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Paradoxical configuration effects for faces and objects in prosopagnosia

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Abstract

Selective impairment in recognition of faces (prosopagnosia) has been advanced as an argument for a brain module dedicated to face processing and focusing on the specific configural properties of faces. Loss of the inversion effect supposedly strengthened the argument ([10]: de Gelder B, Bachoud-Levi AC, Degos JD. Inversion superiority in visual agnosia may be common to a variety of orientation polarised objects besides faces. Vision Research, 1998;38:2855–61; [20]: Farah MJ, Wilson K, Drain H, Tanaka J. The inverted face inversion effect in prosopagnosia: Evidence for mandatory, face-specific perceptual mechanisms. Vision Research 1995b;35:2089–93). The present study of prosopagnosic patient LH reports that he has lost the normal pattern of superior performance with upright faces and objects and shows instead paradoxical inversion effect for faces but also for objects. Experiment 2 investigated whether LH's use of features based route for processing upright objects would be hindered by the whole-based encoding when processing upright objects. The data show the same context effect for objects as was found for faces. Therefore the inversion effect does not present decisive evidence for the existence of a face module. Moreover, the importance of configuration-based recognition known to be crucial for face processing, must also be taken seriously for object recognition.

Keywords: Object perception; Face perception; Visual agnosia; Prosopagnosia; Inversion effect

1. Introduction

Two contrasting views of the relation between disorders of visual object recognition (visual object agnosia) and face recognition (either in the narrow or the wide sense of prosopagnosia) are currently pursued with a variety of research methods. The search for neuroanatomical substrates special to faces was the topic of animal studies using single cell recording in the temporal cortex ([35], but see [24]) and continues with recent fMRI and ERP studies (e.g. [25–27]). At the core of the debates in neuropsychology is the question whether prosopagnosia reflects the existence of an autonomous processing system possibly based on a hard-wired face module (e.g. [19,20]). Support for the view that faces are unique perceptual stimuli has been provided by studies of patients with brain damage that have established material specific dissociations (for recent studies see Refs. [17,19,23,31]). In the literature on normal face processing arguments in favor of a specialized face processor are related to special effects obtained in studies of face processing. These include the inversion effect and the face context effect, both explained by reference to the stimulus configuration in the sense of the relation between the parts of a stimulus [1,8,13,37] and special processing strategies like holistic encoding [21]. An alternative view challenges the idea of a radical dissociation between a processing

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route for faces and a separate one for other visual objects. Prosopagnosia thus appears as an extreme manifestation of damage to the object recognition system. For example, prosopagnosia has been interpreted as a problem in discriminating highly resembling items [6,7,33], as when within = category discrimination is required (see also [28]). A similar prediction is that specific patterns of performance (like the inversion effect or the context effect) found in studies of face recognition also obtain in object perception given the right control stimuli and task demands [10].

The best known example of a characteristic pattern of performance linked to the nature of the visual stimulus is the inversion effect (the relative loss of performance with inverted as contrasted to upright faces). Yin [40] showed that upside-down presentation affected recognition performance for faces but much less so for other mono-oriented stimuli such as houses. In a follow up study Yin [41] asked whether brain damage in areas thought to be critical for face recognition would have a negative impact on the preferential treatment of upright faces. He observed that right posterior brain damage eliminated the normal inversion effect. This finding fueled the idea that the inversion effect presents a benchmark of normal face processing and subsequently the inversion effect is absent after the loss of face recognition abilities in adulthood.

Pursuing Yin's idea Farah and collaborators [20] studied the inversion effect in a prosopagnosic patient LH expecting that this effect would have disappeared. They reached a very different conclusion since the patient was actually better at matching upside-down faces. In an effort to explain this puzzling result the authors argued that it is due to a continuing interference from an impaired but still active face processor, and therefore constitutes conclusive evidence (an 'existence proof') for a face module. There are two major problems with this conclusion. The first problem for such a strong modularist conclusion concerns the relation between face and object processing, and the absence of an appropriate control task for fully intact object processing. The second is that this conclusion is too broad and leaves entirely open what the pattern of spared and intact aspects of the face processor might be.

