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The effect of prior experience on recognition thresholds for plane-disoriented pictures of familiar objects

REBECCA LAWSON
University of Liverpool, Liverpool, England

and

PIERRE JOLICOEUR
University of Waterloo, Waterloo, Ontario, Canada

We investigated plane rotation effects on the minimum presentation duration that is required in order to recognize pictures of familiar objects, using the method of ascending limits. Subjects made unspeeded verification responses, selecting from 126 written alternatives. Replicating similar identification studies in which brief, masked pictures (Lawson & Jolicoeur, 1998) were presented, disorientation reduced the efficiency of recognition. Mirroring the findings in speeded picture naming studies (e.g., Jolicoeur, 1985; Jolicoeur & Milliken, 1989), but in contrast to those of Lawson and Jolicoeur (1998), orientation effects were found over a wide range of views and were attenuated but not eliminated with experience with a given object. The results bridge the findings from unspeeded verification and speeded naming tasks. They suggest that the same orientation-sensitive processes are tapped in both cases, and that practice effects on these processes are object specific.

It has been repeatedly observed that increasing the plane disorientation of pictures of objects correspondingly increases the time taken to identify the objects in speeded naming tasks, over a range of rotations from 0° to 120° or greater (see, e.g., Jolicoeur, 1985; Jolicoeur & Milliken, 1989; McMullen & Jolicoeur, 1990; Murray, 1995a). The theoretical interpretation of this strong and consistent sensitivity of recognition to the plane orientation of an object is as yet unclear.

One commonly cited hypothesis (see, e.g., Jolicoeur, 1990) is that the increased latencies that are required in order to name more disoriented stimuli reflect the increased amount of mental rotation that an internal representation of the stimulus must undergo in order to align the orientation-sensitive, internal representation with the canonical, upright orientation. Countering this proposal, it was found in recent studies that neither a perceptual illusion of rotary motion nor the physical rotation of pictures of familiar objects influenced speeded naming responses, although both of these manipulations did affect left–right facing judgments made in response to the same stimuli (Jolicoeur, Corballis, & Lawson, 1998). This result suggests that mental rotation is employed when disoriented stimuli have to be discriminated from their mirror images, but that it is typically not involved in picture identification.

An alternative hypothesis to account for the systematic effects of orientation on object identification was proposed by Corballis (1988), who suggested that upright and disoriented stimuli are generally identified equally efficiently but that since disoriented stimuli look unusual, subjects often double-check such stimuli to ensure that they have been correctly identified. Subjects double-check by transforming disoriented stimuli to match an upright view, which results in slower naming latencies for disoriented as opposed to upright views. This account further assumes that the transformation process takes longer for more disoriented stimuli. We recently tested this hypothesis by reasoning that any costs for double-checking should be observed only in speeded identification tasks. In an unspeeded task, subjects' performance would not be penalized even if they did double-check, so no orientation effects would be predicted if orientation effects were simply artifacts caused by double-checking. We required subjects to make an unspeeded verification response to briefly presented, immediately masked stimuli, and found robust and systematic effects of plane rotation on accuracy (Lawson & Jolicoeur, 1998). This result indicates that the orientation effect cannot be due solely to double-checking.

This leaves a third proposal, that before images of plane-disoriented stimuli can be matched to stored representations of canonically oriented (upright) stimuli, they must

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usually be transformed or normalized to the upright. The transformation process employed is not mental rotation (see Jolicoeur et al., 1998) and is as yet unspecified. The latter account is obviously unsatisfactory, since it provides no more than a description of the present experimental results.

Comparing the Results From Unspeeded Verification and Speeded Naming Studies

It is clear that a greater understanding is needed of the conditions under which orientation effects are observed, preferably under a wider range of experimental conditions than have been reported to date. To address this issue, we (Lawson & Jolicoeur, 1998) investigated the effects of plane rotation on recognition by making use of a very different task from that of speeded naming—namely, unspeeded picture–word verification. In this task, a picture was briefly presented at a plane orientation between 0° (upright) and 180° (upside down). Subjects then selected which of three written response alternatives named the object presented. The two distractor alternatives named objects that were both either visually similar or dissimilar to the object presented.

