and typical exemplars. Typical exemplars, being highly similar in appearance (Rosch et al., 1976; Jolicoeur et al., 1984) will map onto the same general visual class which connects to semantics at the basic level name (i.e., "bird"). Atypical exemplars, being visually distinct, may map onto a separate general visual class which is linked to verbal-semantics at the subordinate name, and the basic level name is then derived from semantic knowledge (Jolicoeur et al., 1984). Under such conditions, subordinate identification of atypical exemplars will be faster than typical exemplars at the subordinate level with the reverse pattern shown for basic level identification. This pattern of identification latencies was obtained by Jolicoeur et al. (1984). This explanation predicts that atypical exemplars will not show effects of orientation on subordinate or basic level identification as both responses require activation of a general visual class which is orientation-invariant, with basic level identity being derived semantically. This is similar to the explanation for why neither basic nor superordinate identification show effects of orientation (see Experiments 2 and 3)

A second explanation for the faster subordinate identification of atypical exemplars than typical exemplars (Jolicoeur et al., 1984) involves the activation of the semantic response. Although atypical exemplars are visually different from typical exemplars (Rosch et al., 1976) these differences may not be sufficient to result in the formation of different general visual classes. However, the differences may result in weaker activation of the basic level name when presented with an atypical exemplar. Visual processing proceeds to contact the specific visual class which then activates the subordinate name. For typical exemplars, naming at the subordinate level will be interfered with by the high activation of the basic level name competing for response while atypical exemplars will have less interference due to the lower competition from the basic level name. Similarly, basic level naming will be rapid for typical exemplars due to the high levels of activation of the basic level name while atypical exemplars will be slower due to the lower levels of basic level activation. Because subordinate identification requires additional processing (Jolicoeur et al., 1984), the basic level name may be produced before any interference from the subordinate level name arises. So long as the basic level name becomes activated based on input from the general visual class rather than from semantic input from the atypical exemplar's subordinate name, this explanation predicts that subordinate naming of atypical exemplars will show effects of normalisation for subordinate identification but not for basic identification. However, assuming that visual processing continues until a response is made, atypical exemplars may show effects of orientation on basic level identification if they become identified at the subordinate level through normalisation and then semantically derive the basic level name more quickly than the general visual class activates the basic level name. The effect of orientation for basic level identification of atypical exemplars would therefore be equal to or less than the effect of orientation for subordinate level identification. This pattern would be predicted as atypical exemplars are requiring contact with a specific visual class which requires normalisation.

If in Experiment 4, some of the less typical objects were identified at the subordinate level and the basic level name retrieved semantically before the general visual class activated the basic level name, then this may explain why subjects might have processed some objects to the subordinate level prior to producing the basic level name. Examination of the upper and lower quartile of objects, in terms of their typicality ratings, supports this explanation. Highly typical exemplars showed effects of orientation of 0.90 ms/deg and 0.40 ms/deg for subordinate and basic level naming respectively. The less typical objects, however, showed effects of orientation of 1.94 ms/deg and 0.91 ms/deg for subordinate and basic level naming respectively. For highly typical exemplars, only subordinate naming showed effects of orientation suggestive of normalisation. However, both basic and subordinate naming of the less typical exemplars suggest the use of normalisation. Notice, however, that the effects of orientation during basic level naming are smaller than for subordinate naming of the less typical objects. This is the pattern which was predicted if, for less typical exemplars, normalisation for subordinate identification leading to semantic retrieval of the basic level name is faster than the orientation-invariant activation of the basic level name.

However, it must be noted that the current stimulus set does not contain many atypical exemplars. The lower quartile only represents less typical exemplars, and not atypical exemplars. If the current stimulus set contained more objects rated as atypical (typicality ratings of 1.00 -

2.50), then we may have found evidence for orientation-invariant identification at the subordinate-name level for these objects. Further research into this area is necessary.

<u>How might orientation-invariant identification be achieved?</u>

For this last section, I shall speculate on the processing which may achieve orientation-invariant identification of a general visual class. In Figure 18, we have a route simply labelled "An orientation-invariant route". It is important to note that the details of this route have not been directly tested by the experiments presented in this thesis. However, because we have demonstrated that basic level identification is orientation-invariant, we draw details for this route from orientation-invariant models of object identification.

Marr (1982; Marr & Nishihara, 1978) and Biederman (1987) suggest that the visual image is parsed at points of deep concavity into regions which may be roughly described by a cylinder (Marr, 1982; Marr & Nishihara, 1978) or some other simple geometric volume which Biederman (1987) refers to as a geon. Subsequent to this parsing, objects may be described in terms of a collection of these "geons" and the spatial arrangements between them. The information which arises from the geons and their arrangements would provide a general description of the global shape of the object.

Boucart & Humphreys (1992) have shown that attending to the global shape of an item results in semantic access, which suggests that global shape plays an important role in the early processes that lead to identification of objects. The orientation-invariant route shown in Figure 18 is therefore postulated to employ the previous processing which is able to provide a description of the global shape of the object. Global shape information may then be sufficient to access, or even be identical to, the representation of the general visual class. Figure 19 is an expanded version of Figure 18 in which the above details of the orientation-invariant route are filled in.

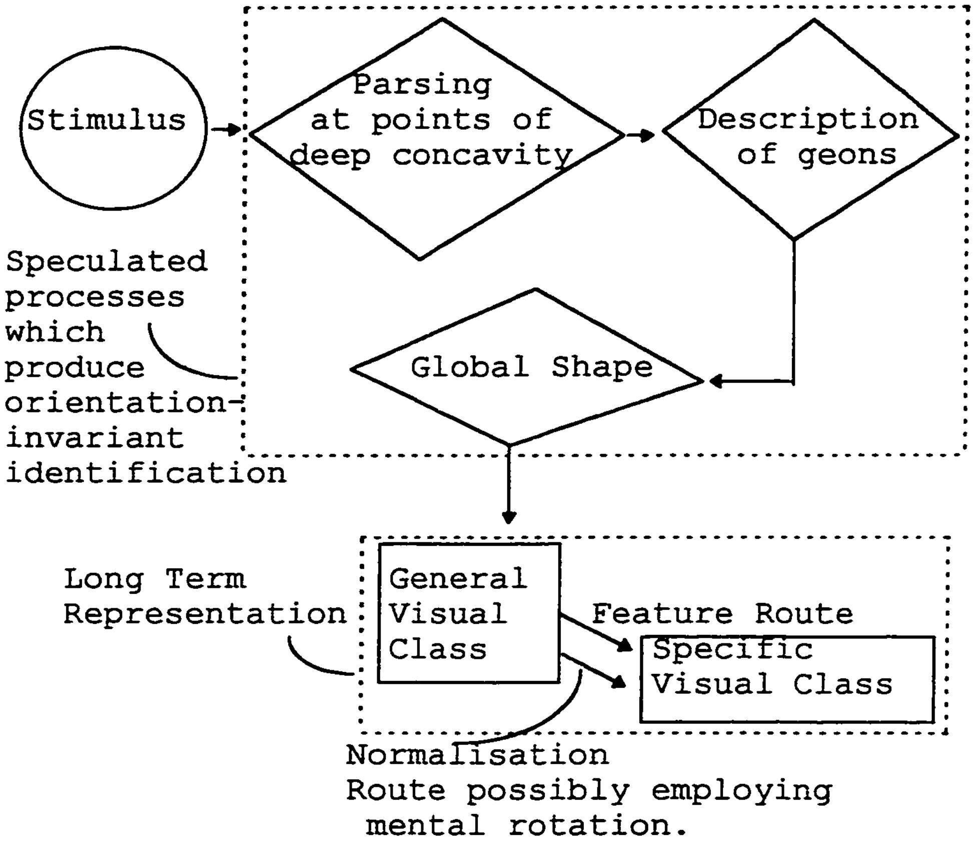


Figure 19: Graphic representation of proposed processes involved in orientation-invariant access to a general visual class and orientation normalisation for access to a specific visual class

Although the experiments in this thesis are not designed to examine questions concerning the details of this orientation-invariant route, we may examine the above speculative details to determine whether our results remain consistent with such an arrangement.

The pattern masking employed in Experiment 4 may have disrupted basic level identification by interrupting the geon identification stage or possibly by interfering with the calculation of the overall global share prior to accessing a basic visual class representation. If the determination of the spatial arrangements amongst the geons is affected by orientation (Biederman, 1987; Hummel & Biederman, 1992) then the pattern masking would be more likely to interfere prior to contact with a general visual class or prior to sufficient semantic activation when the stimuli are rotated. This may explain the decrease in basic level naming accuracies. However, as mentioned earlier, because this failure to identify at the basic level was not replicated with the modified scoring of the subordinate naming and because such effects of orientation on identification accuracy do not reduce through repetition (Jolicoeur & Landau, 1982), the above explanation may be unnecessary.

