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Discrimination and association processes for faces and non-faces: The effect of rotation

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Abstract

Most current theories of face perception claim that inversion leaves the coding of non-face stimuli largely unaffected, while causing a qualitative change in the coding of faces. Empirical support for this hypothesis mainly stems from recognition studies which typically show a larger inversion decrement for faces than for other stimuli. Several recent studies using experimental paradigms that do not contain a substantial memory component have however yielded contradicting results. This observation suggests that the disproportionate effect of inversion for faces might be related to the presense, or absence, of a memory component in the experimental task. In order to explore this hypothesis we investigated the effect of inversion within a discrimination learning paradigm, which contains a memory component comparable to that included in a recognition paradigm.

We compared the effect of rotation on discrimination and association processes for faces and cars. Subjects learned to discriminate pairs of similar faces and similar cars and to associate them with neutral responses. The stimulus pairs were presented upright, inverted, and additionally in two intermediate orientations. We found that discrimination performance was generally better for faces than for cars and that associations were learned faster for faces than for cars. However, we did not find any evidence that rotation affected discrimination and association processes for faces differently than for cars. In this sense, our results provide no evidence for the hypothesis that memory processes are responsible for the disproportionate effect of inversion which is found in recognition experiments.

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1. Introduction

Recognition of faces is impaired by inversion to a far greater extent than recognition of other classes of objects. This effect was first observed by Yin (1969) and since then it has been found in a large number of studies comparing the effect of stimulus inversion on faces and other objects, e.g. houses, air planes, dogs (for a review see Valentine, 1988).

Theoretical accounts of this effect typically assume that faces are coded in a way that is qualitatively different from the coding of most other classes of visual stimuli. Moreover, while this type of coding is assumed to be very effective under normal viewing conditions, it is assumed to be very sensitive to stimulus disorientation. Rhodes et al. (1993), for instance, hypothesized that the coding of faces involves the comparison between a perceived face, on the one hand, and a facial prototype, on the other hand. This prototype is supposed to represent roughly the average of all the faces one has seen. They argue that the above mentioned recognition decrement is caused by difficulties in coding information from rotated faces relative to an upright prototype. Most other visual objects are assumed not to be coded relative to a prototype, thus no substantial recognition decrement should result when the stimuli are presented upside-down. More recently, Farah et al. (1995) proposed another distinction between the coding of faces and that of non-faces. They assume that faces are represented as holistic units, whereas other objects are decomposed into separable parts. Again, the holistic representation is supposed to be more sensitive to stimulus inversion than a part-based representation.

The most influential account of the inversion effect is the approach by Diamond and Carey (1986). They drew a distinction between two types of spatial information that underlie the processing of visual objects: first-order relational and second-order relational properties. While first-order relational properties refer to information about the spatial relationships among parts of a visual object, second-order relational properties refer to information about the spatial configuration between the parts of an object, on the one hand, and the prototypical spatial configuration of its parts, on the other hand. For a visual stimulus to be coded by means of second-order relational properties two necessary conditions must be fulfilled. First, the visual stimulus must be an element of a stimulus class whose elements share a common configuration; second, the observer must be an expert with respect to the stimulus class, who is able to extract this configural information. Diamond and Carey hypothesized that inversion is particularly sensitive to the processing of second-order relational properties while it does not affect the processing of first-order relational properties and that of more isolated features. Hence, recognition performance for faces should be affected disproportionately by inversion in comparison to the performance for stimuli which are not coded in terms of second-order relational properties.

The hypothesis of a qualitative difference between the coding of upright and inverted faces accounts for the results from the recognition studies mentioned above. However, this view does not account for the results from some other studies using different experimental paradigms. In fact, these studies showed results that do not indicate any qualitative difference between the coding of upright and the coding of inverted faces. Valentine and Bruce (1988), for instance, argued that the putative inability to process configural information in inverted faces should lead to a switch in processing strategy as stimuli are increasingly rotated away from the vertical. In a mental rotation experiment they found that response time for same–different judgements for pairs of sequentially presented faces increased linearly as a function of rotation angle when the second face of the pair was rotated away from the vertical. They claimed that such a linear relationship does not indicate a switch in processing strategy. Furthermore, Bäuml (1994) did not find any evidence for the assumption that inversion causes a qualitative change in the processing of faces using a preference paradigm. He measured preference probabilities for pairs and triples of faces regarding the perceived attractiveness of the faces. These measurements were made both when the faces were presented upright and when they were presented upside-down. There was hardly any effect of inversion on the preferences, indicating that roughly the same kind of facial features are coded for upright and inverted faces.

