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The effects of context on learning to identify plane-misoriented views of familiar objects

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Two studies examined how training context influences the naming of plane-misoriented pictures of familiar objects. The disadvantage for naming misoriented views of an object can reduce if the object is seen repeatedly in training. In the first study, training reduced the misorientation disadvantage for pictures of objects only if training presented misoriented pictures of the objects and not if training presented misoriented words that named the objects or if training presented upright pictures or words. In the second study, if shape discrimination in training was easy, performance improved in training but not subsequently when the difficulty manipulation was removed. The misorientation disadvantage was thus sensitive to the nature of the training context (whether upright or misoriented pictures or words were presented) but not to the difficulty of that context (whether useful orientation-invariant information was easy or hard to extract). People only appear to extract orientation-invariant information under tightly restricted conditions. However once this strategy is triggered, it seems equally effective regardless of the difficulty of discrimination.

The human visual system is remarkably efficient—but not perfect—at coping with the variability of the input image of familiar objects. It can rapidly and accurately recognize objects depicted at different sizes, views, with varied lighting conditions, and so on. We are far from understanding how this generalization over viewing conditions is achieved, but recent progress has been made in specifying how the plane-orientation of pictures of objects influences their recognition.

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Many studies have found that plane-misoriented views of familiar objects (such as upside-down chairs) are harder to identify than upright views of the same objects. Furthermore, this misorientation disadvantage is reduced but not eliminated by repeatedly presenting a given picture of an object (see Jolicoeur, 1990; Lawson, 1999 for reviews). Similarly, misoriented words are initially harder to identify than upright views, but this disadvantage reduces with practice (Jordan & Huntsman, 1990, 1995). This reduction in the misorientation disadvantage does not occur for new stimuli presented after practice at the task with other stimuli. This indicates that participants learn something specific about the trained stimuli rather than generally improving their ability to identify all misoriented stimuli during practice (Jolicoeur, 1985). A common account of these effects is that participants try to detect and remember distinguishing orientation-invariant information from the stimuli which they see. Such information would allow the object to be identified efficiently from any plane orientation the next time that it is seen. If a set of objects are seen repeatedly, then more and more of the objects may be identified using orientation-invariant information and so the misorientation disadvantage would reduce.

People do not, though, seem to search for orientation-invariant information unless they are encouraged to do so by the context of the task. Jolicoeur and Milliken (1989) found that repeated presentation of only upright views of objects did not reduce the subsequent misorientation disadvantage for those objects. Murray (1995a) replicated this result with participants who were instructed to imagine the upright pictures at different, misoriented views during training (although explicit instructions can reduce effects of plane rotation, see Exp. 2 of Takano, 1989).

Jolicoeur and Milliken (1989) reported an exception to their finding: if a given object was only ever seen upright during training but it was seen in the context of naming other objects that were misoriented, then the misorientation disadvantage reduced for that object. Indeed, Jolicoeur and Milliken found that the misorientation disadvantage for objects seen only upright during training was as small as for objects identified at misoriented views during training.

Jolicoeur and Milliken's (1989) results suggest that the training context is critical in determining whether participants try to identify orientation-invariant information to aid their identification of the training objects. If an object is only seen upright and in the context of naming only upright views of other objects, then participants do not expect to have to later identify misoriented views of that object. They therefore do not try to extract discriminating orientation-invariant information. In contrast, even if a given object is only ever seen upright, so long as it is presented in the context of naming misoriented views of other objects, then participants may expect to have to later identify misoriented views of that object. They will therefore try to extract orientation-invariant information from it.

Further evidence that the search for orientation-invariant information is an active rather than a passive strategy comes from Murray (1995b). Here, during training, participants saw misoriented pictures of objects with coloured letters in the centre. Participants who had to attend the objects to overtly or covertly name them during practice showed the expected reduction in the misorientation disadvantage. In contrast, participants who did not have to name the objects and who just had to respond to the coloured letters showed no such benefit of practice on their misorientation disadvantage.

The results from Jolicoeur and Milliken (1989) and Murray (1995b) suggest that learning to compensate for variability in viewpoint, at least over plane misorientation, is not a general, automatic process which occurs whenever a stimulus is presented. Instead, specific conditions need to be satisfied, namely the stimulus must be attended and it must be presented in the context of identifying misoriented stimuli. The two studies presented here explored further the conditions required to encourage participants to extract and use orientation-invariant information.

The first study compared the effectiveness of contexts presenting different misoriented stimuli in reducing the misorientation disadvantage for a given picture of an object. Would the misorientation disadvantage reduce for pictures of an object if, during practice, only upright pictures of that object were named but in the context of naming misoriented words which named other objects? This tested whether identifying any misoriented stimuli (such as words) would elicit a strategy of searching for discriminating orientation-invariant information in pictures. Second, would the misorientation disadvantage for pictures of an object reduce if, during practice, only upright words that named that object had to be identified, but in the context of naming misoriented pictures of other objects? The misoriented pictures should elicit the strategy of searching for discriminating orientation-invariant information in those pictures. Would that strategy be extended to try to anticipate information which could identify the objects represented only by words during training?

The second study tested whether participants could be encouraged to acquire orientation-invariant information which was more or less specific to a given object by varying across two groups the difficulty of discriminating stimuli in training. Misoriented stimuli were presented to both groups, so they were both expected to try to extract and use discriminating orientation-invariant information. This study tested whether the context manipulation of varying discrimination difficulty affected first, the ease of acquiring orientation-invariant information and second, in a subsequent transfer block, the effectiveness of that information in discriminating between misoriented views of visually similar stimuli.

EXPERIMENT 1

This study examined whether the misorientation disadvantage was sensitive to the nature of the training context in which an item was first seen. Three groups of participants named 80 objects in each of three blocks (see Table 1). The first two blocks were training trials in which half the objects were represented as pictures and half as words which were the names of the objects. The pictures and words were intermingled randomly in each block. The third block involved transfer trials in which all the objects were presented as pictures, regardless of whether they had been primed as words or as pictures during training. The three groups only differed in the orientation at which stimuli were seen during training.

The control Training:PicturesUp–WordsUp group named only upright pictures and words during training. Since no misoriented stimuli were presented in training, this group was not encouraged to try to find and use orientation-invariant information to identify the objects. They were therefore predicted to name misoriented views much slower than upright views in the final transfer block. This group provided a baseline to compare misorientation disadvantages at transfer in the other two groups.

The Training:PicturesUp–WordsMisoriented group named pictures that were all upright but named words that were both upright and misoriented during training. This tested whether participants were influenced by the training context

TABLE 1
Design of Experiment 1

Block	*Task and Block name*	*Purpose*	*The two sets of stimuli presented*
Training:PicturesUp–WordsUp control group			
1	Naming1	Training	Pictures all upright; words all upright
2	Naming2	Training	Pictures all upright; words all upright
3	Naming3	Transfer	Upright and misoriented pictures primed by pictures Upright and misoriented pictures primed by words
Training:PicturesUp–WordsMisoriented group			
1	Naming1	Training	Pictures all upright; words upright and misoriented
2	Naming2	Training	Pictures all upright; words all misoriented
3	Naming3	Transfer	Upright and misoriented pictures primed by pictures Upright and misoriented pictures primed by words
Training:PicturesMisoriented–WordsUp group			
1	Naming1	Training	Pictures upright and misoriented; words all upright
2	Naming2	Training	Pictures all misoriented; words all upright
3	Naming3	Transfer	Upright and misoriented pictures primed by pictures Upright and misoriented pictures primed by words

Testing of the three groups only differed in the Naming1 and Naming2 training blocks.

of having to identify misoriented stimuli (words). Specifically, participants may have tried to extract orientation-invariant information for the pictures if they expected that they would have to identify misoriented pictures as well as misoriented words. If so, then in the transfer block the Training:PicturesUp-WordsMisoriented group should have a smaller misorientation disadvantage than the control Training:PicturesUp–WordsUp group for pictures primed by upright pictures. The experience of the Training:PicturesUp–WordsMisoriented group was similar to that of the participants tested in Experiment 2 of Jolicoeur and Milliken (1989). During training, Jolicoeur and Milliken's participants saw some pictures only upright but in the context of seeing other pictures misoriented; in contrast, in Experiment 1 here the training context for the upright-only pictures was provided by misoriented words not misoriented pictures.