The pattern masking in Experiment 4 would disrupt the description of the global shape during the normalisation phase necessary to name the objects at the subordinate level, or to name the less typical objects at the basic level for reasons explained earlier. This disruption of the global shape did not appear to occur fast enough to prevent basic level identification, resulting in the subordinate naming errors to be within-category errors only. This suggests that the pattern mask interfered with the global shape during the normalisation necessary to access a specific visual class representation rather than the geon descriptions stage since basic level identification was achieved.

Unlike pattern masking in Experiment 4, stimulus degradation in the form of random pixel removal, as employed in Experiment 5, did not influence the effect of orientation on subordinate level judgements. Although this form of stimulus degradation would slow down the determination of the geons by degrading the line segments which comprise them, pixel removal would not impair the description of the global shape once the geons were determined. As was shown, 50% pixel removal produced a main effect on identification but did not interact with the effects of orientation.

In conclusion, the findings from the experiments presented in this thesis suggest that upon obtaining a description of the global shape of the object, the object may be determined to be a member of a general visual class of objects. In order to differentiate members of the same general visual class, the global shape information is normalised to the upright orientation, possibly through the use of mental rotation. Because members of the same general visual class will map onto the same upright orientation, the shortest direction of normalisation to the upright may be determined upon activation of the general visual class.

Hopefully, the distinction made between the "visual class" and the "semantic name" will help clarify some of the conflicts found within the literature. Future research is required in the examination of atypical exemplars in order to determine if atypical exemplars access the same general visual class representation as typical exemplars. Similar research into the areas of expertise may reveal that experts develop general visual class representations which correspond to a novices specific visual class. Finally, by determining the level at which orientation-invariant identification may occur, a systematic approach may be developed to determine the processing involved in achieving this level of object constancy.

As a closing note, I would like to reiterate here a few important methodological concerns when studying the above questions concerning object identification. Tasks which employ the comparison of two stimuli, either presented simultaneously or singularly and then later for specific recognition, may not reflect the processing involved in order to access a long term identifying representation. Furthermore, careful examination of the stimuli employed is required to determine what level of visual processing is required to perform the task. Many objects may belong to the same general visual class, but only be nameable after contact with specific representations which reflect subordinate identification; shirts and jackets. The match/mismatch procedure may be employed to examine both the normalisation process required to access a specific visual representation and the accessing of an orientation-invariant general visual representation. And finally, the match/mismatch procedure has benefits over object naming in the ability to manipulate the relationship between the name and the mismatch objects.

Appendix A

Stimuli used throughout the Experiments:

In order to obtain typicality ratings for the new stimuli employed in these experiments, half the subjects in experiments 1 through 3 rated the items in terms of how typical the exemplar represented its basic category on a scale of 1 to 7. This task was performed after the completion of the presented experiments. The number of objects which were rated 1 through 7 are shown in Table 1 below:

	Less ←						→ More
Typicality Rating	1	2	3	4	5	6	7
Number of Objects	0	1	10	14	21	25	1

Table 1: Typicality summary for objects used in Experiments 1 through 4.

Given that only one item in the object set was rated atypical (1-2), 45 were rated average (3-5), and 26 were rated highly typical (6-7) the entry level for this stimulus set should correspond to the basic level.

In the above set of 72 objects, 21 have been selected from Snodgrass & Vanderwart (1980). I have argued that these items are named at the subordinate level in rotated object naming studies; e.g., eagle. As entry level for atypical objects may correspond to the subordinate level, if these objects are atypical exemplars, then they should be rated low. The mean typicality rating for the exemplars selected from Snodgrass & Vanderwart (1980) is 4.92, which shows these objects are not atypical exemplars of their corresponding basic categories. Because the names used for the subordinate labels of these items are the names subjects spontaneously give during free naming studies, this supports my claim that free naming studies correspond to subordinate level identification of typical exemplars, and therefore may not reflect initial basic level identification.

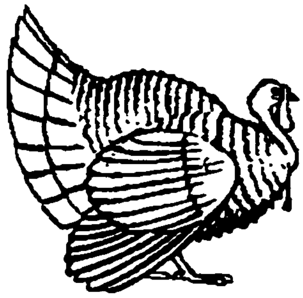
Finally, for Experiment 5, two new categories of objects were added to the stimulus set, namely the fish and chairs. As new stimuli were being employed, the opportunity was taken to replace eleven of the Snodgrass & Vanderwart stimuli with new exemplars of the same item. Two more objects were replaced with a new object. The cockroach was replaced with a beetle and the peacock was replaced with a vulture. Furthermore, a new exemplar of a hot air balloon was employed. Subjects in Experiment 5 then rated the new stimulus set in terms of basic level typicality.

For the following presentation of the stimuli, the objects are grouped by their basic level identity. Below each item is presented the name used during the subordinate match/mismatch tasks of Experiment 1 and 5 and two typicality values. The first value is the mean rating given by the subjects from Experiment 1 while the second value is the mean rating given by the subjects from Experiment 5.

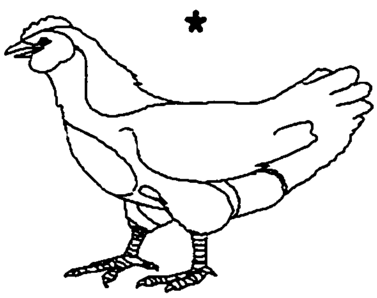
Stimuli marked with an asterisk are those items which replaced a Snodgrass & Vanderwart item. As such, the first typicality value was collected employing a different image than the one shown, which I've indicated by underlining the first value. Objects marked with the letters SV are objects found in the Snodgrass & Vanderwart corpus (1980). An item analysis showed that the rating of the objects given by subjects from Experiment 1 do not differ from those given by subjects from Experiment 5 ($t(142) = -1.72$, $p = 0.09$; mean rating 4.83 vs. 5.11) and the ratings were significantly correlated ($R^2 = 0.89$). More importantly, the typicality ratings for the new exemplars employed in Experiment 5 do not differ from those of the previous versions ($t(22) = -0.63$, $p > 0.50$; mean rating 4.92 vs. 5.13) and again were significantly correlated ($R^2 = 0.89$). Finally, as subjects in Experiment 1 had not rated the fish or chairs the first of the typicality ratings is marked as N/A.