We found clear effects of plane rotation on performance, but the pattern of results differed significantly from that obtained in speeded naming studies. First, orientation effects were largely confined to the range 0°–60°, particularly for visually dissimilar distractor alternatives. In contrast, naming latencies typically increase monotonically as plane rotation increases from 0° to 120° (Jolicoeur, 1985; Jolicoeur & Milliken, 1989; McMullen & Jolicoeur, 1990; Murray, 1995a). Second, the orientation effects did not attenuate with practice. In contrast, orientation effects on naming latencies do attenuate (although they are not eliminated) with practice (Jolicoeur, 1985; Jolicoeur & Milliken, 1989; Murray, 1995a).

Since the task demands for unspeeded verification and speeded naming are so different, and given that the orientation effects in these tasks differed, it is possible that the two tasks tap different orientation-sensitive processes or representations. In this case, results from the unspeeded verification studies cannot be used to test accounts of the orientation effects observed in speeded naming tasks.

Alternatively, and more interestingly, it could have been that the same processes and representations were used in both the verification and the naming studies, but that methodological differences meant that the two tasks measured different aspects of performance. In particular, because the image was likely to be transient and highly degraded in the verification studies, it may have been too unstable to undergo extensive transformation or normalization. In that case, orientation effects would be restricted to views close to the upright; for more disoriented views, subjects would be forced to rely on extracting orientation-invariant features. In addition, if the degraded image was not clear and specific enough to influence long-term object representations, no practice effects would be expected.

In the present study, we attempted to bridge the methodological differences between the unspeeded verification studies of Lawson and Jolicoeur (1998) and typical speeded naming studies, in order to examine whether similar effects of orientation would be observed when the verification task was more like a typical naming task. Such a result would enable us to draw more general conclusions about the nature of plane rotation effects on performance, based on wide-ranging empirical results from clearly related, but methodologically diverse, studies.

In our initial verification studies (Lawson & Jolicoeur, 1998), we presented the stimuli briefly (for less than 50 msec) and at low contrast, and they were immediately masked. In contrast, in the naming studies of Jolicoeur (1985), unmasked, high-contrast stimuli were presented until the subject responded (generally for hundreds of milliseconds). The verification studies required an unspeeded keypress response, which was simply a choice between three written alternatives, whereas the naming studies required a speeded verbal response, with (initially) unlimited alternatives. Accuracy was little over two thirds correct in the verification studies, with chance levels being one third correct, whereas accuracy was over 90% correct in the speeded naming studies, with chance levels presumed to be close to zero.

In the verification studies of Lawson and Jolicoeur (1998), the target object had to be discriminated from only two alternatives. Simple orientation-invariant features would therefore often have been sufficient to identify the target. Such features could be extracted even if only degraded representations of the objects were available. In particular, when visually dissimilar distractor alternatives were presented (such as a vase and plate, when a windmill had been depicted), even very coarse information, such as overall shape or complexity, could be used to identify the target accurately: simple and rounded, versus complex and angular. In contrast, in a typical speeded naming task, subjects must identify many different objects presented with no cue in a random order. Coarse features would not be unique enough to discriminate between all the objects.

To reduce the task differences between the present verification study and typical speeded naming studies, we made two major methodological changes relative to the initial verification studies of Lawson and Jolicoeur (1998). First, we used a recognition threshold response measure and employed the method of ascending limits. On each trial, an object was presented initially for 33 msec for subjects to try to identify. The same object was then presented repeatedly at the same orientation, with the duration being incremented by 16.7 msec (the time taken for one screen refresh) on each presentation (from 33 msec initially, to 50 msec, 67 msec, and so on), until either the stimulus was correctly identified, or the subject had seen the stimulus on 14 consecutive presentations (at which point the presentation duration was 250 msec). This ensured that even highly disoriented views of objects were identified accurately and specifically while the unspeeded response measure from our initial verification studies was retained.

Second, subjects were required to choose from a list of 126 (rather than just 3) written response alternatives. Although the task was still a verification task, it was unlikely that subjects could guess correctly which stimulus had been presented. Furthermore, there were usually many distractor objects which were visually similar to any given target object, so that subjects could not identify a stimulus from very general properties (such as overall shape) or by using just a single distinguishing feature. The task was therefore much harder than the task used by Lawson and Jolicoeur (1998), since correct responses required more accurate and complete stimulus information.