In view of the conflicting evidence from different experimental paradigms, it may be concluded that the validity of the proposed coding theories by Diamond and Carey (1986), Rhodes et al. (1993) or Farah et al. (1995) is tied to the use of a particular class of paradigms, which is specified through certain characteristics of the experimental situation. Indeed, evidence in favor of the coding theories mainly comes from recognition studies, whereas results from studies not involving a substantial memory component – i.e., the matching paradigm, the preference paradigm – are in conflict with these theories. This observation suggests that the disproportionate effect of inversion for faces might be related to the presence, or absence, of a memory component in the experimental task: If the task includes a substantial memory component, like in the recognition paradigm, faces are impaired by inversion to a larger extent than are non-faces; if the task does not include a substantial memory component, like in the matching or the preference paradigm, faces and non-faces are impaired to roughly the same extent. A similar conjecture has recently been expressed by Valentine (1988). The present study addresses this issue.

We examine whether a disproportionate effect of inversion is found for faces within a paradigm that is different from the recognition paradigm but contains a memory component that is comparable to that included in recognition tasks. The paradigm is similar to the one employed by Goldstein (1965). Goldstein investigated the effect of inversion on face processing in a paired-associates learning task using faces as stimuli and consonants as responses. He used the anticipation method for the learning of the paired associates. In this procedure, subjects must learn to give the response member of a paired associate when presented with the stimulus member of the pair. On each block the stimulus member is presented as a cue to which subjects attempt to recall or ‘anticipate’ the associated response. Following the response, feedback is given as to the correct pairing. Since subjects must learn several associations simultaneously, this task involves a substantial memory component.

For this paired-associate learning task Goldstein found that the inversion of the faces reduced the number of correct responses to a considerable extent. While this result is interesting in its own, it leaves open the question whether this effect is specific to faces, or whether it holds for other classes of objects as well. If the effect were specific to faces, this result would be consistent with the hypothesis proposed above that the presence of a memory component is responsible for finding the inversion effect. If it were not specific to faces, this would suggest that the memory component either is not important at all for the inversion effect or is only one of several factors which are jointly responsible for the effect. To address this issue we compared the inversion effect for faces with that for non-faces within a paired-associates learning task.

Goldstein's (1965) finding supports the coding theories mentioned above, if we assume that the ease of forming stimulus-response associations is a function of the kind of stimulus coding; concretely, if we assume that configural coding enhances the chance for association formations, while, in comparison, piecemeal coding reduces this chance. Right or not, we can come up with a more direct test of the coding theories by using a variant of the paired-associates task employed by Goldstein, namely discrimination learning. In a task involving discrimination learning, subjects are presented with similar, potentially confusable stimuli. These stimuli are paired with different responses and therefore subjects must learn to discriminate between the similar stimuli in order to make the proper responses (Riefer and Batchelder, 1988; Houston, 1991; Bäuml, 1992). In our case, we present subjects pairs of similar faces (non-faces) and the subjects must learn to discriminate between the two faces (non-faces) of each pair.

Encoding theories, such as the Diamond and Carey (1986) approach, postulate that upright faces are coded more efficiently than inverted faces. This is because upright faces are supposed to be coded mainly in terms of configural information while inverted faces are supposed to be coded mainly in terms of isolated features. Thus, provided that the ability to discriminate faces reflects their quality of coding, discriminating upright faces should be easier than discriminating faces rotated away from the upright. A different prediction arises for most non-face stimuli. It is assumed that subjects are not able to code non-face stimuli in terms of configural information, neither for the upright nor for the inverted orientation, but code these stimuli in terms of more isolated features. Thus, roughly the same type of features should be coded in the two orientations and not much of an effect of inversion is expected for the discrimination of non-face stimuli.

If we found this pattern of results in our data it would provide evidence in favor of the coding theories mentioned above. More important in the present context, this pattern of results provided evidence for the hypothesis that the presence of a memory component is responsible for finding the inversion effect. On the other hand, if we found the same effect of orientation for non-faces as for faces, this result would challenge the coding theories. Again, more important, it would indicate that the memory component is not responsible for the inversion effect. We examined the effect of rotation on association and discrimination processes for face and non-face stimuli not only for the upright and inverted orientation, but additionally for two further intermediate orientation angles.