BIRDS

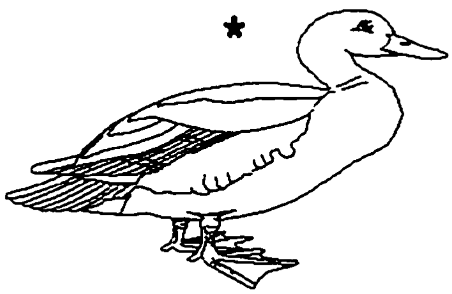
BUDGIE : 6.06 - 6.27



TURKEY : 3.95 - 4.96

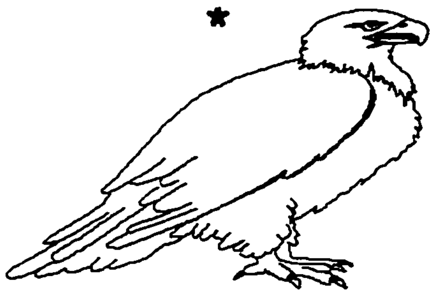


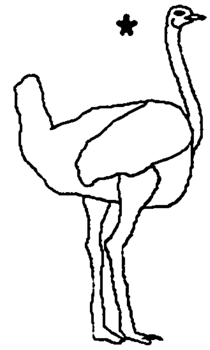
CHICKEN : 4.56 - 4.69



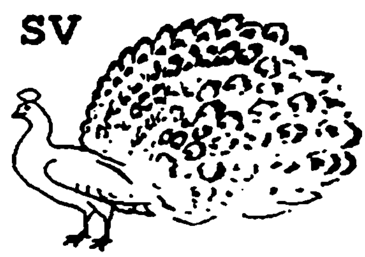
DUCK : 5.28 - 5.63

BIRDS





EAGLE : 5.64 - 5.65 OSTERICH : 3.62 - 4.23

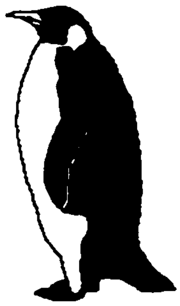


OWL : 4.68 - 4.88 PEACOCK : 3.80 - 4.29

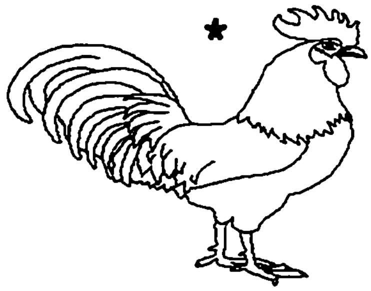
VULTURE : N/A - 3.96

BIRDS

*

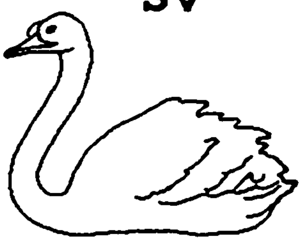


PENGUIN : 3.23 - 4.15

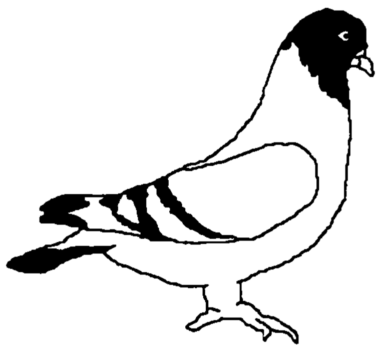


ROOSTER : 4.38 - 4.96

SV

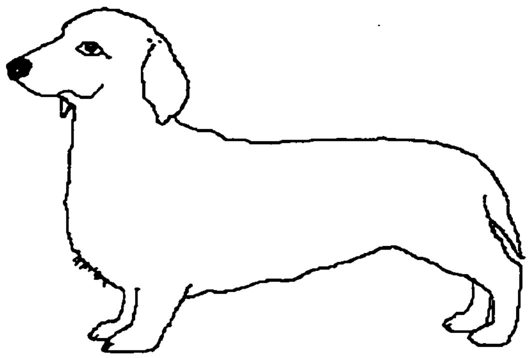


SWAN : 4.59 - 5.17

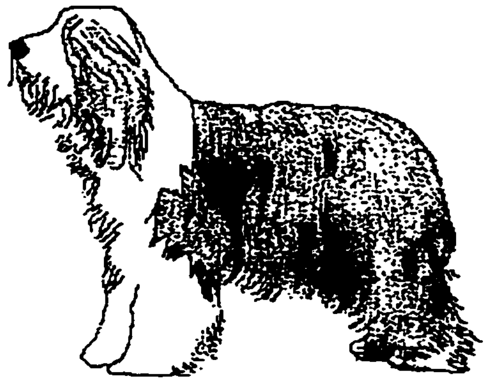


PIGEON : 5.52 - 5.90

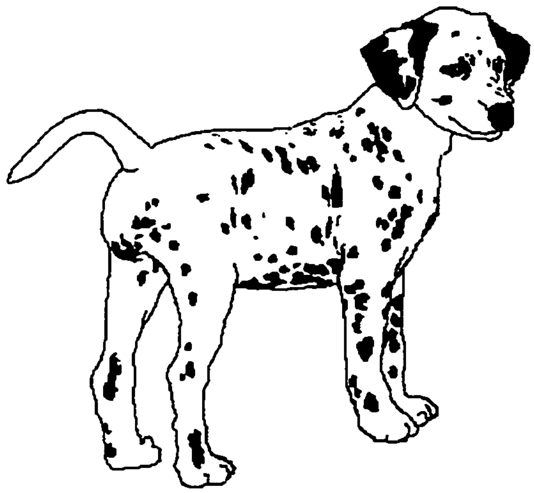
DOGS



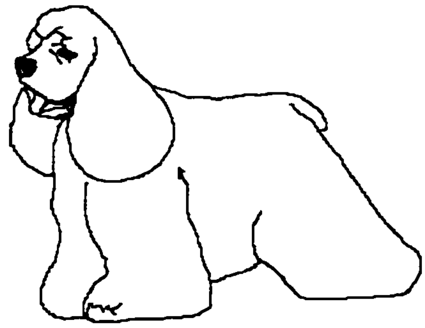
DACHSHUND : 4.28 - 4.92



SHEEP DOG : 5.35 - 5.88

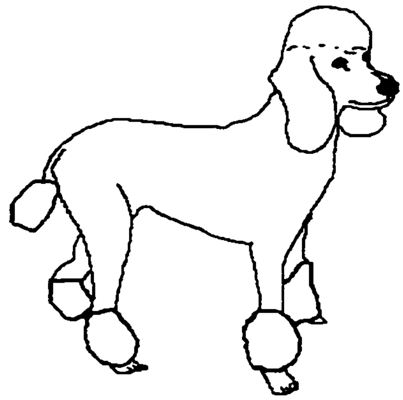


DALMATIAN : 6.23 - 6.40

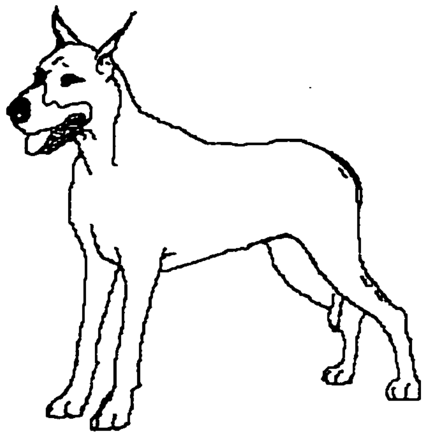


COCKER SPANIEL 4.57 - 5.33

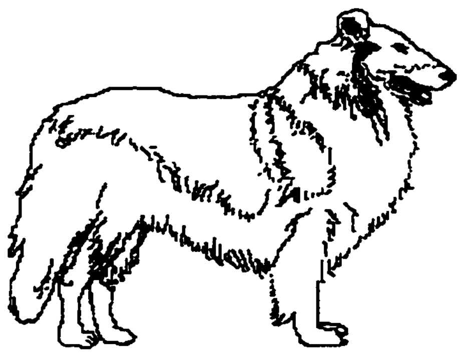
DOGS



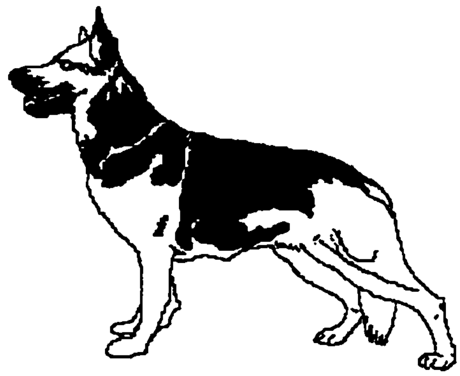
POODLE : 5.00 - 5.88



GREAT DANE : 5.97 - 6.10

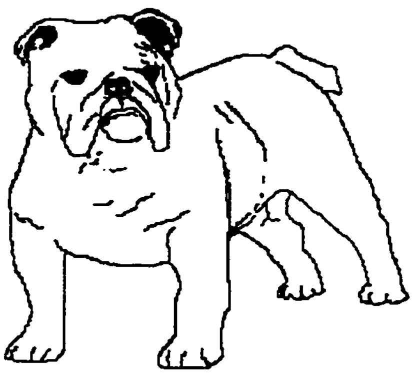


COLLIE : 6.04 - 6.42

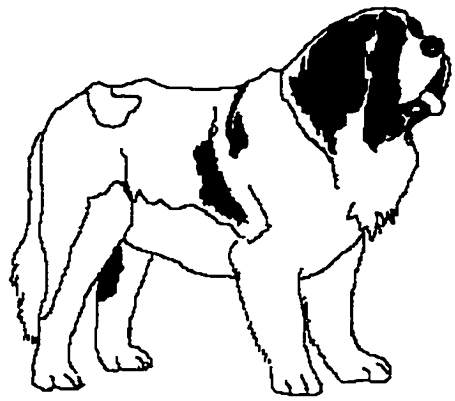


GERMAN SHEPARD : 6.36 - 6.54

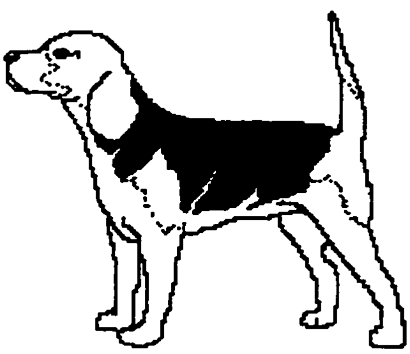
DOGS



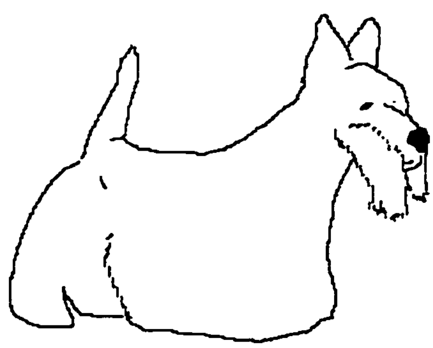
BULL DOG : 5.55 - 6.08



SAINT BERNARD : 5.46 - 5.88

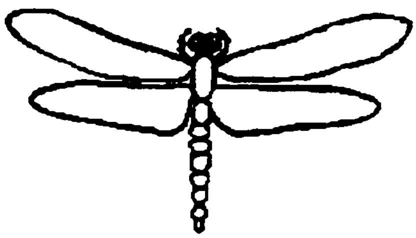


BEAGLE : 6.43 - 6.46



SCOTT TERRIER : 4.02 - 4.67

BUGS



DRAGON FLY: 5.24 - 5.06

MOSQUITO : 5.88 - 5.44

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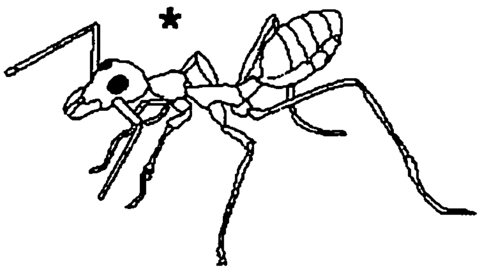