The Training:PicturesMisoriented–WordsUp group named upright and misoriented pictures but only upright words during training. Their misorientation disadvantage for pictures was expected to reduce with practice, and so to be smaller in the transfer block than for the control Training:PicturesUp–WordsUp group. This finding would suggest that, during training, the Training:PicturesMisoriented–WordsUp participants successfully used a strategy of trying to identify orientation-invariant information with which to discriminate the pictures. At issue here was whether this strategy would extend to trying to anticipate orientation-invariant information which would identify pictures of the objects which, in training, had been represented only by their upright, written names. If so, then in the transfer block the Training:PicturesMisoriented–WordsUp group should have a smaller misorientation disadvantage than the control Training:PicturesUp-WordsUp group for pictures primed by upright words.

Method

Participants. There were 72 students from the University of Liverpool, UK who took part in the study for course credit. They were native speakers of English, and had normal or corrected-to-normal vision.

Materials. There were 80 experimental objects, which were divided into four subsets (see Appendix 1). Each object was represented by three views of a picture of the object (at the environmentally predominant, 0° view and at 120° and 240° misoriented views) and by three views of the written word that was the entry level name of the object as given in Appendix 1 (again, at 0°, 120°, and 240° views). Responses to 120° and 240° views were treated as equivalent in Experiments 1 and 2 here, since both depict a 120° plane rotation away from the canonical upright view of the object. Both a 120° clockwise and a 120° anticlockwise rotation were used to ensure that participants could not benefit by keeping their heads tilted to try to reduce the misorientation disadvantage. Both pictures and words were presented as black stimuli on a white background. The 0° views of the pictures were taken from Snodgrass and Vanderwart (1980).

Design. All participants completed three blocks of 80 naming trials. In each block they saw one representation of each of the 80 objects. In both blocks 1 and 2, 40 objects were represented by words and 40 by pictures. In block 3, all 80 objects were represented by pictures, see Table 1.

Twenty-four participants were assigned to each of three groups: Training:PicturesUp–WordsUp, Training:PicturesUp–WordsMisoriented, and Training:PicturesMisoriented–WordsUp. For each group, there were eight subgroups of three participants. The subgroups counterbalanced which subsets of objects were represented as words or as pictures in blocks 1 and 2, and which stimuli were presented upright or misoriented in block 1. Objects were presented at 0°, 120°, 240°, or 0°, 240°, 120°, or 120°, 240°, 0° or 240°, 120°, 0° in blocks 1, 2, and 3 respectively. Note that in the Up conditions in blocks 1 and 2 these were dummy conditions which just presented different subsets of items for picture or word stimuli, since in the Up conditions all stimuli were actually seen at 0°. For objects shown in the Misoriented condition in block 1, half the stimuli were presented at 0°, a quarter at 120°, and a quarter at 240°. To increase the strength of the context in the Misoriented conditions in block 2, all stimuli were misoriented—half at 120° and half at 240°. In block 3, for the 40 stimuli seen as words and the 40 stimuli seen as pictures in blocks 1 and 2, 20 were shown at 0°, 10 at 120°, and 10 at 240°. Stimuli were shown in a different, random order in each block for each participant.

Prior to the first experimental block, there was a practice block of 20 trials with 10 objects represented by words and 10 by pictures. All were seen upright in the Up conditions; five were seen upright and five misoriented in the Misoriented conditions. The practice trials were identical to the experimental trials except that different stimuli were presented.

Apparatus and procedure. A Macintosh G4 PowerMac computer running the Psyscope Version 1.2.5 presentation package was used to display the stimuli. The experiment lasted about 20 mins. The procedure for each trial was as follows: A central fixation cross appeared on the screen for 500 ms. This was immediately replaced by a picture or the written name of an object until the participant named the object aloud. Response times were recorded by the computer using a microphone and a voice-activated relay. A blank screen was then presented until the experimenter made a keypress to code the participant's response as correct or incorrect. The fixation cross for the next trial then appeared. Participants were encouraged to respond as rapidly and as accurately as possible.

Results

Trials in which participants used an inappropriate name or in which the microphone was accidentally activated before the participant responded were discarded as errors. In addition, response latencies less than 400 ms or exceeding 2000 ms were discarded as errors (less than 1% of trials). No participants were replaced, since all scored less than 15% errors across the three naming blocks. The results for by-participants and by-items analyses are reported using subscripts F_p and F_i respectively.

In order to focus attention on the effects of interest and for simplicity of presentation of the results, for all of the analyses in this study and in Experiment 2, the dependent measure was either the misorientation disadvantage or the response to the upright view. The misorientation disadvantage was calculated as the increase in reaction times (RTs) or in percentage errors to respond to plane-misoriented views relative to upright views. In the block 1 analyses only, for items presented in the Up conditions (where all stimuli were presented at 0°), the difference between ''upright'' and ''misoriented'' views was a dummy variable calculated as the difference between different subsets of items. No results are reported for block 2. Only misoriented views were presented in the Misoriented conditions of block 2, and block 2 was only included in the design to increase the strength of the practice and context manipulations.

ANOVAs were conducted on the mean correct naming RTs and the percentage error rates for word and picture stimuli separately in block 1 and block 3. There was one between-participants factor, Training (Training:PicturesUp–WordsUp, Training:PicturesUp–WordsMisoriented, and Training:Pictures-Misoriented–WordsUp). Only effects significant at $p < .05$ are reported. All comparisons noted are significant at $p < .05$ in post-hoc Newman-Keuls analyses. There were no significant effects for errors in any of the analyses. Figure 1 shows the mean misorientation disadvantage on RTs in blocks 1 and 3. Figure 2 shows the mean RTs to name upright views in blocks 1 and 3.

Misorientation disadvantage

Naming 1. There was a larger misorientation disadvantage for RTs to name *pictures* in the Training:PicturesMisoriented–WordsUp group (108 ms) compared to the Training:PicturesUp–WordsUp group (1 ms) and the Training:PicturesUp–WordsMisoriented group (3 ms), $F_p(2, 69) = 10.699$, $p < .001$, $F_i(2, 158) = 9.424$, $p < .001$.

There was a larger misorientation disadvantage for RTs to name *words* in the Training:PicturesUp–WordsMisoriented group (119 ms) compared to the Training:PicturesUp–WordsUp group (7 ms) and the Training:Pictures-Misoriented–WordsUp group (4 ms), $F_p(2, 69) = 41.496$, $p < .001$, $F_i(2, 158) = 60.534$, $p < .001$.

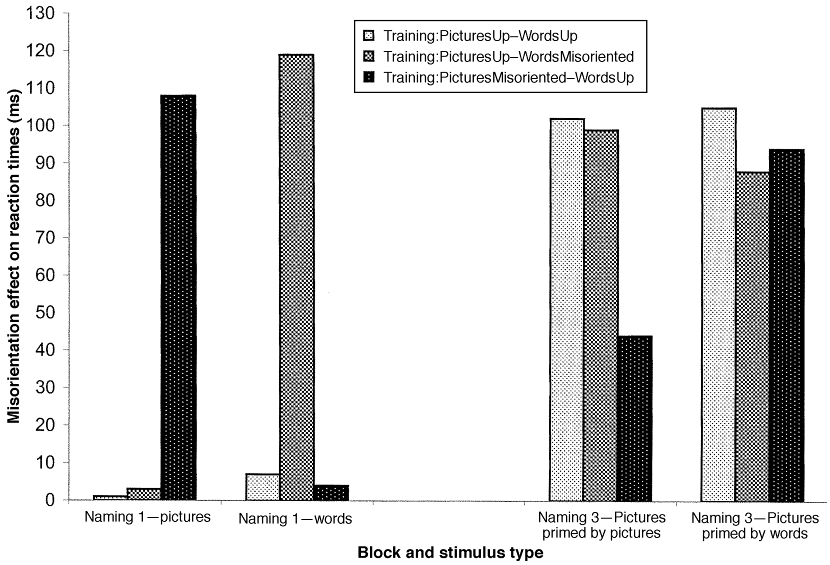

Figure 1. The misorientation disadvantage on reaction times to name both pictures and words in the Naming1 block and to name pictures primed by both pictures and words in the Naming3 block of Experiment 1, for the Training:PicturesUp–WordsUp group, the Training:PicturesUp–WordsMisoriented group, and the Trianing: PicturesMisoriented–WordsUp group.