2. Method

2.1. Subjects

One hundred and fourteen psychology students at the University of Regensburg participated in the experiment. The subjects were tested individually and received credit for fulfilling degree requirements.

2.2. Materials

2.2.1. Faces

Twenty-eight stimulus faces were used. This set consisted of 14 pairs of visually similar faces. The visual similarity between the faces from different pairs was low compared to the similarity between faces forming a pair. The faces were selected to give pairs of faces that were similar in hair length and shade, were about the same age, and were of the same sex. Either both of the faces from a pair wore glasses or none of them. The same was true for the presence of mustaches. The crucial criterion for the selection of the faces was the overall impression of similarity. The photographs were taken from the journal *Physics Today* from the years 1990 and 1991. The faces were from males and females ranging in age roughly from 25 to 65 years. The photographs were taken from a frontal view. All of the faces were unknown to the subjects. The faces were copied individually onto monochrome slides. Copies for each face were made at four orientations with respect to upright (at 0°, 60°, 120°, and 180°).

2.2.2. Cars

Twenty cars were used as non-face stimuli. This set consisted of ten pairs of visually similar cars. The visual similarity between cars from different pairs was low compared to the similarity between cars forming a pair. The cars were selected to give pairs of cars that were similar in color and type. Again the overall impression of similarity was decisive for the selection. The pairs were composed of the following makes: (1) Ferrari 512 TR and Honda NSX, (2) Rover 214 SI and Honda Concerto, (3) Mitsubishi Space Runner 1800 GLXi and Mitsubishi Space Wagon, (4) Daihatsu Feroza and Chrysler Jeep Wrangler, (5) Lancia Y10 and Daihatsu Cuore, (6) Toyota Previa and Pontiac Trans Sport, (7) Lexus LS 400 and Honda Legend, (8) Nissan Primera and Mazda 626 GLE, (9) Jaguar XJ 6 and Jaguar Daimler Double Six, (10) Citroen AX and Citroen ZX. The photographs were taken from a special issue of a German motor journal (*ADAC Spezial Autos'93*). Cars were shown approximately in 3/4-view and each of them was copied onto a monochrome slide. For each car four copies were prepared at the same four orientations as for the faces (at 0°, 60°, 120°, and 180° rotated away from the upright).

2.2.3. Responses

For both types of stimuli the following consonants were used as responses that had to be associated to the stimuli during the learning procedure of the experiment: r, t, z, s, d, f, g, h, k, l. For face stimuli four additional consonants – c, v, b, n – were used, because this set of stimuli was larger than the set of non-face stimuli. The same consonants were used for all four orientations of the stimuli.

2.3. Apparatus

Slides were presented using a KODAK CAROUSEL S-RA 2500 projector which was controlled by a computer. The slides were presented on a blank wall. The subject sat about two meters in front of the wall. Each stimulus subtended about six degrees of visual angle. The subject indicated his or her response by using a computer keyboard and the response was recorded by the computer.

2.4. Design and procedure

2.4.1. Faces

One hundred subjects took part in the discrimination learning of faces. The faces were presented in four different orientations: 0°, 60°, 120°, and 180° rotated away from the upright position. Each subject saw all the faces in only one of the four orientations, so the orientation of the stimuli was a between-subjects variable. Twenty-five subjects were assigned randomly to each orientation. The subjects were tested individually.

Each subject was presented with a list of 28 paired associates, one at a time. The two paired associates with similar face stimuli were presented successively, i.e., with no intervening paired associates.[1] Recall was by an anticipation procedure, in which subjects were presented with the stimulus face for 3 s, then asked to make the push-button response, and then given a 2-s presentation of the correct stimulus-response pair. During this feedback period, the correct response appeared on a computer screen which was located just below the location where the face stimulus was projected. Thus the subjects had to do a slight eye movement to see the face stimulus as well as the associated consonant response.

After the first presentation of all 28 paired associates (during which the subjects' anticipation responses were guesses) the list was presented for eight blocks. Successive blocks were separated by a 10-s break. Across blocks the presentation order of the two paired associates with similar face stimuli was random, as was the order of the 14 different pairs of paired associates. At the beginning of an experimental session, each subject participated in a practice block, in which six paired associates were presented. Geometric patterns were used as stimuli, consonants as responses. This block served to familiarize the subjects with the procedure.