ANT : 6.14 - 5.88

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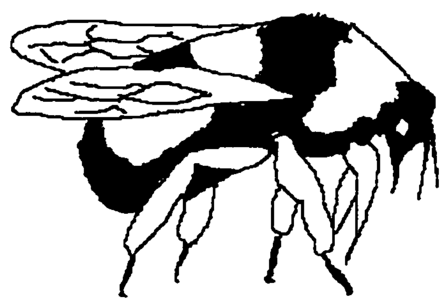
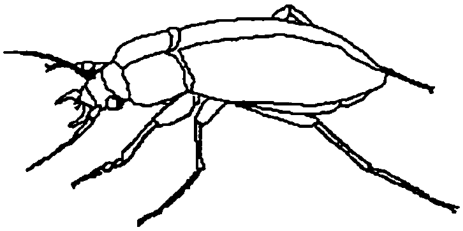


BEE : 5.65 - 5.15

BUGS

*



COCKROACH/BEETLE : 5.57 - 5.69

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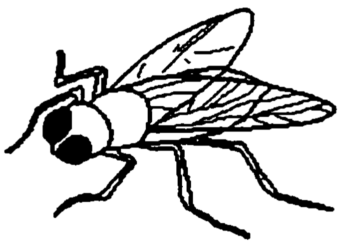
CATERPILLAR : 4.79 - 4.79

SV



FLY : 6.30 - 6.02

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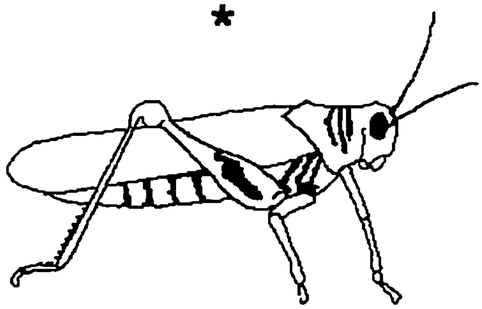
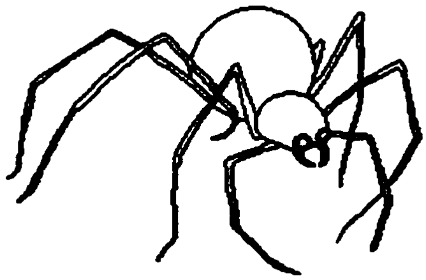


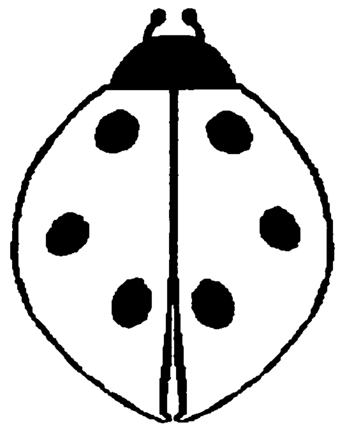
GRASSHOPPER : 5.98 - 5.90

BUGS

SV



SPIDER : 5.57 - 5.31



LADY BUG : 5.54 - 6.13

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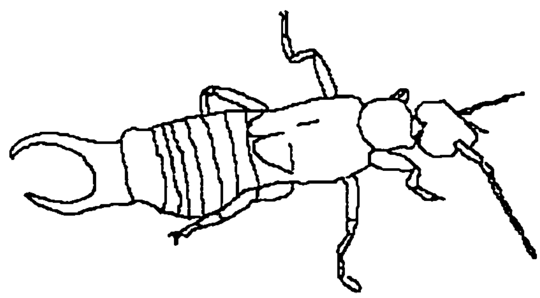
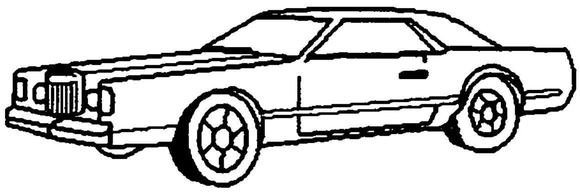
BUTTERFLY : 4.23 - 4.79