Naming 3. The misorientation disadvantage for RTs to name pictures *primed as pictures* was smaller in the Training:PicturesMisoriented–WordsUp group (44 ms) compared to the Training:PicturesUp–WordsUp group (102 ms) and the Training:PicturesUp–WordsMisoriented group (99 ms), $F_p(2, 69) = 6.603$, $p < .003$, $F_i(2, 158) = 7.972$, $p < .001$.

The misorientation disadvantage for RTs to name pictures *primed as words* was not significantly different for the Training:PicturesUp–WordsMisoriented group (88 ms), the Training:PicturesUp–WordsUp group (105 ms), and the Training:PicturesMisoriented–WordsUp group (94 ms), $F_p(2, 69) = 0.236$, $p > .7$, $F_i(2, 158) = 0.474$, $p > .6$.

As predicted, there was a clear disadvantage in the Naming1 block for identifying misoriented compared to upright pictures (for the Training:PicturesMisoriented–WordsUp group) and for identifying misoriented compared to upright words (for the Training:PicturesUp–WordsMisoriented group). However in the Naming3 transfer block, practice only reduced this misorientation disadvantage for the Training:PicturesMisoriented–WordsUp group. Furthermore, for this group, practice only helped to identify misoriented stimuli which had been primed as pictures, not stimuli which had been primed as words. The nature of the training context (whether a given object was repre-

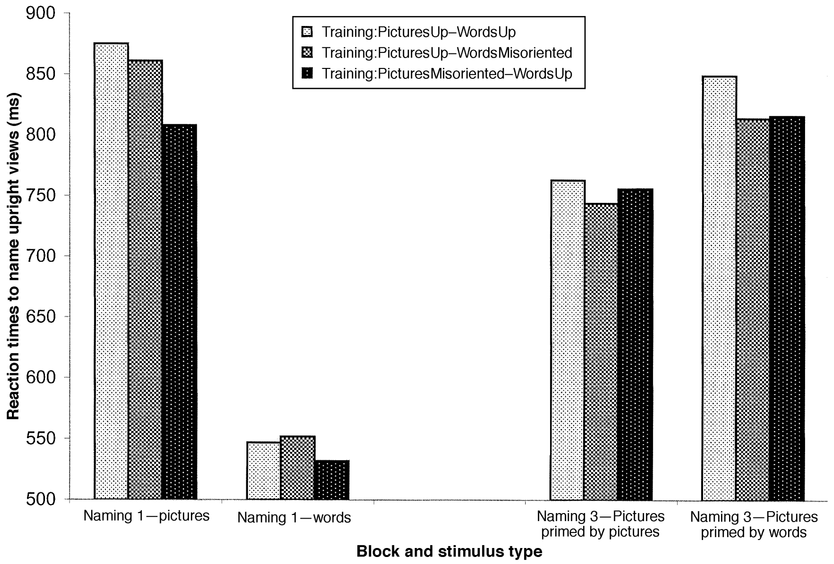

Figure 2. Reaction times to name upright views of both pictures and words in the Naming1 block and to name pictures primed by both pictures and words in the Naming3 block of Experiment 1, for the Training:PicturesUp–WordsUp group, the Training:PicturesUp–WordsMisoriented group, and the Training:PicturesMisoriented–WordsUp group.

sented as an upright or misoriented picture or word during training) determined whether there was a reduction in the misorientation disadvantage in the transfer block.

Upright views

Naming 1. Upright views of *pictures* were named faster by the Training:PicturesMisoriented–WordsUp group (808 ms) than the Training:PicturesUp–WordsUp group (875 ms) and the Training:PicturesUp–WordsMisoriented group (861 ms; only significantly different for items), $F_p(2, 69) = 3.420$, $p < .04$, $F_i(2, 158) = 7.289$, $p < .001$.

Similarly, for the items analysis only, upright views of *words* were named faster by the Training:PicturesMisoriented–WordsUp group (532 ms) than the Training:PicturesUp–WordsUp group (547 ms) and the Training:PicturesUp–WordsMisoriented group (552 ms), $F_p(2, 69) = 1.140$, $p > .3$, $F_i(2, 158) = 8.419$, $p < .001$.

Naming 3. There was no significant difference in the naming of upright views of pictures *primed as pictures*.

For the items analysis only, upright views of pictures *primed as words* were named faster by the Training:PicturesMisoriented–WordsUp group (816 ms) and the Training:PicturesUp–WordsMisoriented group (814 ms) than by the Training:PicturesUp–WordsUp group (849 ms), $F_p(2, 69) = 1.016$, $p > .3$, $F_i(2, 158) = 4.611$, $p < .02$.

In the Naming1 block, the Training:PicturesMisoriented–WordsUp group was rather faster than the other two groups at naming upright views of both words and pictures. This effect had not been predicted and may just have been due to individual differences. There was little difference between the three groups in the Naming3 block.

Picture naming in blocks 1 and 3 for the Training:PicturesMisoriented–WordsUp group only

The Training:PicturesMisoriented–WordsUp group improved at naming upright pictures and, to an even greater extent, at naming misoriented pictures, from block 1 to block 3. The misorientation disadvantage reduced from block 1 (108 ms) to block 3 (44 ms), $F_p(1, 23) = 4.946$, $p < .04$, $F_i(1, 79) = 5.354$, $p < .02$. Upright views were also named faster from block 1 (808 ms) to block 3 (756 ms), $F_p(1, 23) = 8.620$, $p < .008$, $F_i(1, 79) = 10.691$, $p < .002$.

Discussion

As predicted, misoriented pictures were named slower than upright pictures in the Naming1 block for the Training:PicturesMisoriented–WordsUp group. This misorientation disadvantage reduced by over 50% by the Naming3 transfer block and was significantly less than the misorientation disadvantage for pictures primed by upright pictures in the control Training:PicturesUp–WordsUp group. These results replicate earlier studies (see Jolicoeur, 1990; Lawson, 1999). Note that the Training:PicturesMisoriented–Words group always named a different view of a given object at transfer than they named during training (an upright view at transfer if training presented misoriented views and vice versa). Their reduction in the misorientation disadvantage at transfer was not simply due to priming for identical stimuli; instead this group had learnt to generalize from the training stimuli. In contrast, providing a context of misoriented pictures during training for the Training:PicturesMisoriented–WordsUp group did not reduce the misorientation disadvantage at transfer for pictures primed by upright words. Finally, providing a context of misoriented words during training for the Training:PicturesUp–WordsMisoriented group did not reduce the misorientation disadvantage at transfer for pictures primed by upright pictures (or, indeed, for pictures primed by the misoriented words).

These results indicate that there are only rather restricted conditions under which the training context triggers a strategy of trying to extract discriminating orientation-invariant information. Use of such information would allow misoriented pictures of objects to be identified as efficiently as upright views and so should reduce the misorientation disadvantage. However for the strategy to be triggered, first, pictures of the objects must be presented and second, those pictures need to be identified in a context of identifying misoriented pictures.

On the first point, it is not sufficient to present the word that is the name of the object, even if a context is provided of needing to identify misoriented pictures of other objects so that the second condition is satisfied, as in the Training:PicturesMisoriented–WordsUp group here. This may be because it is difficult for participants to anticipate what the picture of an object might look like, even for familiar stimuli depicted in typical poses, as for the Snodgrass and Vanderwart (1980) pictures used here (see also Murray, 1995a). Alternatively, participants may not expect stimuli presented as words during training to subsequently be presented as pictures.