The consonants being used as responses were marked with a colored label on the keyboard. For the discrimination learning of faces 14 different consonants were used. Since the alphabet does not comprise 28 consonants, each consonant was used as response for two different faces. The consonants were assigned pseudo-randomly to the faces with the restriction that two similar faces were associated with different consonants.

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[1] In pre-experimental tests we found evidence that this blocked presentation makes the discrimination between the confusable stimuli more difficult compared to a non-blocked presentation of the two paired associates.

2.4.2. Cars

One hundred subjects took part in this experiment. Eighty-six of them also participated in the discrimination learning of faces. These subjects passed two separate experimental sessions, one for faces and one for cars. Half of the subjects started with the faces, the other half with the cars. The sessions were separated by an interval of at least one week. The cars were presented in the same four orientations as the faces. Each subject saw all the cars in only one of the four orientations. Again, 25 subjects were assigned randomly to each of the orientations.

The procedure was exactly the same as for the faces with only two exceptions: First, a list consisted of only 20 paired associates with ten pairs of similar stimuli. Second, only ten different consonants were used as responses. As for the faces, each consonant was associated with two different car stimuli. As Section 3 shows, this difference in list length between faces and cars was necessary in order to make the tasks for faces and cars comparable.

3. Results

Three distinct recall events were possible to each stimulus member: a correct response, a confusion error, and a nonconfusion error. A response was scored as confusion error, if the subject responded with the consonant associated with the related similar stimulus. A nonconfusion error was any other incorrect response. This separation of errors into confusion and nonconfusion errors is at the heart of many models of discrimination learning (Riefer and Batchelder, 1988; Bäuml, 1992), and was also adopted in this study. For each block relative frequencies of correct responses and confusion errors were computed. [2] We analyzed the correct responses and confusion errors separately.

3.1. Correct responses

Fig. 1 shows the relative frequencies of correct responses for all four orientations as a function of the learning block, both for faces (A) and for cars (B). We compared the relative frequencies for the two materials for the first block in the upright orientation. Analysis of variance revealed no significant difference ($F(1,48) < 1$), indicating that the initial performance was matched between the two materials.

As inspection of the graphs suggests, across blocks the relative frequency of correct responses was higher for faces than for cars (0.70 vs. 0.55), indicating that it was generally easier to form associations to the faces than to the cars. The frequency of

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[2] For the correct responses we calculated the relative frequencies by dividing the absolute frequency of correct responses by the number of paired associates in a list (28 for faces, 20 for cars). For the confusion errors we divided the absolute frequency of confusion errors by the number of different pairs of paired associates (14 for faces, 10 for cars). The reason for this is that, because feedback was given after the response to the first paired associate, subjects made practically no confusion errors in responding to the second paired associate.

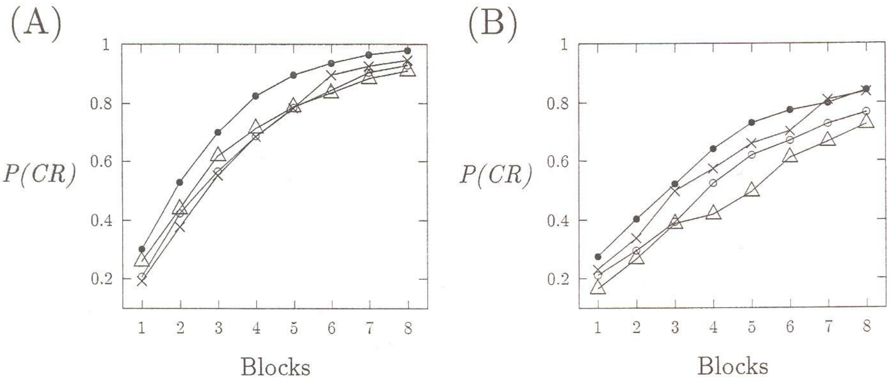

Fig. 1. Relative frequencies of correct responses (P(CR)) for all four orientations as a function of the learning block. (A) Data for faces; (B) data for cars. (● 0°, × 60°, △ 120°, ○ 180°.)

correct responses increased with the increasing number of blocks, climbing from 0.23 in the first block to 0.87 in the last block, thus demonstrating a considerable amount of learning over the eight blocks. Finally, there was some variation of the correct responses across the four orientations, with 0.69 correct responses in the upright orientation, 0.63 in the 60° disorientation, 0.57 in the 120° disorientation, and 0.60 in the inverted orientation. This pattern of results shows that performance deteriorated with disorientation. Analysis of variance confirmed that there were main effects of material ($F(1,192) = 53.3$, $p < 0.001$), block ($F(7,1344) = 1042.6$, $p < 0.001$), and orientation ($F(3,192) = 6.7$, $p < 0.001$).