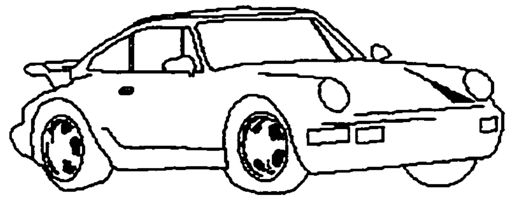
EARWIG : 4.70 - 4.67

CARS

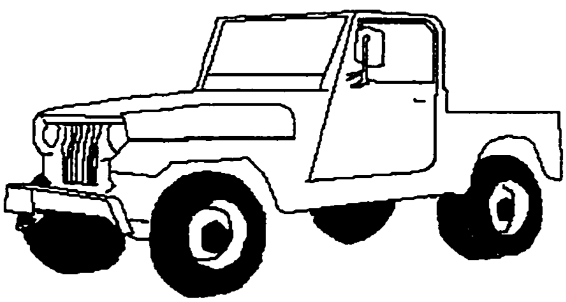
SV



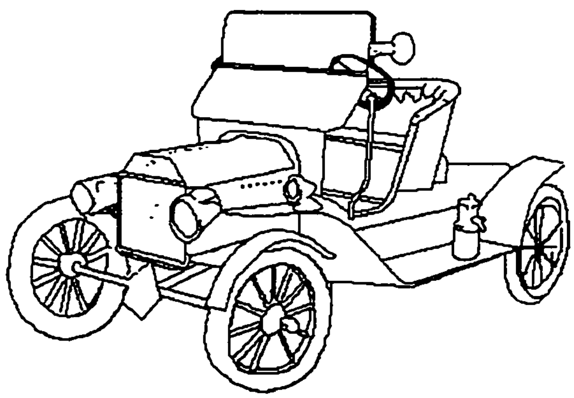
TOWN CAR : 6.26 - 6.35



PORSCHE : 5.70 - 5.94

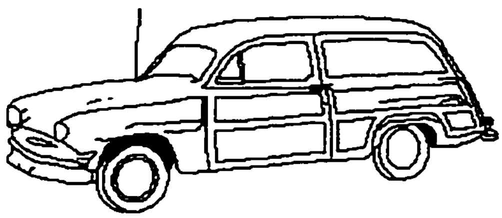


JEEP : 4.87 - 4.65

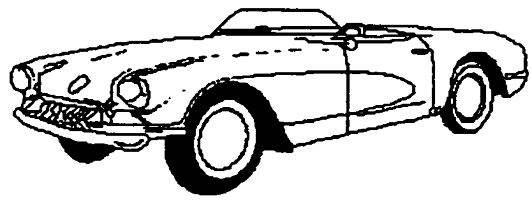


MODEL T FORD : 3.15 - 3.92

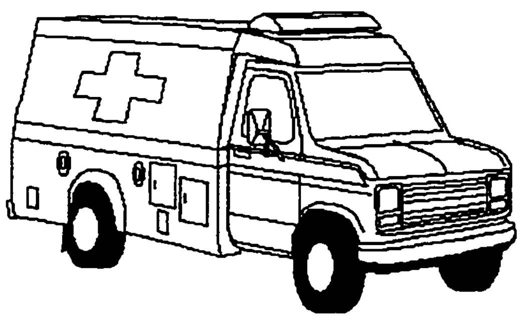
CARS



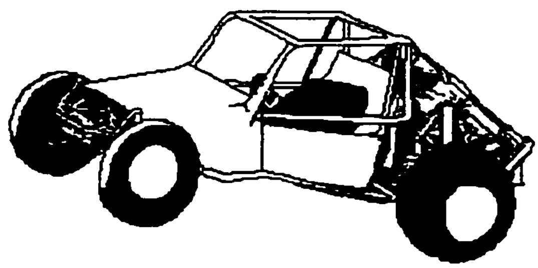
STATION WAGON : 4.94 - 5.48



CORVETTE : 5.56 - 5.94

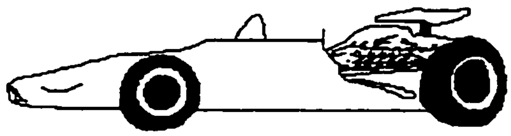


AMBULANCE : 3.83 - 3.75

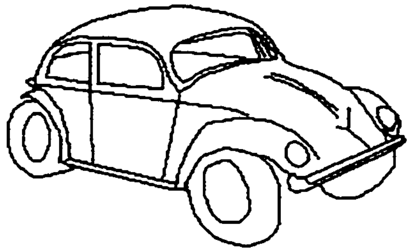


DUNE BUGGY : 3.19 - 3.58

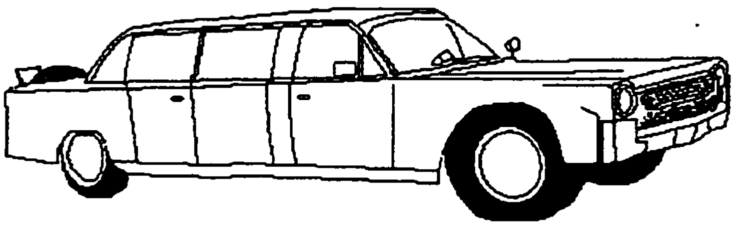
CARS



RACE CAR : 3.32 - 4.10



VOLKSWAGEN : 5.50 - 6.10

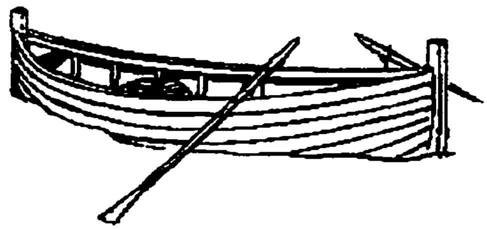


LIMOUSINE : 5.32 - 5.38

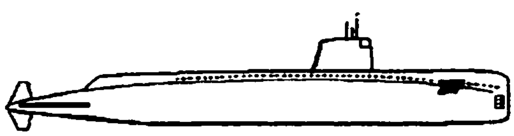
POLICE CAR : 5.84 - 6.02

BOATS

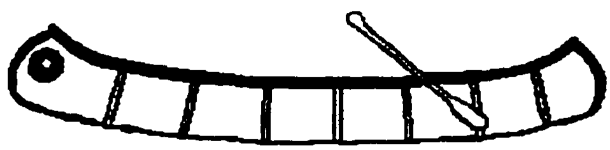
KAYAK : 3.21 - 3.50



ROW BOAT : 5.17 - 5.38

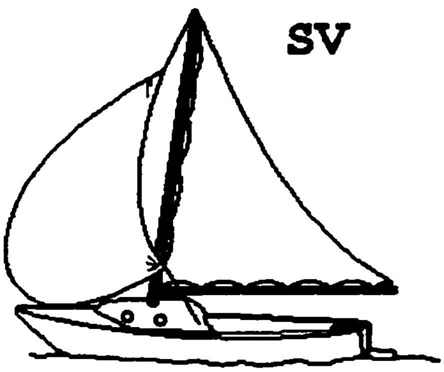


SUBMARINE : 2.82 - 3.54

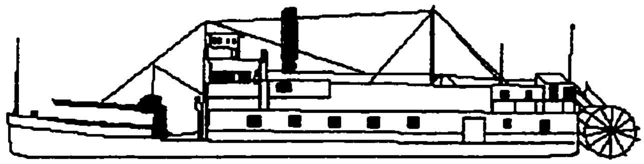


CANOE : 4.18 - 5.33

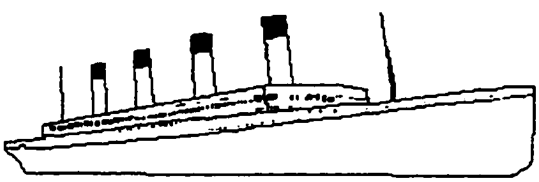
BOATS



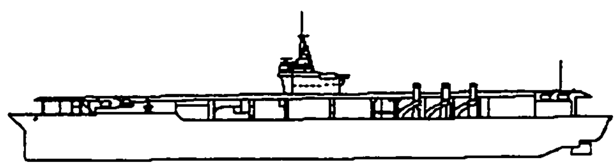
SAIL BOAT : 5.98 - 6.21