On the second point, it is not sufficient to provide pictures of the objects in a context of identifying misoriented words, as in the Training:PicturesUp–WordsMisoriented group here, for whom the first condition was satisfied. Instead, the context must require misoriented pictures to be identified, as in Jolicoeur and Milliken (1989). The Training:PicturesUp–WordsMisoriented group had seen upright pictures of the objects intermingled with misoriented words during training, but the misorientation disadvantage for those pictures at transfer was not reduced by that training.

EXPERIMENT 2

If participants learn to extract and use orientation-invariant information to identify stimuli, the misorientation disadvantage should decrease. However, no orientation-invariant information can uniquely identify a given object in all contexts. In particular, orientation-invariant information which was useful for identification in one situation (such as during training) may be less useful if participants must later discriminate between the original set of training stimuli and a new set of visually similar distractors.

The second study investigated whether participants could be encouraged to acquire orientation-invariant information that was more or less specific to a given object by varying the discrimination difficulty of identification across two groups during training. First, I examined the rate of reduction in the misorientation disadvantage for a set of test stimuli seen repeatedly during training. This indicates how rapidly orientation-invariant information is acquired. Second, I examined the misorientation disadvantage in a subsequent transfer block in which the test stimuli were presented together with a new set of visually similar distractors. This tested the specificity of any orientation-invariant information acquired during training, as only highly specific information can discriminate test stimuli from visually similar distractors.

Recent studies by Hayward and Williams (2000) and Newell (1998) have examined whether the context of the difficulty of discrimination influences depth rotation effects. Newell found context effects, whereas Hayward and Williams did not, except when a colour cue produced orientation-invariant performance. Unlike the present study, though, these studies did not go on to compare directly how groups trained with different contexts performed when transferred to a task with an identical discrimination context.

In Experiment 2, two groups of participants identified the same set of test objects and various sets of context objects in each of seven blocks (see Table 2). First, both the subtle-trained group and the gross-trained group named only upright views of the test objects and of visually dissimilar context objects in a baseline block, Naming1. Both groups then did four blocks of Object Decision training, Object Decision 1, 2, 3, and 4. Here, the subtle-trained group had a difficult discrimination context since they saw nonobjects that differed in only minor details relative to the test objects (see the stimuli on the right of Figure 3). The gross-trained group had an easy discrimination context since they saw nonobjects that had large sections removed or new parts added relative to the test objects (see the stimuli on the left of Figure 3). Different nonobjects were shown in each Object Decision training block so participants could not learn to detect just one feature that always differed between a given test object and its nonobjects. Finally, both groups undertook two transfer blocks in which they named upright and misoriented views of the test and of context objects. The context objects were visually dissimilar to the test objects in the Naming2 transfer block, but were visually similar to one of the test objects and were presented on the trial immediately before or after that test object in the

TABLE 2
Design of Experiment 2

Block	*Task and Block name*	*Purpose*	*Stimuli shown: Test Objects and Context Objects*
1	Naming1	Baseline	Test Objects and Dissimilar Distractors
2	Object Decision1	Training	Test Objects and Nonobject Distractors
3	Object Decision2	Training	Test Objects and Nonobject Distractors
4	Object Decision3	Training	Test Objects and Nonobject Distractors
5	Object Decision4	Training	Test Objects and Nonobject Distractors
6	Naming2	Transfer	Test Objects and Dissimilar Distractors
7	Naming3	Transfer	Test Objects and Similar Distractors

Testing of the gross-trained and subtle-trained groups only differed in the Object Decision training blocks, where the nonobject distractors were either grossly or subtly different from the test objects (see Figure 3). Stimuli were presented at both upright and plane-misoriented views except in the first Naming1–Baseline block in which all stimuli were presented upright.

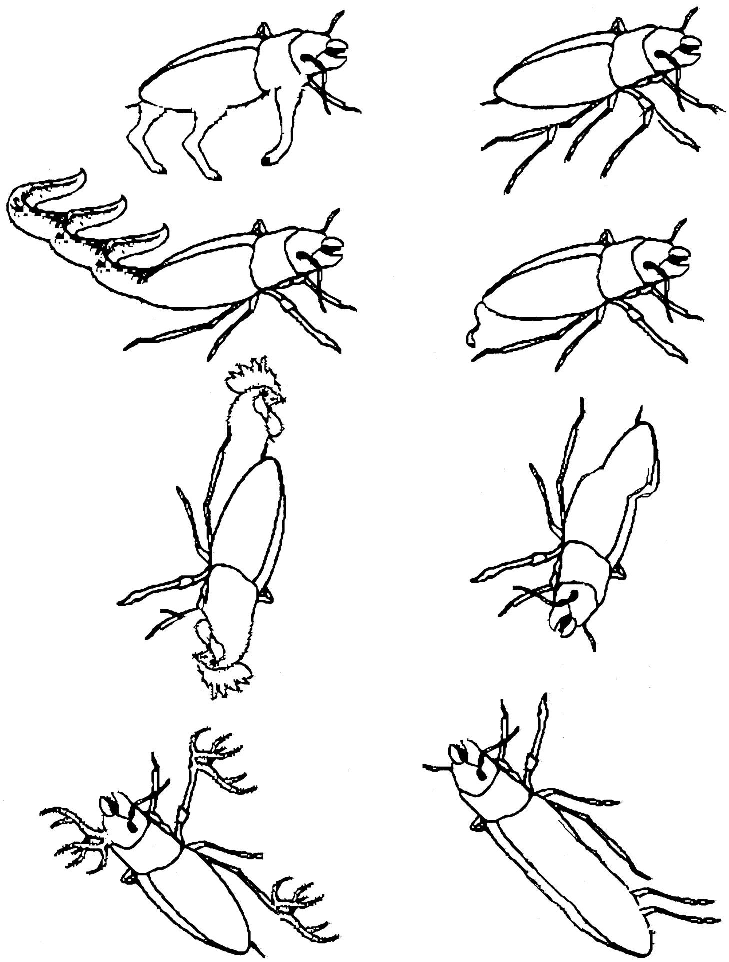

Figure 3. The eight nonobject versions of one of the test objects (beetle) that were presented to the gross-trained group (left column) and the subtle-trained group (right column) during training in Experiment 2. The top two rows show upright views, the third row shows 120° misoriented views and the fourth row shows 240° misoriented views.

subsequent Naming3 transfer block. Experiment 2 was identical for the subtle-trained and gross-trained groups except for the difficulty of the Object Decision task during training.

During Object Decision training, if context influences the rate at which useful orientation-invariant information is acquired and used then the misorientation disadvantage should reduce faster for the gross-trained group than the subtle-trained group. During training the gross-trained group should quickly find coarse, broad-tuned orientation-invariant information that would identify many of the test stimuli, as they only needed to discriminate test objects from dissimilar nonobjects. If the gross-trained group used such information, they should soon have to rely less on orientation-sensitive normalization processes to identify misoriented stimuli. In contrast, discriminating the test objects from the similar nonobjects should be much harder for the subtle-trained group. Larger misorientation disadvantages have been reported when objects must be discriminated from more visually similar distractors (Lawson & Jolicoeur, 1998, 2003; Murray, 1998). Hence, during training, the subtle-trained group might be slow to find orientation-invariant information that was specific enough to identify misoriented views. In the Naming2 block, only visually dissimilar context objects were presented. Here again the gross-trained group should show a smaller misorientation disadvantage for the test stimuli than the subtle-trained group, since coarse orientation-invariant information should still successfully distinguish many of the test objects.

In contrast, in the Naming3 block visually similar context objects were presented. Here, coarse orientation-invariant information would not discriminate accurately between the test objects (such as a horse) and their associated, similarly shaped context items (such as a donkey). The gross-trained group might be forced to revert to using orientation-sensitive normalisation processes to identify many of the misoriented test stimuli. If so, their misorientation disadvantage would increase relative to the Naming2 block. In contrast, during training the subtle-trained group was forced to attend closely to the shape of the test objects. Any orientation-invariant information that was useful during their training should still be specific enough to discriminate the test objects from visually similar distractors. The subtle-trained group was thus not expected to show a greater misorientation disadvantage in the Naming3 relative to the Naming2 transfer block.