There was a significant interaction between block and material ($F(7,1344) = 16.7$, $p < 0.001$), indicating that the associations were learned significantly faster for faces than for cars. There was also a significant interaction between orientation and block ($F(21,1344) = 2.4$, $p < 0.001$), revealing that the effect of orientation varied across blocks. Most interestingly, however, there was no significant interaction between orientation and material ($F(3,192) = 1.6$, $p = 0.18$), which indicates that the effect of orientation was the same for the cars as for the faces. The three-way interaction was not significant ($F(21,1344) = 1.0$; $p = 0.46$).

We explored the effect of orientation on the correct responses in more detail. Analysis of variance showed that there were significant differences of orientation between 0° and 60° ($F(1,96) = 7.9$, $p < 0.01$), 0° and 120° ($F(1,96) = 17.6$, $p < 0.001$) and 0° and 180° ($F(1,96) = 10.6$, $p < 0.01$). For the other pairs of orientations no significant effects were found (all $p > 0.05$).

3.2. Confusion errors

Fig. 2 shows the relative frequencies of confusion errors for all four orientations as a function of the learning block, both for faces (A) and for cars (B). We compared the relative frequencies for the two materials for the first block in the upright orientation.

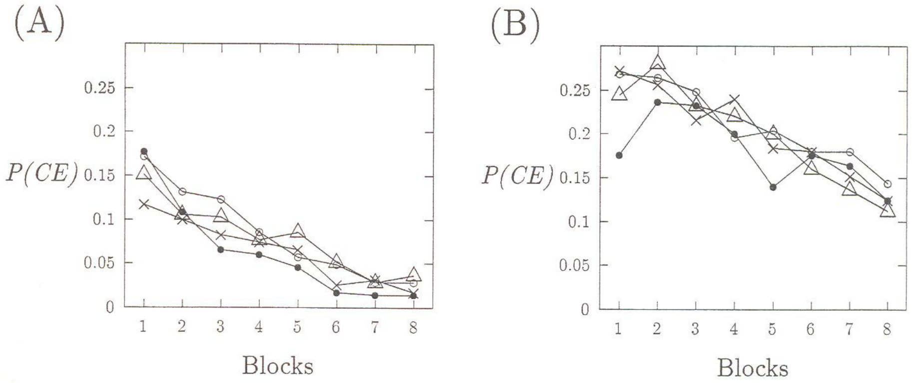

Fig. 2. Relative frequencies of confusion errors (P(CE)) for all four orientations as a function of the learning block. (A) Data for faces; (B) data for cars. (● 0°, × 60°, △ 120°, ○ 180°.)

Analysis of variance showed no significant difference ($F(1,48) < 1$), indicating that the initial performance was matched between the two materials.

As inspection of the graphs suggests, across blocks the relative frequency of confusion errors was higher for cars than for faces (0.20 vs. 0.07), indicating that it was generally more difficult to discriminate cars than to discriminate faces. Confusion errors decreased with increasing learning block, falling from 0.20 in the first block to 0.08 in the last block, thus demonstrating that discrimination improved over blocks. Finally, there was a slight variation of errors across the four orientations, with a relative frequency of 0.12 in the upright orientation, 0.13 in the 60° disorientation, 0.14 in the 120° disorientation, and 0.15 in the inverted orientation, suggesting that performance deteriorated somewhat with increasing disorientation. Analysis of variance confirmed that there were main effects of material ($F(1,192) = 264.6,\ p < 0.001$) and block ($F(7,1344) = 36.5,\ p < 0.001$). The slight effect of orientation, however, did not reach the level of significance ($F(3,192) = 1.9,\ p = 0.13$).