PADDLE BOAT : 3.47 - 4.15

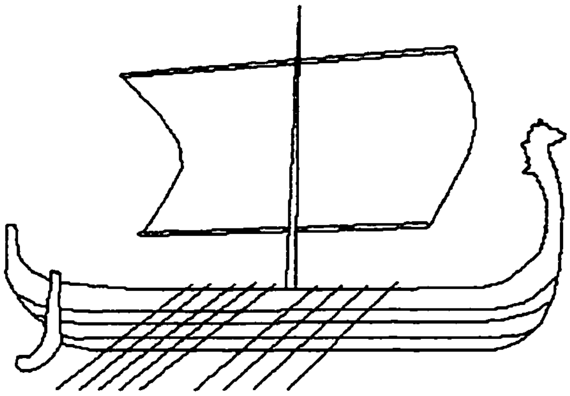


CRUISE SHIP : 5.57 - 5.46

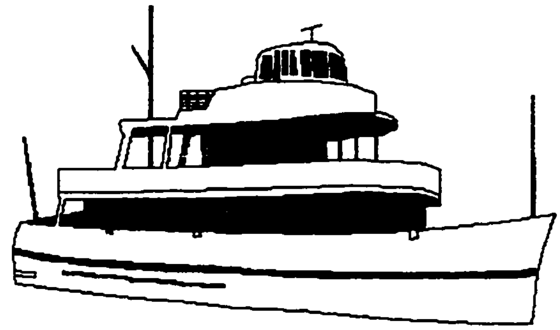


AIRCRAFT CARRIER : 4.09 - 4.08

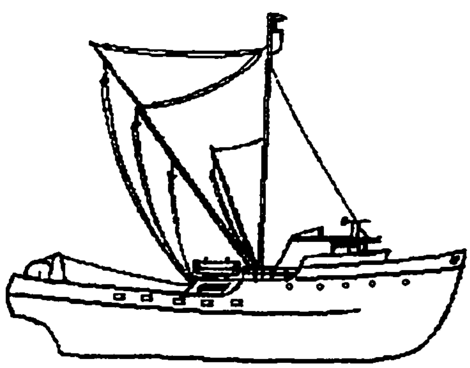
BOATS



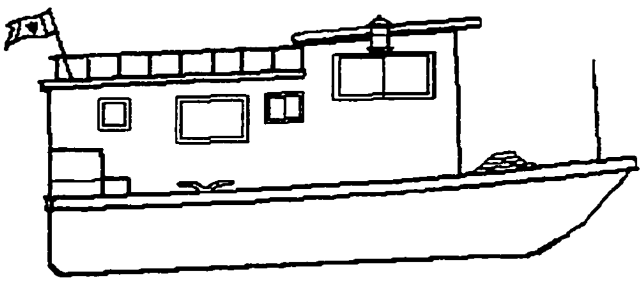
VIKING LONGSHIP : 3.04 - 3.90



YACHT : 5.26 - 5.17

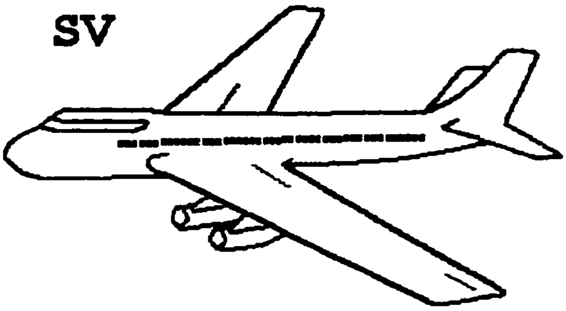


TRAWLER : 5.16 - 5.15

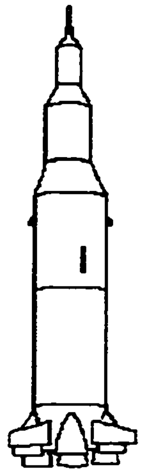


HOUSE BOAT : 3.79 - 3.77

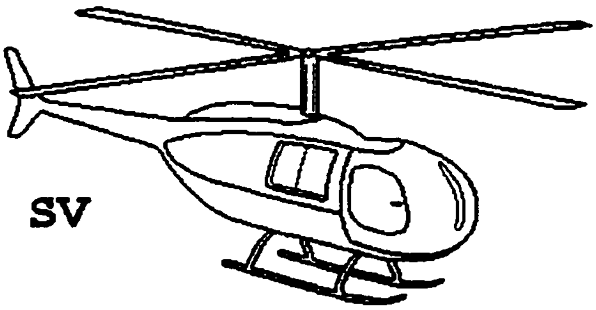
AIRCRAFT



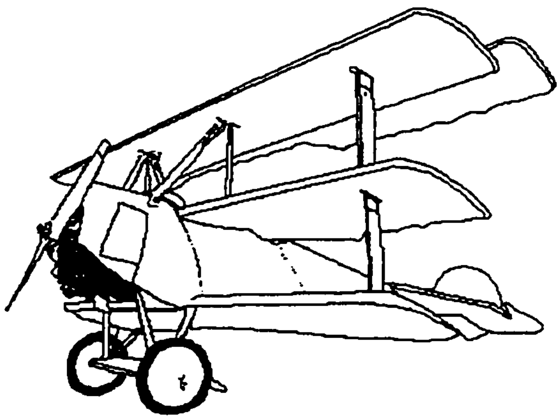
JUMBO JET : 6.80 - 6.65



ROCKET : 2.77 - 3.13

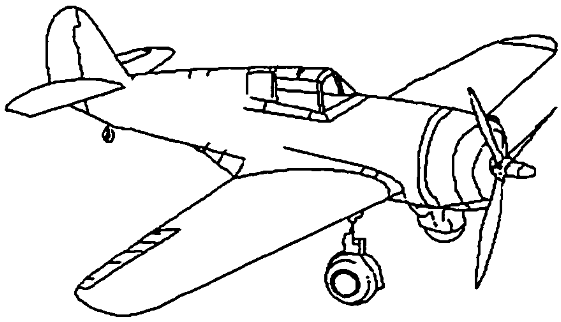


HELICOPTOER : 5.02 - 5.42

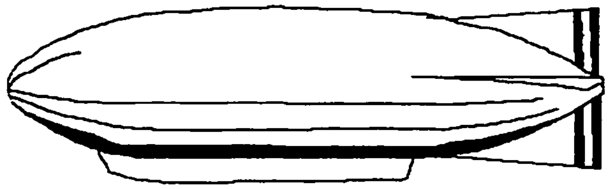


RED BARON : 3.55 - 4.35

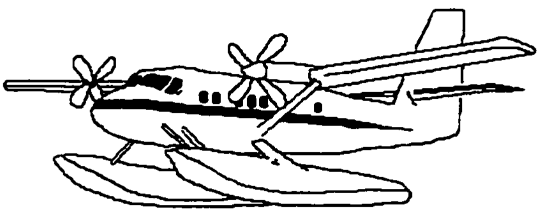
AIRCRAFT



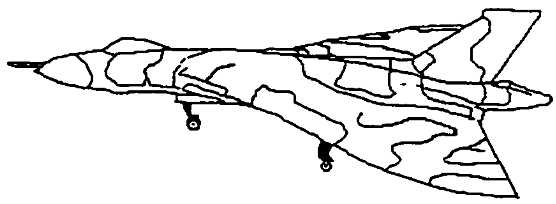
WW2 PLANE : 5.27 - 5.35



BLIMP : 2.56 - 3.04



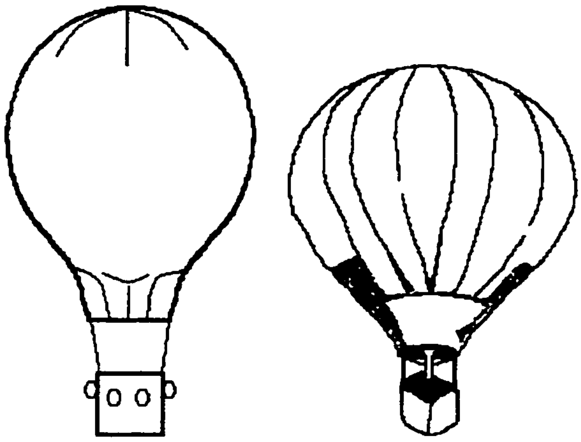
SEA PLANE : 4.90 - 5.33

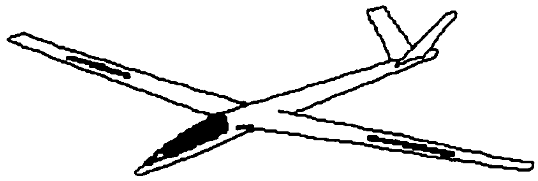


JET FIGHTER : 4.98 - 5.10

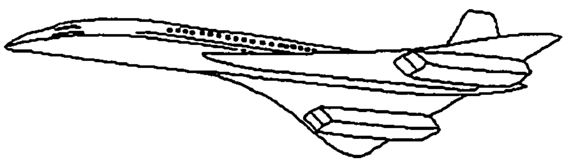
AIRCRAFT

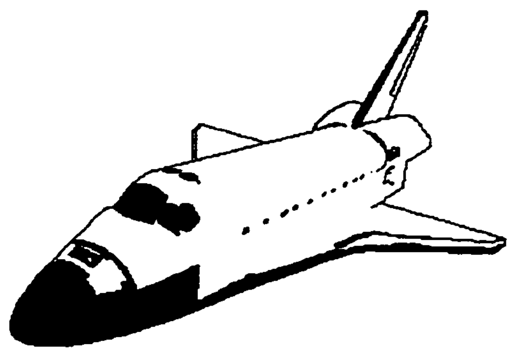
a b





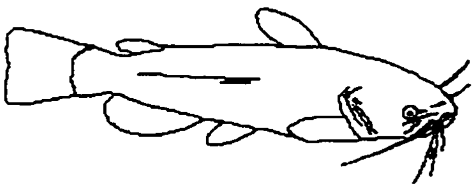
HOT AIR BALLOON : 2.28(a) - 3.04(b) GLIDER : 4.09 - 4.48