Method

Participants. There were 96 students from the University of Liverpool, UK who took part in the study for course credit. They were native speakers of English, and had normal or corrected-to-normal vision.

Materials. The stimuli were line drawings of 60 familiar objects, with all of the upright pictures of the test objects being taken from Snodgrass and Vanderwart (1980). There were 20 objects in each of three sets, the test, visually dissimilar context and visually similar context sets (see Appendix 2). Each object was depicted at its environmentally predominant view at 0°, and at 120° and 240° misoriented views. The test stimuli and the visually dissimilar context stimuli were selected to have visually dissimilar shapes, although there were some similarities amongst them.

Each visually similar context stimulus was selected to be highly similar in shape to its paired test stimulus (see Appendix 2). A rating study was conducted to check that each test stimulus was more similar to its paired visually similar context stimulus than to other stimuli. Six raters selected the most visually similar item to each of the test stimuli from a set of eight items comprising four of the visually similar and four of the visually dissimilar items. All pictures were presented upright. The paired visually similar item was selected on 95% of trials (range 90–100% for individual raters), where chance was 12.5%. The paired visually similar item selected least often was still chosen by four of the six raters, so on 67% of trials.

There were a further two sets of stimuli comprising 80 visually dissimilar (grossly altered) nonobjects and 80 visually similar (subtly altered) nonobjects. All the nonobjects were derived from the 20 test objects. For each test object, four pictures (two 0° views, a 120° view, and a 240° view) were grossly altered and four pictures were subtly altered, with different alterations made to all eight versions (see Figure 3).

Design. There were seven blocks, each comprising 40 trials. Each block presented 20 test objects and 20 context objects. Different context objects were presented in the different blocks (see Table 2). In the Naming1–Baseline block, all 40 stimuli were presented upright and all participants saw the same stimuli. In all the subsequent blocks, half the stimuli (10 test and 10 context pictures) were presented upright and half misoriented. The subset of stimuli assigned to each view was counterbalanced across participants.

For each participant, over the four Object Decision training blocks, each test item was presented twice in one block as a normal version of the test object, twice in another block as a context, nonobject version of the test object, and in the remaining two blocks the test item was presented once as a normal version and once as a context, nonobject version. This variability ensured that participants could not predict whether the second presentation of a given test object in a block would be the normal or nonobject version. The assignment of object decision stimuli to viewing conditions was counterbalanced across participants and across training blocks. The Object Decision training blocks were the only blocks in which the testing of subtle-trained and gross-trained group differed. In these blocks, the subtle-trained group saw subtly altered nonobjects and the gross-trained group saw grossly altered nonobjects.

In all but the last Naming3 block, stimuli were presented in a different, random order in each block for each participant. In the Naming3 block, stimuli were presented in a fixed order to increase the power of the context manipulation. Half of the test objects were immediately preceded by their associated visually similar context object (see Appendix 2). The remaining test objects were followed on the next trial by their associated visually similar context object. If the test object was seen upright then its paired visually similar context object was seen misoriented and vice versa.

There were eight subtle-trained and eight gross-trained conditions. Six participants were assigned to each of these 16 conditions, of whom half named pictures in the Object Decision training blocks and half did a word–picture verification task. For both the subtle-trained and gross-trained groups, there were two orders of presentation of Object Decision training blocks (one order being the reverse of the other) and four presentation orders for the Naming2 and Naming3 blocks (varying whether the test object was seen upright in Naming2 and misoriented in Naming3 or vice versa, varying which subset of test objects preceded and which followed their associated visually similar objects in Naming3, and varying the order of presentation of test objects in Naming3, one order being the reverse of the other).

Apparatus and procedure. A Macintosh G4 PowerMac computer running the Psyscope Version 1.2.5 presentation package was used to display the stimuli. The experiment lasted about 30 min. The procedure for each trial in the three Naming blocks was as follows: A central fixation cross appeared on the screen for 200 ms. The fixation cross was immediately replaced by a picture of an object until the participant responded by naming the picture aloud. Response times were recorded by the computer using a microphone and a voice-activated relay. The name of the picture then appeared as written feedback until the experimenter made a keypress to code the participant's response as correct or incorrect. There was an intertrial interval of 500 ms. Participants were encouraged to respond as rapidly and as accurately as possible.

For the first half of the participants run in this study, trials in the Object Decision training blocks were identical to those in the three Naming blocks except that first, participants responded ''made up'' to the nonobjects rather than naming these stimuli; second, feedback to nonobjects was the word ''made up'' rather than the name of the object; and third, all stimuli were presented for 2000 ms, 1600 ms, 1200 ms, and 800 ms in Object Decision training blocks 1, 2, 3, and 4 respectively. To simplify the running of the study, the second half of the participants did a word–picture verification task in the Object Decision training blocks. These trials were identical to those for the first half of the participants except for the following points. The fixation point was replaced by the name of the test object or the test object from which the nonobject was derived, on object and nonobject trials respectively. This word was followed by a blank screen for 250 ms before the picture was presented. Participants made a speeded m or z keypress response on object and nonobject trials respectively. Feedback was the letter m or z presented for 500 ms on the right or left of the screen for object and nonobject trials respectively. There was an intertrial interval of 1500 ms.

Prior to the first experimental block (Naming1–Baseline) there was a practice block of eight trials which were identical to the Naming1 trials except that different stimuli were presented. Prior to the Object Decision training block 1 there was a second practice block of 16 trials, which presented the same stimuli as in the first practice block plus subtly or grossly altered versions of these stimuli for the subtly trained and grossly trained groups respectively. Participants were given a self-timed break after the Object Decision training block 2 and after the Naming2 transfer block.

Results

Trials in which participants used an inappropriate name or in which the microphone was accidentally activated before the participant responded were discarded as errors. In addition, response latencies less than 500 ms (less than 300 ms on verification trials) or exceeding 2500 ms were discarded as errors (less than 1% of trials). Participants were replaced if they scored over 25% errors overall or over 15% errors in the three Naming blocks. Five participants in the gross-trained group and ten in the subtle-trained group were replaced in Experiment 2 using these criteria. The results for by-participants and by-items analyses are reported using subscripts F_p and F_i respectively.

ANOVAs were conducted on the mean correct naming RTs and the percentage error rates for the misorientation disadvantage and for responses to upright views for the test objects. The analyses reported below include some or all of the following three factors: Training (between-participants: Subtle-training or gross-training), Training Response (between-participants: Naming or word–picture verification in the four Object Decision training blocks), and Block (within-participants: Specified below for each analysis). Main effects and interactions involving the Training Response factor are not reported below since these were not of theoretical interest. To summarize these effects, word–picture verification was generally faster and more accurate than naming in the Object Decision training blocks. In contrast, in the Naming transfer blocks the reverse effect occurred, presumably because practice at the task of naming rather than word–picture verification during training helped subsequent performance at naming in the Naming transfer blocks. Only effects significant at $p < .05$ are reported below. All comparisons noted are significant at $p < .05$ in post-hoc Newman-Keuls analyses.

Figure 4 shows the mean misorientation disadvantage on RTs and percentage errors for the test and context objects in the four Object Decision training blocks and the two Naming transfer blocks, Naming2 and Naming3. There are no means for the first, Naming1–Baseline block since only upright views were presented in that block. Figure 5 shows the mean RTs and percentage errors to name upright views of the test and context objects in all seven blocks.