The Influence of Practice on Orientation Effects in Unspeeded Verification Tasks

As we have noted above, in our initial verification studies, the orientation effect did not attenuate across repeated presentations of a given object (Lawson & Jolicoeur, 1998). This result contrasts with the results of speeded naming studies (e.g., Jolicoeur, 1985; Jolicoeur & Milliken, 1989; Murray, 1995a), in which the orientation effect did attenuate rapidly with practice. Interestingly, practice effects on naming latencies are confined to objects that have previously been seen, suggesting that subjects cannot learn a general compensation strategy to overcome the effects of disorientation (Jolicoeur, 1985; Jolicoeur & Milliken, 1989). Murray (1995a) reported that if upright views of objects were *imagined* at disoriented views, this did not subsequently attenuate orientation effects. In contrast, seeing an upright view of an object in the context of naming other objects which *are* disoriented reduces orientation effects just as much as if the object had actually been seen in a disoriented view (Jolicoeur & Milliken, 1989). Jolicoeur (1990) suggested that subjects may learn to extract orientation-invariant features from previously experienced stimuli, if those stimuli have been identified in the context of recognizing disoriented views of objects. Detection of invariant features for a given object would prevent the need to subsequently normalize images of disoriented views of that object prior to identification.

Task differences may have eliminated effects of practice in the unspeeded verification studies of Lawson and Jolicoeur (1998). Evidence for this explanation comes from a similar dissociation in the effects of practice in studies requiring the identification of alphanumeric stimuli. Jolicoeur and Landau (1984) found no reduction with practice in the strong effects of plane orientation on the identification of briefly presented, immediately masked letters. In contrast, Corballis, Zbrodoff, Shetzer, and Butler (1978) reported a rapid attenuation in the initial, small orientation effects on the speeded naming of unmasked, disoriented characters (see also Jolicoeur, Snow, & Murray, 1987).

In Jolicoeur and Landau's (1984) study, stimulus duration was set by first requiring subjects to identify upright letters at decreasing exposure durations until performance had leveled off. In the test phase, different alphanumeric stimuli were presented for 50 msec or less. Subjects identified correctly less than 30% of the highly disoriented stimuli (where chance was 8%). Similarly, performance was inaccurate but well above chance in the verification studies of Lawson and Jolicoeur (1998). In both sets of studies, subjects could probably extract simple distinguishing features which would be adequate for identifying stimuli in the task, but the image of the briefly presented stimulus was likely to be degraded and would not be normally and fully analyzed. It may be impossible to identify and store new, orientation-invariant features for transient, degraded, poorly specified images. This would then account for the lack of practice effects in these studies.

By contrast, in the present verification study, stimuli were presented for durations of up to 250 msec, and they had to be identified specifically. If poor image quality had eliminated effects of prior experience in the studies reported by Lawson and Jolicoeur (1998) and Jolicoeur and Landau (1984), practice effects would be predicted in the present ascending limits task. In the present task, subjects would usually have a good representation of the object when they identified it, as in the speeded naming tasks of Corballis et al. (1978) and Jolicoeur et al. (1987). Alternatively, if verification studies tap different processes and representations to naming experiments, no effects of practice would be predicted in the present verification study, replicating Lawson and Jolicoeur.

To study object-specific effects of prior experience, the introduction of objects in the present study was staggered. Only half of the items, the "early" objects, were presented in the first experimental block, whereas all of the objects (the early objects and the remaining "late" objects) were presented in the second and third blocks. Thus, in Block 1, the early items only were seen for the first time. In Block 2, the early items were identified for the second time, whereas the late items were presented for the first time. Finally, in Block 3, the early items were seen for the third time and the late items for the second time. This design allowed us to distinguish between general and object-specific practice effects, either of which could attenuate the disruption in performance caused by disorientation.

General practice effects would produce an overall improvement in the subjects' ability to compensate for disorientation, independent of the familiarity of the particular object to be identified. In this case, orientation effects should be reduced through the experiment, from Block 1 to 2 to 3. Specifically, if only general practice effects were observed, orientation effects for early and late items should be identical in both Blocks 2 and 3, since the subject would have had an equal amount of practice *at identifying disoriented stimuli* when presented with either early or late objects, in both Blocks 2 and 3.