As a matter of fact, the study by Farah et al. reached somewhat strong conclusions given that it did not use objects as a control stimuli with an exemplar level recognition task [6,7]. It is well known that the inversion effect, though normally strongest with faces, has also been found with objects. Inversion effects have been reported for visual materials like handwriting [3] and gundogs, but not landscapes or houses [13]. A recent study by Donnelly and Davidoff [14] used houses and scrambled houses and found clear evidence for the importance of configuration in object recognition. The relevance of the appropriate comparison was brought home by a recent study reporting that patient AD suffering from visual object agnosia and prosopagnosia showed an inversion superiority effect not only for faces but also for objects [10]. The object category selected for the comparison with faces in this study were shoes. Like faces, shoes have a similar shape and are found in many exemplars. Shoes were also chosen because they had two characteristics that allowed to maximize similarity between the object and face task. Like faces, shoes have a canonical orientation, a relevant property for studying the face inversion effect. Moreover, often in daily life visual search is aimed at recognition at the exemplar level, as is the case in face recognition.

In this study our goal was to investigate patient LH who unlike patient AD was known to be agnosic only for faces [30]. Therefore we expected to find a clear dissociation between his performance for face and object stimuli equated otherwise for task and level of recognition. It is worth noting though that a recent study of LH mentions without further detail that this patient does have some problems in the domain of object and animal recognition [16]. But since this patient is considered in the literature as a particularly good case of prosopagnosia [16,19,20] our prediction was that LH would show the paradoxical pattern of better performance with upsidedown stimuli only for faces and not for objects. Such an outcome would be in line with the strong assumptions about face modularity encountered in the study by Farah et al. But if there is a similar impairment for faces and objects the radical explanations of face modularity would not be supported. In contrast, such an outcome would be consistent with theories that envisage a stage or a separable dimension of visual processing related to the overall orientation and configuration of both object and face stimuli. It might even be hypothesized that influence of configuration needs to be studied in the light of external factors such as memory involvement, expertise, and similar exemplar recognition rather than stimulus class [13,22,32].

The second problem with the idea of inhibition from an impaired face processor is that the notion of a face processor seems too general and opaque to be helpful in sorting out which aspects of face processing are lost and which ones are still intact and thus for understanding which intact aspects if any inhibit which others. For example, an explanation for inversion superiority envisaged by Farah and collaborators is holistic processing or the notion that in face processing the face as a whole is stored and that individual parts are not coded separately [21]. The finding that the patient is unable to match upright faces and base his judgement on local similarities between face parts could be advanced in support of the claim that faces are encoded holistically and that face parts are not represented in any detail. A different explanation is that when presented with a face intact configural processing is still triggered and overrules or inhibits the patients' intact general (i.e. non face specific) processing routes making it impossible for him to deal with stimulus parts [34].

This brings us to the second issue. Studies of the inversion effect do not allow to select the best of those two explanations of the face inversion effect because they only provide insight into the role of face configuration in connection with canonical orientation and do not inform directly about the impact of configuration on the ability to process parts of the face in isolation. This issue was the focus of a recent study where the goal was to assess whether structural encoding of the face was still intact in LH [11]. Those experiments centered on the face context effect and tasks were selected because they encourage processing of the separate face parts. The results showed that unlike normal viewers LH cannot attend to the face parts even when the task explicitly requires it and that faces need to be presented to him upside-down or at least scrambled before he manages to match parts. In this study we investigate whether similar context effects as those found with faces can be replicated and extended to objects. Since context effects have also repeatedly been reported for objects the second question in the present study is whether the abnormal context effect for faces will also be observed in a parts matching task for objects. Experiment 2 focuses on that question.

2. Case presentation

Patient LH is a 46 year-old man who has been prosopagnosic since an automobile accident 25 years earlier. Brain damage from the accident and subsequent surgery consisted of bilateral occipito-temporal and right frontal and anterior temporal lesions. For additional neuropsychological information, see [16,19,20,30]. Copying, drawing, reading and writing are normal. From these reports it appears that his recognition of real objects and pictures is only mildly impaired. The authors mention that some informal testing also included discrimination of common animals which is said to be impaired but no data are provided [16]. Testing of object recognition requiring only category assignment ([19], Experiment 1) and within category discrimination using eyeglass frames ([19], Experiment 2) was normal. He is profoundly prosopagnosic and unable to recognize friends, neighbors or even his wife and children in the absence of other cues to identity besides the face.