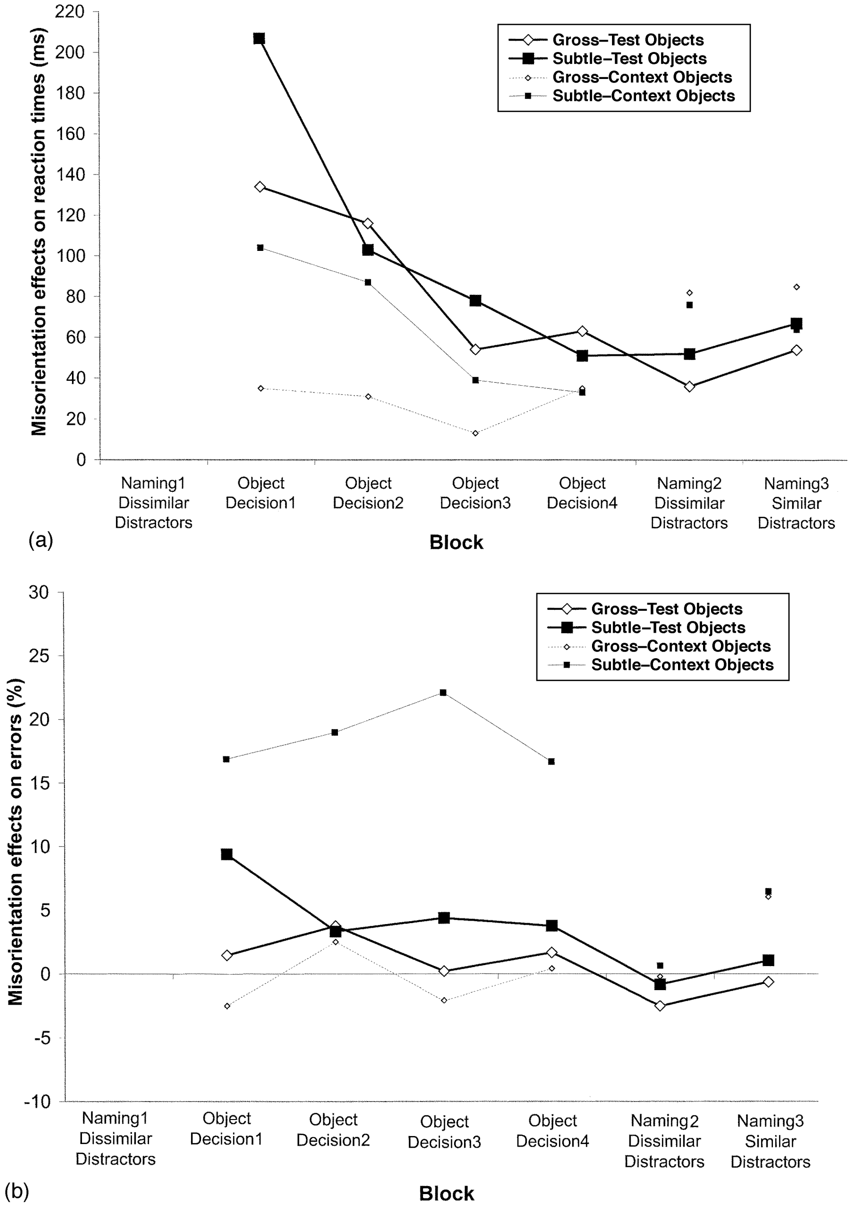

Figure 4. The misorientation disadvantage on (a) reaction times and (b) percentage errors to name the test and context stimuli in the Object Decision 1, 2, 3, and 4 training blocks, the Naming2 (Dissimilar Context) transfer block and the Naming3 (Similar Context) transfer block of Experiment 2, for the gross-trained group and the subtle-trained group. There are no means plotted for the Naming1–Baseline block since only upright views were presented in that block. Note that three different sets of context objects were presented to the gross-trained and subtle-trained groups: Dissimilar Distractors in the Naming1 and Naming2 blocks, nonobjects in the Object Decision blocks, and Similar Distractors in the Naming3 block (see also Table 2).

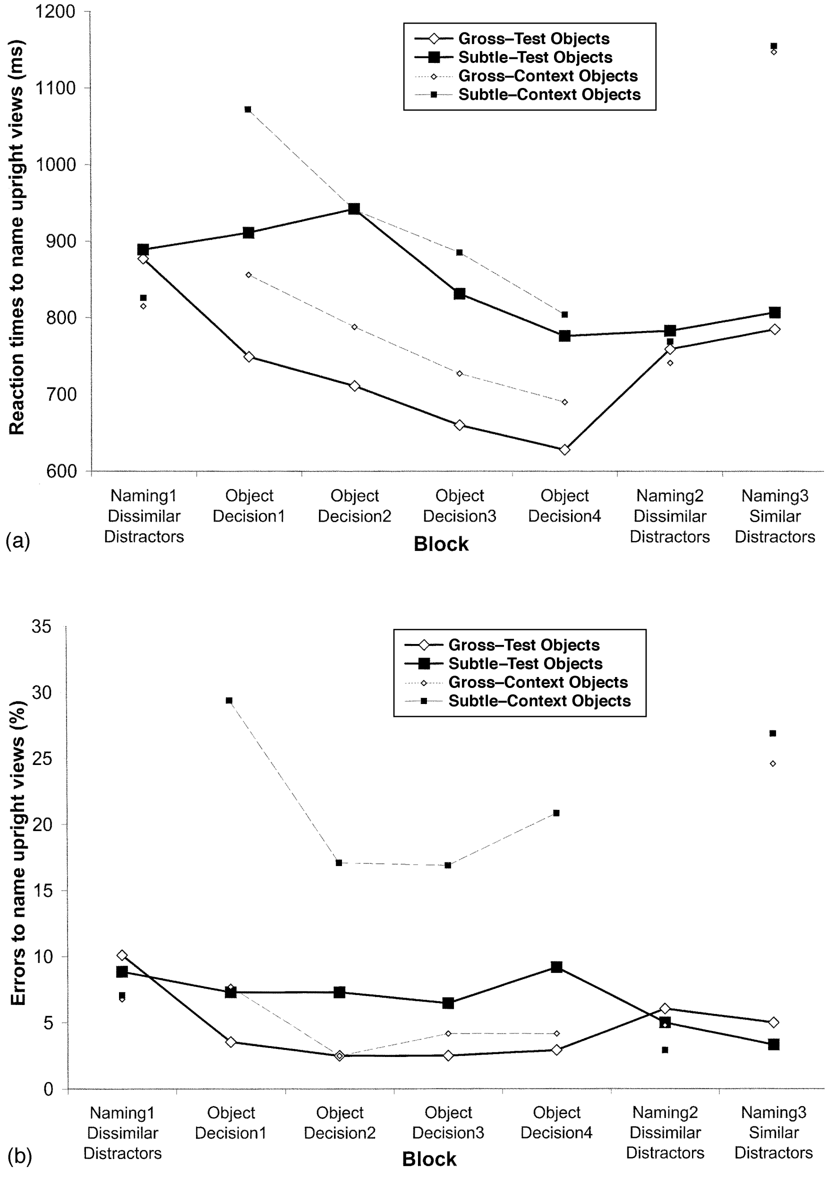

Figure 5. The (a) reaction times and (b) percentage errors to name upright views of the test and context stimuli in the Naming1–Baseline block, the Object Decision 1, 2, 3, and 4 training blocks, the Naming2 (Dissimilar Context) transfer block and the Naming3 (Similar Context) transfer block of Experiment 2, for the gross-trained group and the subtle-trained group. Note that three different sets of context objects were presented to the gross-trained and subtle-trained groups: Dissimilar distractors in the Naming1 and Naming2 blocks, nonobjects in the Object Decision blocks, and similar distractors in the Naming3 block (see also Table 2).

Test objects—object decision training blocks

Factors in these analyses were Training, Training Response, and Training Block (Object Decision training blocks 1, 2, 3, or 4 for participants and, for reasons of counterbalancing, blocks 1 and 2 combined or blocks 3 and 4 combined for items).