In contrast, object-specific practice effects would be tied to the prior experience of the subject in identifying a particular object. Since only early objects were seen in Block 1, then in Blocks 2 and 3, any attenuation of orientation effects with prior experience should reduce orientation effects more for early as compared with late objects. In fact, if only object-specific practice effects were observed, orientation effects for early items in Block 1 and late items in Block 2 should be the same (where a given object was seen for the first time in both cases), as should orientation effects for early items in Block 2 and late items in Block 3 (where objects were seen for the second time).

METHOD

Subjects

The 14 subjects, from the University of Waterloo, were paid to participate or volunteered for course credit. The subjects were native speakers of English, and they had normal or corrected-to-normal vision.

Materials

The stimuli were 126 line drawings of familiar objects taken from Snodgrass and Vanderwart (1980) and listed in the first column (Target Picture Presented) of the appendix in Lawson and Jolicoeur (1998). All the objects had an environmentally predominant orientation, which we labeled as 0°. Each drawing was rotated in steps of 30°, to give seven views of each object, from 0° (upright) to 180° (inverted). A pattern mask was produced, which was composed of small overlapping sections of a large number of different objects, none of which were presented in the experiment.

Design

The 126 objects were divided into two equal sets by placing objects with alphabetically consecutive names into different sets. Seven subjects were randomly assigned to each set. In each set, for Block 1, 9 of the 63 objects were assigned to each of the seven orientations (0°, 30°, 60°, 90°, 120°, 150°, and 180°). The orientation assigned to a given object was different for every subject. Across the 14 subjects, all items were depicted once at each orientation. The order of presentation of trials was random and was different for every subject.

The subjects completed three experimental blocks. In the first block, they identified one view of each of one set of 63 objects. In the second and third blocks, the subjects identified one view of all of the 126 objects. During the experiment, each subject thus saw either three views (if the object was presented in the first block—early items) or two views (if the object was initially presented in the second block—late items) of each object. For a given subject, each object was presented at a different plane-rotated view in each block. The view of each object was rotated by 30° clockwise in each successive block, up to a 180° view, at which point the object was seen at a 0° view in the subsequent block.

The subjects were given a sheet on which were listed the names of all the 126 objects, together with a three-digit number associated with each object. The subjects responded by typing in the number corresponding to the object that they thought had been presented. They were instructed to guess if possible, but to respond using the arrow keys if they had no idea what object had been presented. The subjects were told that speed of response was irrelevant to the task. The same sheet was used throughout the experiment, and the subjects were not permitted to mark on it the objects that they had identified.

Each picture was displayed initially for 33 msec and was then immediately pattern masked. Identification was rarely possible at this duration (around 1% of trials). Stimulus duration was then increased in increments of the time taken to refresh the screen (16.7 msec) each time the stimulus was presented. The second duration was therefore 50 msec, then 67 msec, 83 msec, and so on. If the subject correctly identified the stimulus, the subject heard a triple beep, and a new object was presented on the next trial (initially for a duration of 33 msec). If the subject failed to type in the correct number, there were no beeps, and the same object at the same orientation was presented again, for a slightly longer duration. The object was presented up to 14 times consecutively, giving a duration of 250 msec on the final presentation. If the subject still failed to recognize the object on the 14th presentation, the triple beep warning sounded and a different object was presented on the next trial. These trials were discarded as errors. The subjects were told that they would be automatically moved onto the next object if they failed to identify a given object on their 14th attempt, but they were not informed of the identity of objects that they thus failed to identify.

The subjects completed a practice block of 10 trials before the experimental block. The practice trials were identical to the experimental trials, except that different objects were presented, the experimenter helped the subject to complete the initial trials, and the subjects used a different sheet, which listed only 32 object names and their numbers (none of which appeared on the experimental sheet).

Apparatus and Procedure

A PC-compatible 486 computer running the MEL Version 1.0 presentation package was used to display the stimuli. The experiment lasted about 120 min, but there was considerable variation in the time taken to complete the study.