There was a significant interaction between block and material ($F(7,1344) = 2.2$, $p < 0.05$), indicating that discrimination over blocks improved to a larger extent for the faces than for the cars. The interaction between orientation and block did not reach the level of significance ($F < 1$), thus the improvement in discrimination can be assumed to be the same for all four orientations. Most interestingly, there was also no interaction between orientation and material ($F < 1$), which indicates that rotation did not affect the discrimination of the faces and the cars differently. The three-way interaction was not significant ($F(21,1344) = 1.1;\ p = 0.35$). [3]

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[3] A more thorough inspection of the data raised the question to what extent the results might have been influenced by a floor effect. For the last three blocks hardly any confusion errors occurred for faces with the relative frequencies being close to 0. Data from these blocks could possibly conceal a significant effect of orientation. We therefore ran an additional analysis based on the data from the first five blocks only. We found exactly the same pattern of results as we had found for the data from all eight blocks.

4. Discussion

In the present experiment subjects had to learn lists of paired associates with similar, potentially confusable stimuli. When using faces as stimuli subjects had to learn a list of 28 paired associates, when using cars as stimuli they had to learn a list of only 20 paired associates. This difference in list length across materials, however, led to a match in the subjects' initial performance (block 1) for the upright orientation, both with respect to association formation and with respect to discrimination. Based on this performance match the present data allow meaningful comparisons of the effects of orientation and block across materials.

Subjects showed a considerable amount of learning across blocks. This learning is reflected both in the increasing number of correct responses and in the decreasing number of confusion errors across blocks, which demonstrates improvements in both association formation and discrimination. However, in both cases the amount of learning was quite different for the faces and the cars. It was much easier for the subjects to form associations to face stimuli than to form associations to car stimuli. Similarly, it was much easier for the subjects to discriminate between similar faces than to discriminate between similar cars. Together with the different list lengths that were necessary to equate initial performance across materials, this pattern of results demonstrates a clear superiority of face processing over the processing of cars in the present experiment.

As expected, orientation affected association formation for the faces. Rotating the stimuli away from the vertical reduced the number of correct responses that were given to the presented stimuli. This result is consistent with the results from Goldstein (1965), who also found an effect of face inversion on the formation of associations. Our result, however, is more general than Goldstein's finding. First, we found an effect of orientation not only for inverted faces but also for two intermediate orientations. Second, based on our data we could compare the effect of orientation for face stimuli with that for non-face stimuli. As it turned out, orientation did also affect the association formation for the cars. This effect was of about the same size as the effect that we found for the faces. That is, the disorientation of the stimuli led to about the same deterioration in the association formation for cars than for faces. This result suggests that the orientation effect found for faces is not specific to this kind of stimulus class but can also be met in other stimulus classes.

A similar picture arises for the discrimination between confusable stimuli. We found the same pattern of results for the faces as for the cars, indicating that the orientation effect is not different for faces than for non-faces. This conclusion arose from the fact that orientation had neither a reliable effect on discrimination of the faces nor on discrimination of the cars. This finding suggests that there are no face-specific effects with respect to discrimination learning. At first sight, the fact that we found no effect of orientation on discrimination of the faces may appear contradictory to the results from several previous studies which found that the angle of rotation affects face processing to a considerable amount (Rock, 1973; Valentine and Bruce, 1988; Bäuml, 1992). These studies, however, examined the effect of rotation on the processing of *differently* rotated faces involving a mental rotation of the stimuli, while in the present study we examined the effect of rotation on the processing of equally rotated faces. Bäuml (1994) investigated the effect of inversion on differences in interface attractiveness, finding only a minor effect of orientation on the attractiveness differences between *equally* oriented faces. Furthermore, he found the differences between faces to become slightly smaller with inversion. The present result is consistent with this previous result by Bäuml. We also found only minor effects of orientation with a small tendency for an increasingly poorer discrimination with increasing rotation angle. [4]

Combining the results from the association and discrimination data we end up with a fairly consistent picture, finding no evidence for any face-specific effect in the present paradigm. Recall that the purpose of the present experiment was to examine whether the inversion effect that is typically met in recognition experiments can also be found in other experimental paradigms which, like the recognition paradigm, involve a substantial memory component. Based on previous results that failed to find an inversion effect within paradigms that do not include a substantial memory component, we argued that the present experiment might provide us information on the role of memory processes for the finding of the inversion effect. The fact that we used a paradigm that involves a memory component but did not find any face-specific effect suggests that the presence of a memory component is not responsible for the inversion effect. While this component may still be necessary to find the inversion effect, it does not seem to be sufficient.