3. Experiment 1. The inversion effect for faces and objects

The goal of this experiment was to investigate whether the superior performance with upside down stimulus presentation which was previously reported in patient LH for faces would also obtain when the patient was presented with a similarly designed object matching task.

3.1. Materials and tasks

The material consisted of photographs of human faces and of shoes. These materials were previously used in a study of normal subjects tested with standard computer presentation and short exposure times in order to provide a normal baseline concerning the effects of inversion on recognition of these two materials (see Ref. [10], Experiment 1). The faces were those of eight young male adults, each photographed once in frontal view and once in 3/4 orientation. For shoes, eight exemplars were similarly photographed once in upper front view, i.e. with the tip of the shoes pointing toward the camera, and once in 3/4 orientation. The photographs were taken with a Canon Still Video Camera RC-560 and stored on video disc VF-50. They were presented manually as 7 × 7 cm black and white laser prints.

The experiment used a 2AFC task. Three pictures of the same type (faces or shoes, upright or inverted), one target and two probes, were presented simultaneously (Experiment 1a) or sequentially (Experiment 1b). The target picture was always a front view one, and the positive probe was the 3/4 profile view of the same person/shoes, while the negative probe represented a different person/pair of shoes. Twenty combinations with shoes and 16 with the face stimuli were created. The target picture was presented above the two probe pictures shown side by side below. The patient was instructed to indicate the positive probe by verbal response. In Experiment 1a the stimuli

Table 1
Number (percentage) correct responses on faces and shoes in simultaneous presentation

	Upright	Inverted
Faces	36/80 (45%)	65/80 (81%)
Shoes	31/64 (48%)	51/64 (80%)

were shown in free vision. In Experiment 1b the pictures were shown for 3 s. followed after a 2 s interval by the probe pictures. Testing was always run in separate and equivalent blocks of trials, with the same number 'same' and 'different' trials for the different type of material. Blocks alternated between faces and shoe stimuli, and between upright and inverted presentation. The experiment was preceded by eight practice trials (two of each stimulus type).

3.2. Results

LH's identification performance was significantly better with inverted stimuli than with upright ones for faces as well as for shoes (see Tables 1 and 2). That pattern obtained with simultaneous matching (faces: $\chi^2(1, 160) = 22.6$, $p < 0.001$; shoes: $\chi^2(1, 128) = 13.6$, $p < 0.001$), as well as with delayed matching (faces: $\chi^2(1, 160) = 31.3$, $p < 0.001$; shoes: $\chi^2(1, 128) = 9.9$ $p < 0.002$). It will be noted that for both materials, identification of upright items was at chance level. The pattern shown by LH is thus very different from the normal one. The performance of normal subjects tested previously showed a clear advantage for upright presentations of faces but not of objects when the stimulus pairs were presented simultaneously but with limited (500 ms) presentation time [10]. However, in another study [12] where we used simultaneous matching (with the same paradigm and stimuli as presented here), normal subjects showed a face inversion effect (869 ms and 95% correct for upright vs 973 ms and 94% correct for inverted presentation). Moreover, in this same study normals also showed an inversion effect with the shoes when these were presented for 2500 ms and 2500 ms delay (729 ms and 94% upright vs 773 ms and 94% for inverted).

3.3. Discussion

We presented LH with a matching task that was designed to allow a close comparison between the existence of an inversion effect for faces and for objects. Our result shows that prosopagnosic patient LH had a similar pattern of performance in the two cases, performing at chance with canonical upright oriented stimuli but displaying a very good performance when the stimuli were presented upside down. The finding by Farah and collaborators of better performance on inverted faces in prosopagnosic patient LH is now replicated with new materials. LHs performance with upright faces is poorer than was observed by Farah et al. [20], probably because the present task required matching across a change in viewpoint which makes the present paradoxical inversion effect even stronger.