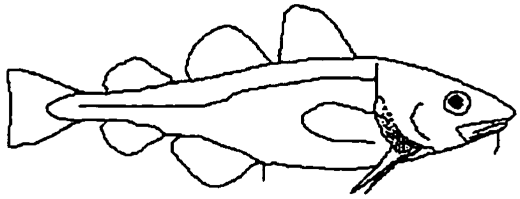


CONCORD : 5.76 - 5.40 SPACE SHUTTLE : 4.07 - 3.96

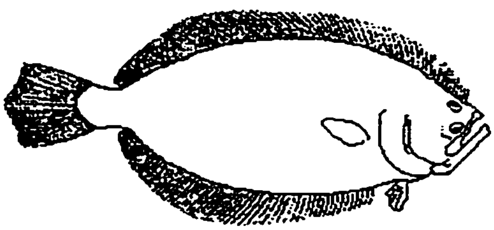
FISH



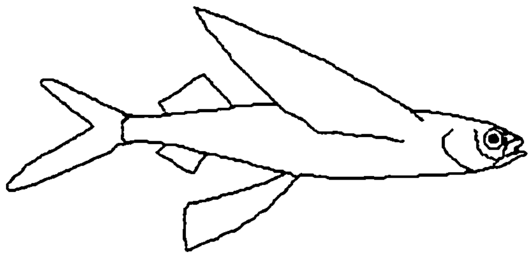
CAT FISH : N/A - 4.46



COD : N/A - 5.52

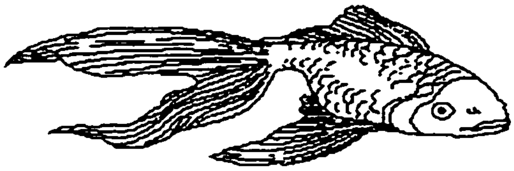


FLOUNDER : N/A - 4.42

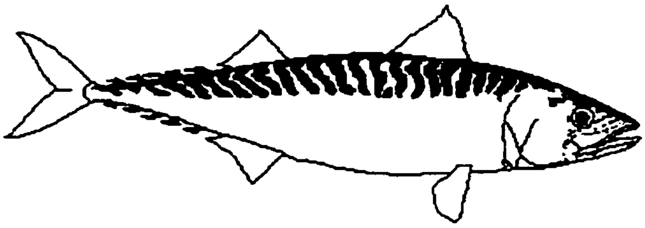


FLYING FISH : N/A - 3.85

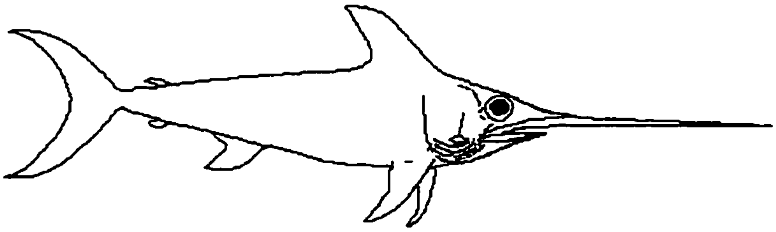
FISH



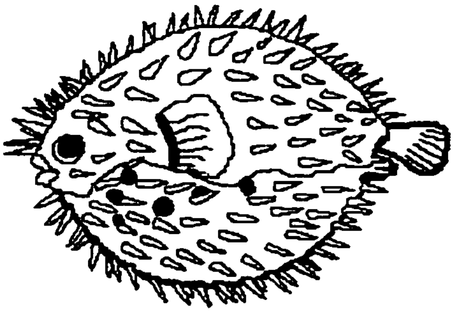
GOLD FISH : N/A - 5.58



MACKEREL : N/A - 6.00

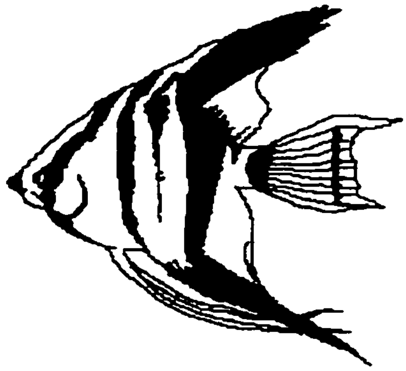


SWORD FISH : N/A - 4.65

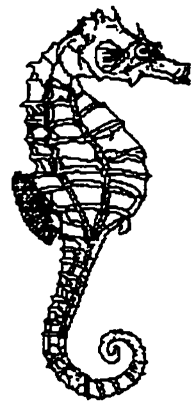


PUFFER FISH : N/A - 3.81

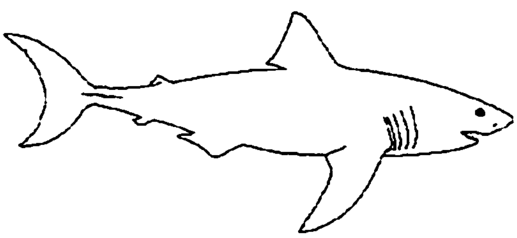
FISH



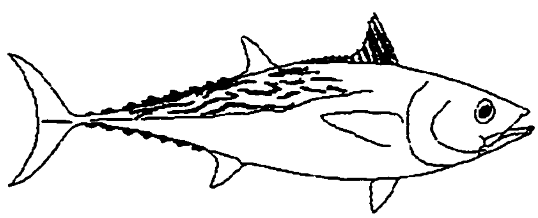
ANGEL FISH : N/A - 5.44



SEA HORSE : N/A - 3.02



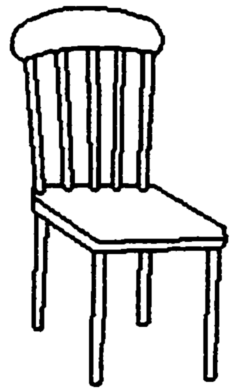
SHARK : N/A - 4.98



TUNA : N/A - 5.42

CHAIRS

SV



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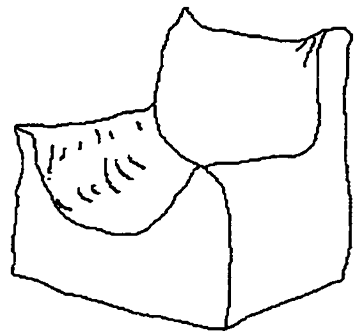

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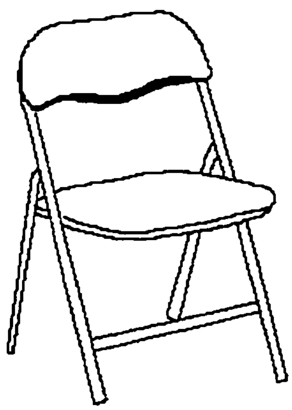

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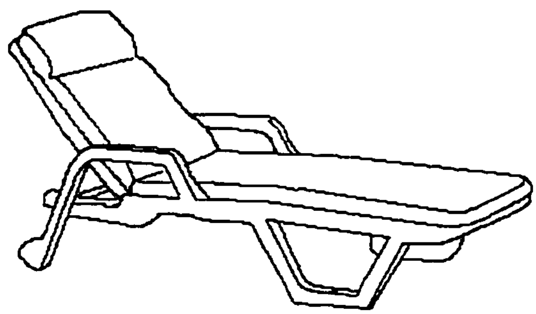

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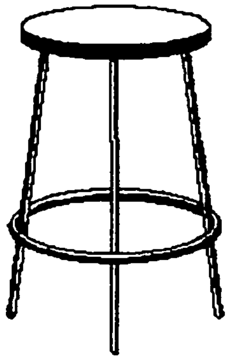
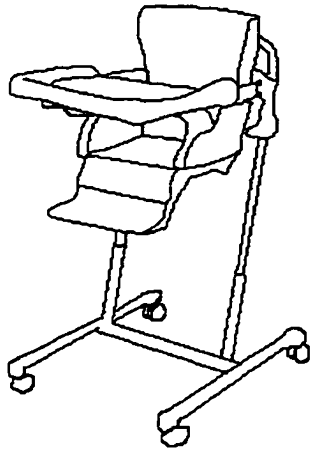
CHAIRS



BAR STOOL : N/A - 5.15



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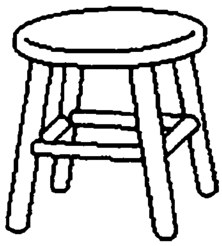

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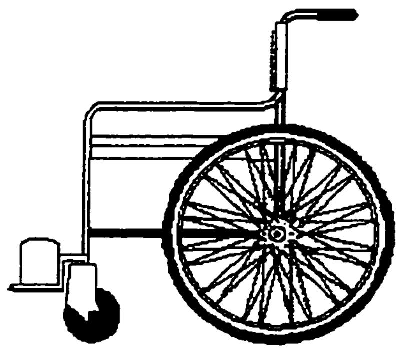
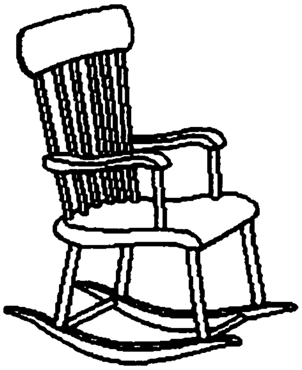


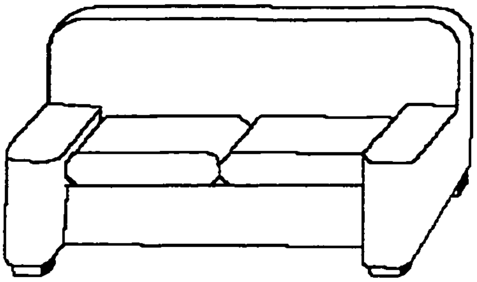
WHEEL CHAIR : N/A - 4.21

CHAIRS

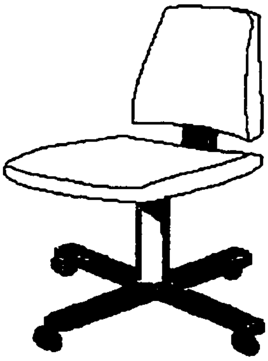
SV



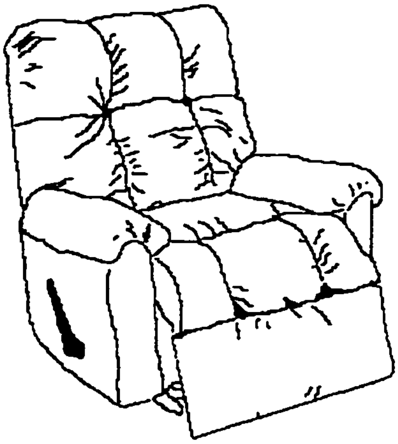
ROCKING CHAIR : N/A - 6.33



COUCH : N/A - 4.56



SWIVEL CHAIR : N/A - 6.40



LAZY BOY : N/A - 6.31

Appendix B

Section B-1

General Approach to Analysis

Throughout the experiments presented in this thesis, the statistical procedure employed will be that of analysis of variance (ANOVA). The questions addressed by these experiments focus on the size of the effect of orientation on the speed and accuracy of object identification. All experiments employ six levels of rotation, namely 0^0 through 300^0 degrees clockwise. The questions of theoretical interest are addressed through the use of contrast analysis. Jolicoeur (1985; 1990) has reported that the effect of orientation is linear between 0^0 and 120^0 of rotation, with the latencies for rotations of 180^0 often less than would be predicted by extrapolation. This reduced effect size at 180^0 is often referred to as the dip at 180 (e.g., Jolicoeur, 1985; 1990; Murray, 1997). Furthermore, the effects of orientation tend to be symmetrical around 180^0, meaning latencies found for 60^0 rotations are equal to latencies found for 300^0 clockwise rotations (60^0 counterclockwise).

In order to address these questions, the following set of planned contrasts will be employed, and explained.

	0^0	60^0	120^0	180^0	240^0	300^0
1)	0	1	0	0	0	-1
2)	0	0	1	0	-1	0
3)	-3	-1	1	3	1	-1
4)	-2	1	1	-2	1	1
5)	-2	0	1	0	1	0
6)	-2	2	-1	0	-1	2

Two issues of concern with this set of contrasts are that the contrasts are not mutually orthogonal, and there are six contrasts planned with only five degrees of freedom. I shall first explain the contrasts, and then return to address both of these concerns.

Contrasts 1 2 are simply a check for symmetry around 180^0. Contrast 1 compares performance for 60^0 degrees clockwise against that of 60^0 counterclockwise. Likewise, contrast 2 compares performance for 120^0 clockwise and counterclockwise. Such asymmetries are not commonly found in the literature, nor in the experiments presented here, and so I shall not report the results of these two analysis except in the cases where they reach significance. However, these tests were performed on all of the experiments presented here.

Contrast 3 and 4 respectively test the linear and quadratic trends between 0^0 and 180^0 degrees, collapsing 60^0 with 300^0 and 120^0 with 240^0.