The procedure for each experimental trial was as follows: A fixation cross appeared on the screen until the subject pressed the space bar. The fixation cross was then immediately replaced by a picture of an object for the appropriate duration. The picture was replaced by a mask for 300 msec, which was in turn replaced by the sentence, "Enter the number of the object." The subjects were required to type in a three-digit number to identify the object that they believed had been presented, or to press the three arrow keys if they had no idea what the object was. The background screen was always white (approximately 61 cd/m^2), and the fixation cross and mask were black (approximately 0.5 cd/m^2). The picture was in a low-contrast light gray (approximately 57 cd/m^2) and subtended a visual angle of about 9°.

RESULTS

Two separate sets of analyses were conducted on the mean duration of picture presentation required for a correct response. The first set of analyses investigated practice effects over three presentations of an object during the experiment, using data from the early items only. The second set of analyses compared general and object-specific practice effects across the first two presentations of an object. Mean duration over subjects is shown in Figure 1.

Analyses of Practice Effects Over Three Blocks

These analyses included data only from correctly identified early items (the 63 objects that were initially presented in the first block). There were two within-subjects factors: *orientation*, the plane rotation of the object (0°, 30°, 60°, 90°, 120°, 150°, or 180°) and *block* (1, 2, or 3).

The main effect of orientation was significant [$F(6,78) = 16.42$, $MS_e = 132$, $p < .001$]. Over the range 0°–120°, subjects needed longer durations to identify more dis-

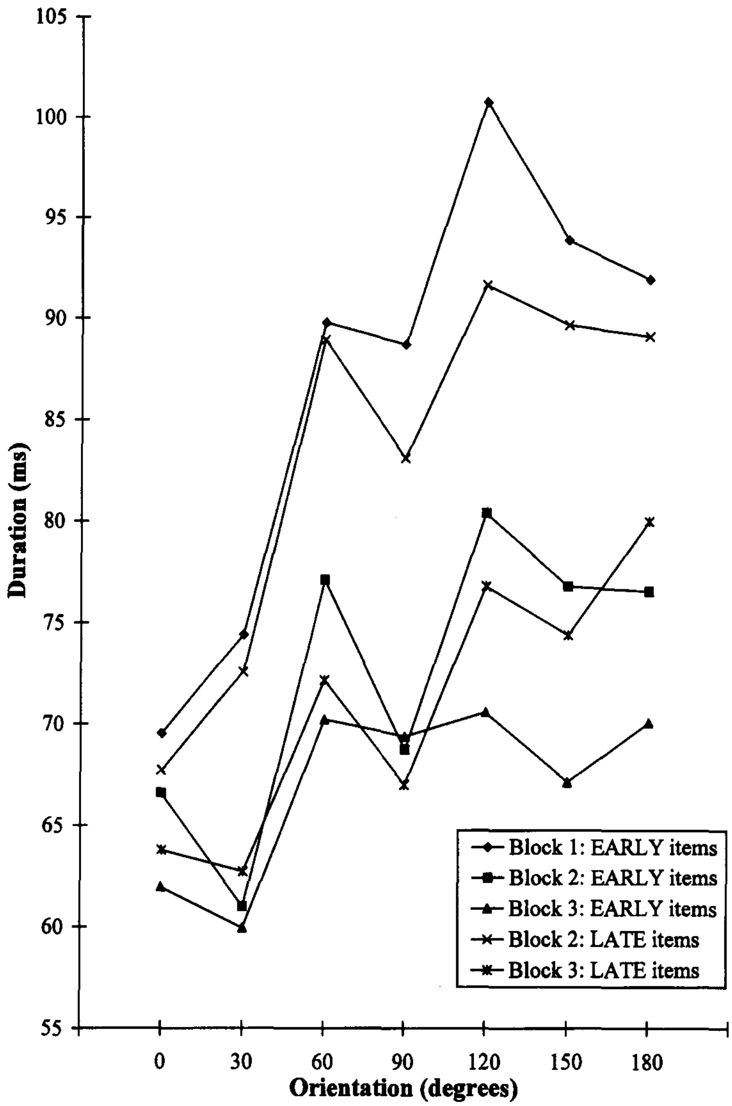

Figure 1. Mean presentation duration at each orientation, in Block 1 (early items only) and Blocks 2 and 3 (both early and late items, plotted separately).

oriented stimuli, but this effect reversed for the most disoriented (150° and 180°) stimuli. These observations were supported by significant effects in the trend analyses for both the linear [$F(1,13) = 42.25$, $MS_e = 192$, $p < .001$] and the quadratic [$F(1,13) = 12.90$, $MS_e = 156$, $p < .004$] components of the orientation effect, calculated over the full range of views. There was also a significant main effect of block [$F(2,26) = 104.42$, $MS_e = 100$, $p < .001$]. Mean duration reduced from 87.0 msec in Block 1 to 72.4 msec in Block 2 to 67.0 msec in Block 3.