One might argue that we did not find a face-specific effect in the present experiment because our subjects coded not only the faces but also the cars in terms of configural properties. In fact, cars share a common configuration and thus, in principle, could have been coded with respect to their common configuration. Based on the current coding theories, however, the presence of a common configuration is not yet sufficient for this kind of coding. Rather, as a second necessary condition, observers must also be experts with respect to this stimulus class in order to be able to extract the configural information from the single stimuli (Diamond and Carey, 1986). The results from this study provide no evidence for the hypothesis that our subjects were experts with respect to cars. In fact, they showed a clearly poorer association formation and a clearly poorer discrimination for this material compared to their performance for faces. Also notice that we had to present a much smaller number of paired associates containing car stimuli than paired associates containing face stimuli in order to match the initial performance for the two materials. Thus, there seems to be good reason to assume that cars were coded quite differently than faces. Based on this line of reasoning, finding the same effects of orientation for faces and cars appears noteworthy.

On the other hand, one might argue that we did not find a face-specific effect because learning associations between a face and a neutral response does not in the same extent presuppose the configural coding of a face as does, for instance, the coding of faces for later recognition. That is, in the present experiment subjects may have coded the faces more in terms of isolated than in terms of configural information. Even if the coding of faces in the present paradigm showed less configural and more isolated coding than is

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[4] In a most recent study (Bäuml et al., 1996) we generalized the results found by Bäuml (1994) to other facial attributes, perceived trustworthiness and perceived age, and also to a non-face stimulus class, namely cars. These findings are consistent with those from the present study.

generally found in recognition paradigms, the coding should still have been based to a larger extent on configural information than the coding of cars. This conclusion is indicated by the clear superiority of face processing over the processing of cars, which is reflected in the longer list of face–letter pairs presented to the subjects and the faster learning rates found for the faces (see above). As a result, observing the same effects of orientation for faces and cars still appears noteworthy.

The current coding theories, like the approaches of Diamond and Carey (1986), Rhodes et al. (1993) or Farah et al. (1995), account well for the effect of stimulus inversion that is found in the recognition paradigm. However, they cannot account for the data from some other paradigms, like the matching paradigm (Valentine and Bruce, 1988) or the preference paradigm (Bäuml, 1994), in which no evidence has been found for differences in the coding of upright and inverted faces. This study adds a further paradigm to this list of paradigms, for which the current coding theories are not adequate. With the present results, however, this list is no longer restricted to paradigms that do not contain any substantial memory component, thus making the solution to the problem of the inversion effect even more difficult.

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References

Bäuml, K.-H., 1992. Diskriminationslernen bei rotierten Gesichtern: eine Markov-Analyse von Kodierungs- und Assoziationsprozessen. Zeitschrift für experimentelle und angewandte Psychologie 39, 1–17.

Bäuml, K.-H., 1994. Upright versus upside-down faces: How inter-face attractiveness varies with orientation. Perception & Psychophysics 56, 163–172.

Bäuml, K.-H., M. Schnelzer and A. Zimmer, 1996. The influence of inversion on the judgment of facial and non-facial attributes. Perception & Psychophysics.

Diamond, R. and S. Carey, 1986. Why faces are and are not special: An effect of expertise. Journal of Experimental Psychology: General 115, 107–117.

Farah, M.J., J.W. Tanaka and H.M. Drain, 1995. What causes the face inversion effect? Journal of Experimental Psychology: Human Perception and Performance 21, 628–634.

Goldstein, A., 1965. Learning of inverted and normally oriented faces in children and adults. Psychonomic Science 3, 447–448.

Houston, J.P., 1991. Fundamentals of learning and memory (3rd ed.). New York: Academic Press.

Rhodes, G., S. Brake and A.P. Atkinson, 1993. What's lost in inverted faces. Cognition 47, 25–57.

Riefer, D.M. and W.H. Batchelder, 1988. Multinomial modeling and the measurement of cognitive processes. Psychological Review 95, 318–339.

Rock, I., 1973. Orientation and form. New York: Academic Press.

Valentine, T., 1988. Upside-down faces: A review of the effect of inversion upon face recognition. British Journal of Psychology 79, 471–491.

Valentine, T. and V. Bruce, 1988. Mental rotation of faces. Memory & Cognition 16, 556–566.

Yin, R., 1969. Looking at upside-down faces. Journal of Experimental Psychology: General 81, 141–145.