At this point, the addition of the cubic trend contrast would provide us with a set of mutually orthogonal contrasts. Trends above the quadratic have not been reliably shown (if at all) in past studies, and therefore we shall not include this contrast. Furthermore, since the above trend calculations include the 180^0 rotation which is often known to deviate from the trends found between 0^0 and 120^0 (e.g., Jolicoeur, 1985; 1990; Murray, 1997), we need to verify if any trends or trend interactions shown are reliable, or a result of the unstable 180^0 point.

Contrasts 5 and 6 respectively test the linear and quadratic trends between 0^0 and 120^0, while collapsing around 180^0[6]. These contrasts serve to ensure that the results indicated from examination of contrasts 3 and 4 are found throughout the data set and just due to the inclusion of the 180^0 point. These contrasts are not mutually orthogonal with each other or with contrasts 3 and 4. See section B-2 for the reasons for choosing these contrasts.

Having now explained the purpose of the contrast set, I wish to address the issue of non-orthogonality. The difficulty of non-orthogonal contrast sets lies in the possibility that conflicting interpretations may arise (Keppel, 1982). However, orthogonality is not a requirement of a planned contrast set (Keppel, 1982). With the given

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[6] Jolicoeur (1985?) used the contrast -6 -1 4 0 4 -1 to test the linear trend between 0^0 and 120^0, however see section B-2 for discussion of why this contrast may be inappropriate.

set of contrasts, conflict between interpretations is likely to take the form of a significant trend effect shown with contrasts 3 and 4 that is not replicated with 5 and 6 (or vice versa). Any such conflicts will require close inspection of the data pattern to determine how the inclusion or exclusion of the 180^0 point results in such a change of findings. However, it is the purpose of contrasts 5 and 6 to ensure that any findings in the trend analysis between 0^0 and 180^0 are consistent throughout the data, and therefore conflicts may be expected. In the cases where differences arise, it may be assumed that these conflicts are a result of including the unstable 180^0 orientation and therefore greater emphasis will be given to interpretation of the analysis between 0^0 and 120^0.

Since the contrast set is planned, having more contrasts than degrees of freedom is not in violation of the statistical procedure (Keppel, 1982). The issue is one of controlling Type I error rates; rejection of the null in error. Keppel recommends a modified Bonferoni level of significance be employed when using a planned contrast set with a larger number of contrasts than degrees of freedom, which is described below.

The normally acceptable level of family wise error accepted with 5 degrees of freedom is approximately 25% (5% for each contrast). Exact calculation of the family wise error is difficult due to the influence of non-orthogonal contrasts (Keppel, 1982). However, this approximation is sufficient for the present purposes (Keppel, 1982). To maintain this level with 6 contrasts, as in the current set, we set the level of significance for each contrast at the following : $(5 * 0.05)/6 \approx 0.04$. Therefore, I shall be using 0.04 as the criterion for significance for any section of the analysis which employs this contrast set, or more simply, which contains orientation as a factor in the analysis. Keppel (1982) also recommends that any contrast which results in a p value between the normal 0.05 and the more conservative 0.04 be neither accepted nor rejected in order to avoid making either a Type I or Type II error. For any such outcomes, judgement should be withheld until further analysis indicates a decision or that determination of significance be left for examination in a future experiment. Note, however, this alternate criterion for significance applies only to the contrasts themselves, and not to the omnibus F.

Finally, when discussing the magnitude of the effect of orientation I shall employ the units milliseconds per degree (ms/deg). The value for ms/deg is the slope of the regression line after collapsing around 180^{0}. A ms/deg value will be reported both for 0^{0} to 180^{0} and 0^{0} to 120^{0} degrees. This unit of measurement will be used primarily to compare effect sizes found in these studies with each other and with effects found in the literature. For those more accustomed to seeing these effects in terms of degrees per second (DPS) conversion of ms/deg to DPS is performed with the following formula: DPS = 1/(ms/deg) * 1000.

Section B-2

Jolicoeur (1985) employed the contrast -6 -1 4 0 4 -1 as a test of the linear trend between 0^{0} and 120^{0}. Throughout the experiments presented in this paper, the contrast -2 0 1 0 1 0 is employed as the test of the linear trend. Since I am employing a set of contrast weights which differs from those previously published, I wish to present an argument to suggest that the contrast used in these experiments are to be preferred.

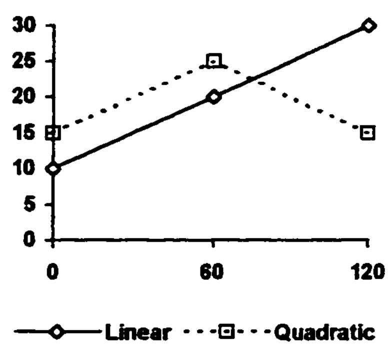

Figure 20. Graphic representation of a pure linear and pure quadratic trend.

I have represented above a pure linear trend, and a pure quadratic trend. The tabled weights for trend analysis

(Keppel, 1982) for testing these trends are (-1 0 1) for the linear, and (1 -2 1) for the quadratic.

The weights for trend analysis which are published in most tables are designed for the situation where there is equal spacing between conditions. This condition is met in the above example, in which each condition differs from it's neighbour by 60^0. The signs of the weights are arbitrary, and as such, (1 -2 1) and (-1 2 -1) would both equally test the quadratic trend.

For the data I have presented, the values are (10 20 30) for the linear trend and (15 25 15) for the quadratic.

In calculating the F for the contrast, we multiply the data by the corresponding weights, sum these values, and determine if the resulting sum is significantly different from 0. In this example, any sum which does not result in 0 indicates significance.

Testing our pure linear trend, we find:

```
(-1)10 + ( 0)20 + (1)30 = 20 Contrast Linear
( 1)10 + (-2)20 + (1)30 = 0  Contrast Quadratic.
```

Where we find a significant Linear, but no significant quadratic trend. Similarly, using the data for the pure quadratic trend we find:

```
(-1)15 + ( 0)25 + (1)15 =  0  Contrast Linear
( 1)15 + (-2)25 + (1)15 = 20  Contrast Quadratic.
```

Where we find a significant quadratic and no significant linear trend.

If we now mirror the 60^0 and 120^0 data around 180^0, then a contrast set which collapses around 180^0, should continue to show the above pattern. This mirrored data is shown graphically below:

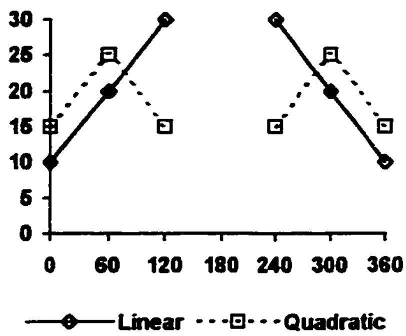

Figure 21. Graphic representation of a pure linear and pure quadratic trend mirrored around 180^0

As is done throughout the experiments presented here, I have duplicated the data for 0^0 at 360^0, however, this is for clarifying the symmetry of the presentation, and the data is only included once in the statistical calculations.

As we know from using our tabled values, that the data shown are pure linear and quadratic trends, we should continue to find them as such when we mirror them as above. Using the data from the linear trend first and testing with Jolicoeur's linear contrast, we find:

(-6)10 + (-1)20 + (4)30 + (4)30 + (-1)20 = 140

and using the preferred linear contrast we find:

(-2)10 + (0)20 + (1)30 + (1)30 + (0)20 = 40

Jolicoeur (1985) does not present a quadratic contrast, however, in order to be orthogonal with the symmetry tests and including the likely contrast of testing 180^0 against the remaining orientations (-1 -1 -1 5 -1 -1) the quadratic contrast would be (-2 2 -1 0 -1 2) which results in (dropping the 0 for 180^0):

(-2)10 + (2)20 + (-1)30 + (-1)30 + (2)20 = 0

Jolicoeur's linear and probable quadratic contrasts show the expected significant linear trend and the lack of a quadratic component when using the pure linear data. However, when we look at the quadratic data we find: (-6)15 + (-1)25 + (4)15 + (4)15 + (-1)25 = -20, which indicates a significant linear tend in a pure quadratic, while using the current linear contrast we obtain: (-2)15 + (0)25 + (1)15 + (1)15 + (0)25 = 0.

As the questions of primary theoretical importance arise from the linear trend, the lack of orthogonality between the currently employed linear and quadratic trend contrasts is considered less of a problem than the possible detection of a linear effect which may not be present. The non-orthogonality of these two contrasts arises in the extra weight given to the 0^0 orientation. This problem does not arise between 0^0 and 180^0 as the extra weighting of the 180^0 data offsets the weighting of the 0^0. In order to present the full data, and given that non-orthogonality does not violate a set of planned contrasts (Keppel, 1982), the current contrast set is considered superior to collapsing the data to 4 orientations.

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IMAGE EVALUATION TEST TARGET (QA-3)

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6″

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