The new finding is that LHs paradoxical inversion effect for faces previously observed by Farah et al. [20] extends also to objects. Poor performance with upright objects compared with previous results may be due to task demands as well as to peripheral factors like stimulus difficulty but we do not believe the latter can explain the result. Our stimuli were more difficult than those used previously to examine LHs visual object abilities. Stimulus difficulty may exacerbate a mild visual object agnosia that goes unnoticed with stimuli that are less taxing or that are less similar to faces like eyeglass frames [19]. Also, our task was more difficult because it was designed to target specifically object identity recognition at the exemplar level, a task that had not been administered to LH previously but which is the critical one for a comparison between performance of face and object recognition. Neither of these factors can however explain the dramatic difference between performance with upright and inverted stimulus presentation. Unlike the within category discrimination task using eyeglasses, our task did not just require detection of physical similarity, but matching across a difference in viewpoint [19]. When this task was presented to normal subjects it did yield an inversion effect for objects which was less strong but similar to that obtained with faces [12]. For the present results with LH, the size of the inversion effect is not important as both objects and faces showed the unexpected effect of improved performance after inversion. In conclusion, the fact that LH can reliably match inverted but not upright stimuli suggests that a parts-based processing route is intact but that there is interference on its application to upright stimuli from a processing route that targets the whole stimulus and focuses on the configuration. Experiment 2 was run in order to obtain evidence for the impact of object configuration on such parts-based processes.

Table 2
Number (percentage) correct responses on faces and shoes in delayed presentation

	Upright	Inverted
Faces	34/80 (43%)	68/80 (85%)
Shoes	33/64 (52%)	50/64 (78%)

4. Experiment 2. The role of context in parts-based matching of objects

In a previous study [11] we reported that LH's performance was strongly under the impact of the overall configuration even when explicitly instructed to judge whether a separately presented face part was the same as the corresponding face part presented inside a face. Here we report the experiment where the critical context for the parts matching task was a house. The house stimuli consisted of complete houses and of house parts and the stimuli as well as the task requirements were designed to be very similar to the face stimuli used in the face context task.

4.1. Materials and procedure

Stimuli were grey scale front view pictures of houses which had been computer edited. One prototypical stimulus was selected to be used as the outer contour in which different house parts (front door, two windows) taken from the other pictures were inserted. With these materials a total of eight different house and house part stimuli were created (eight front doors and eight upper windows). Each full house stimulus was paired with two part probes (its own and a different one), both for the door and for the window, making a total of 16 trials. This procedure for stimulus construction was identical to the one used for construction of the face stimulus presented to LH in a study reported elsewhere [11]. Stimuli were presented once upright and once upside down. Trials were blocked by orientation. Each condition was presented twice resulting in a total of 64 trials. Half of the trials of each block was presented followed by half of the trials of the other block so that condition order was balanced. The Experiment was first run using simultaneous presentation of the whole houses and the part probes (Experiment 2a). The patient was instructed to respond as accurately and as fast as possible but was given unlimited viewing time. Some months later the experiment was repeated with delayed presentation (Experiment 2b). The complete stimuli were shown first for 2500 ms followed by a 2500 ms interval after which the two probes were shown for as long as the patient needed to give his response.

4.2. Results and discussion

The results of the simultaneous matching task show that LH is sensitive to the canonical orientation of the stimulus since matching of the stimulus part is easier when the stimulus is presented upside down than when it is upright ($\chi^2(1, 128) = 17.8$, $p < 0.001$) Likewise, the data of the delayed matching indicate that it is much easier for LH to match a house part to the full stimulus kept in memory with an upside down rather that a normally oriented house ($\chi^2(1, 128) = 31.0$, $p <$ 0.001. In other words, the performance of patient LH in both tasks shows a context inferiority effect (see Table 3).

Table 3
Number (percentage) correct responses on houses in simultaneous and delayed presentation

	Upright	Inverted
Simultaneous	44/64 (69%)	62/64 (97%)
Delayed	30/64 (47%)	59/64 (92%)

It is instructive to compare these results with data obtained with a group of normal controls. Normal viewers were not sensitive to orientation neither in the simultaneous (1138 ms and 98% correct for upright vs 1163 ms and 98% for inverted) nor in the delayed (1081 ms and 84% correct for upright vs 1070 ms and 84% correct for inverted) matching task ([12], exp. 4). The difference between the pattern of normals and that of patient LH suggests again an exacerbated sensitivity to the whole stimulus context in the canonical orientation just as was found in Experiment 1. Moreover, unlike normal subjects LH can not overcome the impact of the whole configuration. We return to this issue below.