Of most interest, there was a significant interaction of orientation × block [$F(12,156) = 2.13$, $MS_e = 118$, $p < .02$]. Orientation effects became attenuated with practice (see Figure 1). For instance, the difference between the mean duration required in order to identify 0° and 120° views was 31.2 msec in Block 1, 13.8 msec in Block 2, and 8.6 msec in Block 3. Confirming this, the interaction between the main effect of block and the linear trend analysis of the orientation effect was significant [$F(2,26) = 10.61$, $MS_e = 74$, $p < .001$], as was the interaction between the main effect of block and the quadratic trend analysis of the orientation effect [$F(2,26) = 5.37$, $MS_e = 73$, $p < .02$].

Subjects identified the object by or before the longest (250-msec) duration on all but 1.35% of the trials. Despite there being so few trials on which subjects failed to identify the object, the distribution of these errors was still significantly influenced by orientation [$F(6,78) = 3.22$, $MS_e = 16$, $p < .008$]. There were 0.0%, 0.3%, 1.6%, 2.4%, 2.9%, 2.4%, and 1.9% of error trials at 0°, 30°, 60°, 90°, 120°, 150°, and 180° views, respectively. In addition, there was a significant effect of block on the distribution of these trials [$F(2,26) = 19.87$, $MS_e = 10$, $p < .001$]. There were 3.2%, 1.2%, and 0.5% of unidentified objects in Blocks 1, 2, and 3, respectively. The interaction of orientation × block was not significant [$F(12,156) = 1.52$, $MS_e = 18$, $p > .1$], but the pattern of results mirrored that reported above for the mean durations.

Analyses Comparing General to Object-Specific Practice Effects

These analyses included only data from correctly identified objects presented for the first or second time. For the early items (the 63 objects presented in the first block), these were the data from the first and the second blocks; for the late items (the 63 objects presented initially in the second block), these were the data from the second and third blocks. There were three within-subjects factors: orientation (0°, 30°, 60°, 90°, 120°, 150°, or 180°), presentation (the number of times that a given object had been seen: once or twice), and item set (early or late).

The main effect of orientation was significant [$F(6,78) = 24.54$, $MS_e = 154$, $p < .001$]. For views between 0° and 120°, subjects required increasingly long durations to identify increasingly disoriented stimuli, but 150° and 180° views were identified at shorter durations than were 120° views. These observations were supported by significant effects in the trend analyses for both the linear [$F(1,13) = 52.13$, $MS_e = 309$, $p < .001$] and the quadratic [$F(1,13) = 22.32$, $MS_e = 105$, $p < .001$] components of the orientation effect.

There was also a significant main effect of presentation [$F(1,13) = 117.44$, $MS_e = 150$, $p < .001$]. Mean duration decreased from 85.1 to 71.7 msec from the first to the second presentation of a given object. Finally, there was a significant main effect of item set [$F(1,13) = 6.42$, $MS_e = 104$, $p < .03$], with mean duration being slightly greater for early items, at 79.7 msec, than for late items, at 77.1 msec.

The only significant interaction was that of orientation × presentation [$F(6,78) = 2.27$, $MS_e = 157$, $p < .05$]. The effects of orientation became attenuated with object-specific practice, from the first to the second presentation of an object (see Figure 1). For instance, the difference between the mean duration required in order to identify 0° and 120° views was greater on the first presentation of an object (27.6 msec) than on the second presentation (13.4 msec). Confirming these observations, there were significant reductions in both the linear and quadratic components of the orientation effect from the first and second presentation of an object: For the interaction between the main effect of presentation and the linear trend analysis, $F(1,13) = 4.88$, $MS_e = 151$, $p < .05$, and for the interaction between the main effect of presentation and the quadratic trend analysis, $F(1,13) = 8.41$, $MS_e = 163$, $p < .02$.