Misorientation disadvantage. For RTs, the gross-trained group (92 ms) had a similar overall misorientation disadvantage as the subtle-trained group (110 ms), $F_p(1, 92) = 2.401$, $p > .1$, $F_i(1, 19) = 1.435$, $p > .2$. Training Block was significant, $F_p(3, 276) = 25.579$, $p < .001$, $F_i(1, 19) = 11.927$, $p < .003$. The misorientation disadvantage in block 1 (171 ms) was greater than that in block 2 (110 ms for participants only) which in turn was greater than that in block 3 (66 ms) and block 4 (57 ms). The interaction of Training × Training Block was significant for participants only, $F_p(3, 276) = 3.862$, $p < .01$, $F_i(1, 19) = 1.1430$, $p > .2$. The gross-trained group (134 ms) had a smaller misorientation disadvantage than the subtle trained group (208 ms) in block 1 but there was no significant difference between the two groups in any of the subsequent blocks (see Figure 4a).

For errors, the gross-trained group had a smaller misorientation disadvantage (1.8%) than the subtle-trained group (5.2%), $F_p(1, 92) = 8.076$, $p < .006$, $F_i(1, 19) = 7.752$, $p < .02$. In addition, for participants only the interaction of Training × Training Block was significant, $F_p(3, 276) = 2.659$, $p < .05$, $F_i(1, 19) = 0.050$, $p > .8$. As for RTs, the gross-trained group (1.5%) had a smaller misorientation disadvantage than the subtle trained group (9.4%) in block 1 but there was no significant difference between the two groups in any of the subsequent blocks (see Figure 4b).

Thus in the first block of training the gross-trained group had a smaller misorientation disadvantage than the subtle-trained group. The misorientation disadvantage reduced with practice for both groups, but particularly for the subtle-trained group, such that the misorientation disadvantage was not significantly different across the two groups in blocks 2, 3, or 4.

Upright views. The gross-trained group (687 ms) were faster overall than the subtle-trained group (865 ms), $F_p(1, 92) = 63.446$, $p < .001$, $F_i(1, 19) = 264.495$, $p < .001$. Training Block was also significant, $F_p(3, 276) = 55.260$, $p < .001$, $F_i(1, 19) = 115.617$, $p < .001$. RTs in block 1 (830 ms) and block 2 (827 ms) were slower than in block 3 (745 ms) which in turn were slower than in block 4 (702 ms for participants only). The interaction of Training × Training Block was significant, $F_p(3, 276) = 4.680$, $p < .004$, $F_i(1, 19) = 14.050$, $p < .002$. The gross-trained group was faster than the subtle-trained group in every block (see Figure 5). In addition, the gross-trained group benefited more quickly from practice, becoming successively faster from blocks 1 to 2 to 3 but showing no significant improvement in block 4. In contrast, the subtle-trained group did not improve from block 1 to 2 but then became successively faster from blocks 2 to 3 to 4. For errors, the only significant effect was that the gross-trained group (2.9% errors) were more accurate overall than the subtle-trained group (7.6%), $F_p(1, 92) = 30.019$, $p < .001$, $F_i(1, 19) = 17.027$, $p < .001$.

Thus, throughout training the gross-trained group performed better on upright views than the subtle-trained group, and both groups became faster with practice.

Test objects—naming transfer blocks

Factors in these analyses were Training, Training Response, and Transfer Block (Naming2–Dissimilar Context or Naming3–Similar Context).

Misorientation disadvantage. There were no significant effects in these analyses. The gross-trained group (45 ms) tended to have a smaller misorientation disadvantage than the subtle-trained group (60 ms), $F_p(1, 92) = 1.387$, $p > .2$, $F_i(1, 19) = 3.223$, $p < .09$. The same trend was found in the Naming2 block (36 ms compared to 52 ms) and the Naming3 block (54 ms compared to 67 ms), $F_p(1, 92) = 0.012$, $p > .9$, $F_i(1, 19) = 0.022$, $p > .8$.

Upright views. Naming was faster in the Naming2 block (771 ms) than in the Naming3 block (796 ms), $F_p(1, 92) = 6.826$, $p < .02$, $F_i(1, 19) = 3.765$, $p < .07$. The gross-trained group (772 ms) tended to be faster than the subtle-trained group (795 ms), $F_p(1, 92) = 1.256$, $p > .2$, $F_i(1, 19) = 4.918$, $p < .04$, but this weak effect was countered by an effect in the opposite direction for errors. The gross-trained group tended to make more errors (5.5%) than the subtle-trained group (4.2%), $F_p(1, 92) = 2.369$, $p > .1$, $F_i(1, 19) = 3.773$, $p < .07$.

Overall, upright views were named a little faster in a dissimilar context (in the Naming2 block) than in a similar context (in the Naming3 block), but performance in both blocks was similar across the gross-trained and subtle-trained groups.

Test objects—naming transfer blocks: Naming3 block only

In the Naming3 block, participants might have realized that successive pairs of pictures showed visually similar objects. If so, they could then predict what the upcoming test object would be (e.g., horse) if they had just named its visually similar distractor (donkey). Any such cueing effects should reduce the RT to name both upright and misoriented views, since participants could start to prepare their response before the picture of the test object appeared. To check whether such cueing occurred, the items analyses for the Naming3 block were rerun but now using factors of Training and Presentation Order (whether the test object was seen on the trial immediately before or after its visually similar distractor; cueing benefits were only predicted when the test object was seen after its distractor).

Misorientation disadvantage. There were no significant effects in these analyses. Any trend was in the opposite direction to the cueing hypothesis: There was a slightly larger misorientation disadvantage when the test object followed—and so could be cued by—its distractor (65 ms, 0.4%) than when it preceded its distractor (54 ms, 0.0%), $F_i(1, 19) = 0.242$, $p > .6$ for RTs, $F_i(1, 19) = 0.037$, $p > .8$ for errors.

Upright views. There was a significant effect of Presentation Order for RTs, $F_i(1, 19) = 5.775$, $p < .03$, though not for errors, $F_i(1, 19) = 0.437$, $p > .5$. However, this effect was in the opposite direction to that predicted by the cueing hypothesis. Upright views were named slower when the test object followed—and so could be cued by—its distractor (821 ms, 4.8%) than when it preceded its distractor (781 ms, 3.5%).

There was therefore no evidence that participants benefited from being cued to the identity of the test object on the Name3 trials when the test object was presented after its paired distractor.

Discussion

Throughout Experiment 2, plane-misoriented views of the test objects were harder to identify than upright views. During Object Decision training, this misorientation disadvantage reduced substantially as the test stimuli were seen repeatedly (see Figure 4). The context manipulation also clearly influenced performance in the object decision task. In every block of Object Decision training, the subtle-trained group were slower and less accurate than the gross-trained group to identify upright views of the test objects (see Figure 5).

As predicted, the misorientation disadvantage in the first block of object decision training was greater for the subtle-trained group than the gross-trained group. However, this relatively large misorientation disadvantage for the subtle-trained group rapidly reduced with practice. Indeed, it was no different from the misorientation disadvantage for the gross-trained group in the subsequent Object Decision training blocks 2, 3, and 4. Thus during training there was no evidence that the easier discrimination task for the gross-trained group benefited the rate of their extraction of orientation-invariant information, since the misorientation disadvantage did not reduce either faster or further for this group. Note that for both groups the misorientation disadvantage only gradually reduced across the four training blocks and it was still substantial in the final training block. The lack of difference between the subtle-trained and gross-trained groups in the later Object Decision training blocks was therefore not simply because it was trivially easy to extract useful orientation-invariant information with which to identify the test objects.

In both the Naming2–Dissimilar Context and the Naming3–Similar Context transfer blocks, the difficulty of the prior object decision training had little effect. In particular, the misorientation disadvantage was similar for the gross-trained and subtle-trained groups in both transfer blocks and it was not significantly increased for the gross-trained group by adding new visually similar distractors in Naming3 compared to Naming2. There was a trend for the misorientation disadvantage to increase from Naming2 to Naming3 for the gross-trained group but a similar-sized trend occurred for the subtle-trained group. This suggests that any orientation-invariant information which the gross-trained group had learnt to use during their Object Decision training was just as effective and object specific as that used by the subtle-trained group. This orientation-invariant information enabled the gross-trained group to discriminate rapidly between misoriented test objects and new, visually similar distractors in Naming3, even though in previous blocks the gross-trained group had only had to discriminate between dissimilar stimuli. In the first study of both Jolicoeur and Milliken (1989) and of Murray (1995b), the misorientation disadvantage was similar for test objects in a final training block and in a subsequent transfer block in which a new set of objects were introduced. Together these results suggest that any orientation-invariant information that participants learn to extract and use during training is highly specific to the trained, test objects. This ensures that the information remains useful even if the context of the task is later changed substantially such that, for example, many new, visually similar objects have to be discriminated.