We can also compare LH's results with data from another patient RP suffering from prosopagnosia as a consequence of a very similar brain trauma [12]. Patient RP also performed better with upside down than with normally oriented houses albeit only in the delayed presentation condition. Finally and most importantly, we can compare LHs results on the present object task with previously obtained results on a very similar parts matching task using faces [11]. The superior performance with objects presented upside down mirrors the results obtained when LH was presented with a parts-based matching task using faces. Taken together these data thus indicate that a whole stimulus context is detrimental for the prosopagnosic patients' matching performances for objects just as was the case for face stimuli.

5. General discussion

The goal of this study was to investigate to what extend the deviant patterns of performance observed previously in a face inversion and a face context task would now also be found in very similar object matching tasks. The results of Experiment 1 show that loss of the inversion effect and its replacement by superior performance with upside down presented stimuli was replicated for faces and was now also found for objects. In the same vein, Experiment 2 shows that the presence of a full stimulus interferes with recognition of one of its parts and that this context inferiority effect obtains as well for houses. Thus, these data replicate the previous reported 'inverted face inversion effect' and significantly extend the findings by revealing mandatory configural processing with objects.

The first thing to note is that the result obtained with faces in Experiment 1 replicated the report of LH [20], of AD [10] and of RP [12]. The fact that at least in some acquired prosopagnosia patients the deficit manifests itself in such a dramatic reversal of the normal pattern underscores the importance of the normal face configuration and thus of the face inversion task as a benchmark for intact face recognition in patients in whom face expertise was present before their brain injury. Interestingly, our study of a developmental prosopagnosic patient revealed that his recognition performance was insensitive to face orientation (Patient AV, [12]). In this context it is also worth noting that brain damage can lead to contrasts between canonical and non-canonical stimulus presentation that are quite a bit stronger than those observed in normal viewers or than what is revealed by brain imaging studies of normal viewers. For example, Jeffreys [26] recorded ERPs from the scalp and observed a similar pattern for upright and inverted faces (but see [38]). Kanwisher et al. [27] reported that the brain area activated with presentation of upright faces responded almost as well with inverted faces. However, these brain imaging studies did not use a task that required full identity recognition as in Experiment 1 here.

The second, more challenging aspect of our data concerns the extension of the paradoxical inversion previously found for faces, to objects. It should be clear that this novel finding undermines the conclusions drawn by Farah et al. about face modularity. Our data might prompt an anti-modularist position, at least to the extent that their argument for a face module was based on the inversion effect. But put in a broader context, a paradoxical inversion effect for objects is not all that more unexpected than one for faces. It should not come as a surprise that other visual objects besides faces can also induce a configural processing style. Indeed, configuration seems to play an important role in object recognition as well and a normal inversion effect was obtained with the present object stimuli in some testing conditions [12]. If processing of the whole stimulus is also important for object recognition, a dominance of the configuration over feature-based recognition can also occur in some cases of brain damage like LH. Moreover, it is important to emphasize that studies of patients with brain damage can reveal aspects of performance that are not manifest in the behavior of normal subjects unless parametrical studies and/or psychophysical testing would be run, which is rarely the case. As we noted previously [10] patients with a visual deficit may show an exacerbated version of a processing pattern that exists in normal subjects but only shows up in extreme testing conditions (for example, very short exposure durations). In any event, the finding of paradoxical inversion effect for objects challenges the strong conclusions drawn from the paradoxical inversion findings for faces. The existence of a hard-wired processor which is part of the strong modularity notion of face specificity is difficult to apply to the case of shoes and houses. In contrast, we would like to explain our data by pointing to the similarity in processing operations between objects and faces (as suggested by many studies showing that the inversion and the context effect are to some extent found with the two stimulus categories). We cannot in the context of this single case report develop further a general theory of object recognition nor even raise the major themes of the extensive literature in this field. It should be clear though from the methodology we adopted that it is our belief that face and object recognition raise very similar problems. Our data substantiate a consistent theme in prosopagnosia research which is that loss of face recognition goes hand in hand with a subtle loss of object recognition ability [6]. Our conclusion that patient LH appears equally impaired on an object and face inversion task is based on two experiments in which object and face stimuli and tasks were equated. Our conclusions should not be overstated though. In our task exemplar level recognition was required for faces as well as for objects and the patient was impaired in dealing with both stimulus categories. One might thus want to conclude from this result that at the level of exemplar recognition this prosopagnosic patient does not show a category specific impairment and that therefore face and object recognition can not be pulled apart. It is unlikely that with the negative evidence for face specifity obtained in exemplar matching the last frontier in the battle against face modularity has been won. Ultimately the specificity of faces might have a different origin than the one is captured by higher order cognitive abilities of the kind at stake in exemplar level recognition.