In contrast, the nonsignificant interaction of orientation × item set [$F(6,78) = 0.59$, $MS_e = 122$, $p > .7$] indicated that the orientation effect was largely independent of when in the experiment an object was first presented. For example, the difference between the mean duration required in order to identify 0° and 120° views was little more for early items, which were presented in the first and second blocks (22.5 msec), than for late items, which were presented in the second and third blocks (18.4 msec). There was no significant reduction in either the linear or the quadratic components of the orientation effect for early as opposed to late items: For the interaction between the main effect of item set and the linear trend analysis, $F(1,13) = 0.02$, $MS_e = 107$, $p > .8$, and for the interaction between the main effect of item set and the quadratic trend analysis, $F(1,13) = 1.42$, $MS_e = 124$, $p > .2$.

Subjects identified the object by, or before, the longest (250-msec) duration on all but 1.98% of trials. The distribution of these trials was significantly influenced by orientation [$F(6,78) = 4.14$, $MS_e = 20$, $p < .002$], with 0.0%, 0.8%, 2.4%, 2.2%, 3.6%, 2.8%, and 2.2% of such trials occurring at 0°, 30°, 60°, 90°, 120°, 150°, and 180° views, respectively. In addition, there was a significant effect of presentation [$F(1,13) = 27.28$, $MS_e = 12$, $p < .001$]. On initial presentation, 2.9% of the objects remained unidentified. On the second presentation only 1.1% were not identified. No other main effects or interactions were significant.

DISCUSSION

In the present study, subjects verified the identity of upright and plane-rotated views of briefly presented line drawings depicting familiar objects. We found clear and strong effects of orientation on identification, replicating the results of the initial verification studies of Lawson and Jolicoeur (1998), but with the use of a different response measure—namely, recognition thresholds. A longer exposure duration was required in order to identify disoriented, as opposed to canonical, upright views. Furthermore, consistent with results from speeded naming studies, we found that stimulus orientation influenced performance for rotations beyond 60°, in contrast to the results of Lawson and Jolicoeur.

Second, orientation effects were strongly attenuated over the course of the experiment. This attenuation was primarily due to object-specific rather than general practice effects. Object-specific learning was predicted to reduce orientation effects as a given object was identified repeatedly, with practice effects being independent of the particular block in which the item was presented. Such learning was observed here. Orientation effects were greater when an object was first presented than when it was identified for a second time, and the size of the orientation effect was similar, whether an object was initially presented early (in the first block) or late (in the second block) in the experiment. This object-specific reduction in orientation effects with practice mirrors the results reported by Jolicoeur (1985) and Jolicoeur and Milliken (1989) for speeded naming studies.

The attenuation of orientation effects was largely independent of general learning, indexed by the block in which an object was presented. Early items (seen initially in the first block) did not produce significantly larger orientation effects than did later items (which were not seen until the second block). Furthermore, early items *did* reveal smaller orientation effects than late items did when early and late items were tested together, in both the second and the third blocks (see Figure 1). As discussed in the introduction, general learning should have reduced orientation effects in a given block equally across early and late items. This prediction was not confirmed.

In summary, although the current verification study had task requirements very different from those of typical speeded naming studies, we observed orientation effects similar to those reported in naming studies. Specifically, orientation effects were found over a wide range of views, and object-specific practice effects were observed. The similarity of results across the verification and naming tasks suggests that both tap the same orientation-specific processes and representations.

The present results contrast to the orientation effects found in our initial verification studies (Lawson & Jolicoeur, 1998). We suggest that the two critical differences between the present and the initial verification studies (and the critical similarities between the present study and typical speeded naming experiments) were the quality of the image available to the subject and its similarity to other stimuli from which it had to be discriminated.

In the initial verification studies, a degraded, poor quality image had to be discriminated from just two alternatives. In the present study, and in typical naming studies, a relatively good quality image had to be discriminated from many alternatives. If only a poor quality image is available, it is unlikely that extensive transformation processes can be undertaken, although views close to the upright might still be able to be transformed to match to orientation-specific representations. Highly disoriented stimuli could then only be identified by detecting orientation-invariant information—but coarse, general features would often suffice if just three response alternatives had to be discriminated, particularly if the alternatives were visually dissimilar to the target object.