GENERAL DISCUSSION

In two studies, plane-misoriented views of a set of familiar objects were initially identified much slower than upright views of the same test objects. Replicating other studies, this misorientation disadvantage reduced significantly but was never fully eliminated, even after substantial practice at identifying misoriented views of the test objects. In both studies, manipulating the training context in which the test stimuli were identified affected performance substantially. In Experiment 1, a misorientation disadvantage in block 1 was found for the Training:PicturesMisoriented–WordsUp group for pictures only and for the Training:PicturesUp–WordsMisoriented group for words only. In Experiment 2, the gross-trained group (who carried out a relatively easy discrimination task during training) identified all views of the test stimuli faster and more accurately during training than the subtle-trained group.

Both studies examined how these training manipulations influenced the misorientation disadvantage in subsequent transfer blocks. In Experiment 1, a reduction in the misorientation disadvantage for a given picture of an object only occurred if, first, that picture had already been seen and attended to during training (and not if only the word which named that object was seen in training, see the Training:PicturesMisoriented–WordsUp group; nor if the picture was seen but not attended to, see Murray, 1995b), and second, if misoriented pictures had to be identified during training (and not if only misoriented words had to be identified during training, see the Training:PicturesUp–WordsMisoriented group; nor if participants were simply instructed to imagine upright pictures at misoriented views, see Murray, 1995a). The results of Experiment 1 suggest that whether a participant adopts a strategy of trying to extract orientation-invariant information depends on the precise training context that they experience—both the type of stimuli presented (words or pictures) and the views of those stimuli (all shown upright or some seen misoriented). Together these and previous findings suggest that only under strictly limited conditions do participants try to learn to use orientation-invariant information to identify misoriented pictures.

The results of Experiment 2 suggest that, once the strategy of trying to extract orientation-invariant information has been triggered, varying the difficulty of shape discrimination during training does not influence the effectiveness of that strategy. Discrimination difficulty did not seem to affect, first, the rate and extent of extraction of orientation-invariant information and, second, the object-specificity of that information. Throughout object decision training in Experiment 2, overall performance was affected by the difficulty of discrimination (see Figures 4 and 5). In Object Decision training block 1, the misorientation disadvantage was larger for subtle-trained than gross-trained participants. In Object Decision training blocks 2, 3, and 4, the misorientation disadvantage was no different for subtle-trained and gross-trained participants. Thus, first, the misorientation disadvantage did not reduce either faster or further during training for the gross-trained group (who had an easy discrimination task during training) compared to the subtle-trained group (who had a difficult discrimination task). Second, the orientation-invariant information extracted by the gross-trained group still seemed to be useful when the group was subsequently transferred to a difficult discrimination task in the Naming3 block (which presented new, visually similar stimuli). Gross-trained as well as subtle-trained participants seemed to extract orientation-invariant information that was highly object specific in order to aid their identification of misoriented stimuli. As a result there was only a small, nonsignificant increase in the misorientation disadvantage in the Naming3 block compared to the Naming2 block (which presented dissimilar distractors) and this increase was similar across the gross-trained and subtle-trained groups.

One explanation of the results of Experiment 2 is that participants are typically conservative in their use of orientation-invariant information. They may only use such information if it seems specific enough to discriminate a given test object from any other object with which they are familiar. Information which would successfully discriminate the test object from all other objects presented during training in a given study may often fail this strict criterion. This account would also predict that misorientation effects for trained objects would not increase when a large, new set of familiar objects are added from which the trained objects must be discriminated, as was found in Experiment 1 of Jolicoeur and Milliken (1989) and of Murray (1995b) as well as in the Naming3 block in Experiment 2 here.

In summary, from Experiment 1 here and earlier research, it appears that participants only adopt a strategy of trying to extract orientation-invariant information in very restricted circumstances. From Experiment 2, it seems that shape discrimination difficulty has little influence on how this strategy is implemented. If a given training context encourages participants to learn to extract orientation-invariant information, then the information which they learn to use is highly specific to the particular test objects presented, regardless of how hard the test objects are to distinguish from distractors during training.

These results suggest that after identifying a given view of an object, we typically do not extract and use view-invariant information which would allow us to subsequently identify that object equally efficiently at any plane orientation. Instead, we keep using view-specific information to identify objects unless the context strongly encourages us to expect that we will have to identify different, plane-rotated views of the objects. Thus restrictive conditions are necessary to trigger a strategy of learning to use orientation-invariant features that can alleviate the misorientation disadvantage. That this strategy is not adopted by default by the visual system suggests that it is effortful. Familiar objects are sometimes seen at unusual, plane-misoriented views even under everyday viewing conditions (for example, if we lie down or tilt our heads). If there were little cost to the search for and use of orientation-invariant features, we would always be expected to use this strategy. Instead, under normal viewing conditions, we appear to continue to use view-sensitive information to identify objects as we gain experience in identifying those objects. Note that this conclusion is consistent with the finding that perceptual expertise at identifying a given set of largely mono-oriented stimuli reliably increases the inversion effect for those stimuli (Carey & Diamond, 1994; Diamond & Carey, 1986; Rossion, Gauthier, Goffaux, Tarr, & Crommelinck, 2002; Yin, 1969). Highly familiar stimuli (such as faces for adults, dogs for dog experts, and Greeble novel objects for people trained to identify Greebles) are much harder to identify upside-down than in their usual, upright orientation. In contrast, the recognition of less familiar stimuli (such as faces for young children and dogs and Greebles for people who are nonexperts) is less disrupted by inversion.

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APPENDICES

1. Experiment 1 objects

Here are the 80 objects that were presented both as written words and as pictures in Experiment 1.

Set 1	Set 2	Set 3	Set 4
Ant	Barn	Basket	Bear
Bottle	Beetle	Bike	Bed
Candle	Bus	Cake	Boat
Cow	Cannon	Camel	Car
Deer	Chair	Cat	Church
Desk	Crown	Coat	Cup
Duck	Dog	Dress	Donkey
Fox	Elephant	Goat	Fish
Gorilla	Frog	Hat	Foot
Helicopter	Gun	Iron	Giraffe
Kangaroo	Horse	Leopard	Harp
Lion	House	Mouse	Jug
Mushroom	Kettle	Peacock	Motorbike
Penguin	Monkey	Pig	Piano
Seahorse	Ostrich	Rabbit	Rhinoceros
Snail	Pineapple	Sledge	Shoe
Squirrel	Pram	Snowman	Snake
Swan	Seal	Suitcase	Tree
Toaster	Stool	Tiger	Trousers
Watering-can	Windmill	Tortoise	Zebra

2. Experiment 2 objects

Here are the 60 objects that were presented as pictures in Experiment 2.

Test objects	Visually similar context objects	Visually dissimilar context objects
Airplane	Space-ship	Basket
Bear	Lion	Bicycle
Beetle	Ant	Bottle
Church	Barn	Car
Crocodile	Lizard	Chair
Desk	Drawers	Cooker
Dog	Fox	Duck
Dustbin	Glass	Elephant
Goat	Deer	Foot
Grasshopper	Sweetcorn	Giraffe
Horse	Donkey	Hat
Ironing-board	Table	Helicopter
Iron	Hovercraft	Kangaroo
Kettle	Watering-can	Mushroom
Owl	Eagle	Ostrich
Frying-pan	Cup	Peacock
Pig	Rhinoceros	Piano
Boat	Windsurfer	Shoe
Toaster	Suitcase	Snail
Train	Lorry	Snake