In the present study, objects had to be identified more specifically than in the initial verification studies, so it would be much more difficult to detect sufficient unique, orientation-invariant information in order to identify the object. Compensating for this, stimuli were, if necessary, presented for up to 250 msec. As the presentation duration increased, the quality of the image would improve until the image could be transformed to match to an orientation-specific (upright) representation. This would then extend the range of orientation effects in the present study, relative to the initial verification experiments.

We hypothesize that practice effects will be observed only when stimuli are identified sufficiently clearly and precisely to allow uniquely distinguishing, orientation-invariant features to be extracted and stored. If objects could subsequently be identified by extracting such orientation-invariant features, orientation effects would be attenuated. We suggest that such features were identified and stored in the present study and in typical naming studies, but not in the initial verification studies.

The preceding argument may appear contradictory. If, in the initial verification studies, the extraction of orientation-invariant features enabled highly disoriented objects to be identified, why were these features not stored and used to identify the object when it was presented again (which was what we believe occurred in the present study)? We suggest that a combination of the coarseness of the features extracted and the design of the initial verification studies (which alternated between providing visually similar and dissimilar response alternatives for a given object in successive blocks) can account for this apparent paradox. In the initial studies, if a subject saw a picture of a bicycle followed by visually dissimilar response alternatives (shoe, nail, and bicycle), then even very general orientation-invariant information (seeing a circle or a complex object) could suffice in order to identify the bicycle correctly. However, these features would be useless in the next block of trials when the bicycle was again presented but was now followed by visually similar response alternatives (motorcycle, car, and bicycle). Thus, the lack of specificity of the information stored from the first presentation of the object and the alternation between visually similar and dissimilar response alternatives on successive presentations of an object would have prevented subjects from benefiting from object repetition in the initial studies.

We have suggested that the same orientation-sensitive processes and representations are tapped by both speeded naming and unspeeded verification tasks. One objection to this proposal might focus on the form of the function relating orientation to performance across the two types of task. In most naming experiments, naming latencies increase almost linearly with increasing plane rotation, at least over the range 0°–120°, whereas in the present verification study this function was apparently noisier. Note, though, that we sampled plane orientation more finely (every 30°) than has been done in most previous studies of plane rotation, in which sampling typically occurred at most every 60° (see, e.g., Jolicoeur, 1985; Jolicoeur et al., 1998; Jolicoeur & Milliken, 1989; McMullen & Jolicoeur, 1990, 1992; Murray, 1995a, 1995b, 1997). Also, note that variation in performance for 180° views is a widely observed phenomenon in speeded naming tasks (see Jolicoeur, 1990; Murray, 1997).

Our results suggest that for 30°, 90°, 150°, and 180° views, the presentation duration required for identification was less than would be predicted by a simple linear extrapolation model based on performance for 0°, 60°, and 120° views. We have replicated these results in two further masked verification studies, suggesting that these departures from linearity were not simply random fluctuations. Instead, we believe that although there is a clear linear component to the effects of orientation, these effects may be considerably more complex than a function derived from performance on 0°, 60°, and 120° views would suggest.

A number of different factors may contribute to the overall orientation function. For example, the cardinal axes of elongation and symmetry for upright, 0° views are generally either aligned with, or perpendicular to, the upright. The identification of other views with the same alignment of their principal axes (viz., 90°, 180°, and 270° views) may then be privileged, since the locations of their cardinal axes will coincide with those of the upright view, which could benefit the extraction of these axes. In addition, if the stored, orientation-sensitive representations accessed by canonically oriented, 0° views are rather broadly tuned, then views near to the upright may be identified more efficiently. For example, 30° and 330° views may benefit from being matched directly to stored, upright representations without requiring prior image transformation. Further careful, empirical investigation will be necessary in order to elucidate the factors underlying orientation effects. Nevertheless, the finding of nonlinear orientation functions provides further evidence of the inadequacy of a simple mental rotation account of compensation for the effects of plane rotation on picture identification.

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Erratum

Giesbrecht, B., & Dixon, P. Isolating the interference caused by cue duration in partial report: A quantitative approach. *Memory & Cognition*, 1999, **27** (2), 220-233. On page 223, in the Method section, under "Stimuli," the next to the last sentence should read as follows:

> Letters presented in the array were selected randomly each trial, under the constraint that no letter appeared more than once in the array.