Another important issue is the convergence between the patient's anomalous results on the inversion task and those on the object context task. Both results point to the importance of canonical orientation. But the context effect provides more specific information as it specifies that the patient processes the whole stimulus rather than just encoding on a feature basis. This finding offers an interesting contrast and complement with the study by Davidoff and Landis [9]. Their prosopagnosic patients had lost configural processing for faces but they had also lost that for objects. In other words, the patients studied by Davidoff and Landis could only attend to features and as a consequence one would not expect them to show either inversion or context effects. In line with previous neuropsychological studies [31] we have suggested a close link between configuration-based processing and intact structural encoding of the stimulus. In other words, those aspects of the object or face recognition process that are responsible for coding the overall configuration and for making the link with stored object representations appear to be intact in these patients. One explanation of this similarity could be that face and object processing systems share processing resources at least up to the stage of encoding orientation and overall configuration. Separate routes for the two stimulus classes would only be required to explain recognition of personal identity in the case of faces. This explanation is consistent with the notion that matching of unfamiliar faces and familiar face recognition are separable abilities [15]. But given the results of Experiment 1 which did focus on matching of the specific instances of unfamiliar faces the common processing resources would also have to include mechanisms for coding token identity similarly for faces and objects.

The present results challenges a taxonomy of visual perception abilities based on a contrast between whole-based and parts-based processing routes that correspond respectively to faces and objects [2,18] and that loss of the face specific system results in loss of configural processing but leaves intact the feature-based route [29]. This idea of two processing routes was exemplified again recently in a study of patient CK suffering from visual object agnosia without prosopagnosia [34]. This study investigated a situation that is the mirror image of the present one and asked whether it was indeed the case that impaired object recognition was not reflected in at least some aspects of face recognition. As an explanation for the important finding that CK has great difficulty telling apart inverted faces, the authors argue that the latter is due to the impairment of feature-based processing route proper to object recognition. But now our result suggests that configuration plays a role in object recognition just as well. This challenges the accepted view, whereby the face system is identified with configuration-based processes and the object recognition system with feature-based processes. Moreover, it does not seem to be the case, as is implied by the accepted view, that loss of the special face recognition system leaves intact an autonomous system for feature-based recognition [34] which would then kick in when the whole-based operations tailored for face processing are impaired or, vice versa a whole-based system which would come to the rescue of a feature-based object recognition system when this is impaired.

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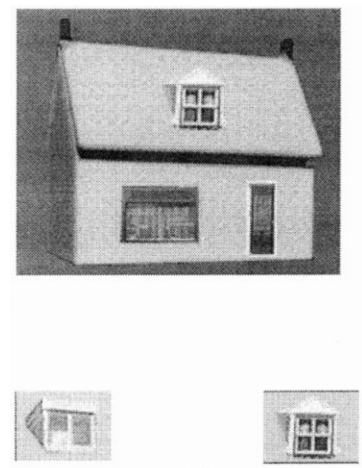
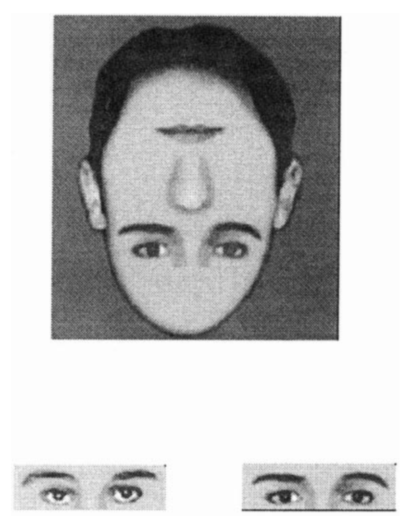
Appendix A

House-stimuli: whole parts matching.



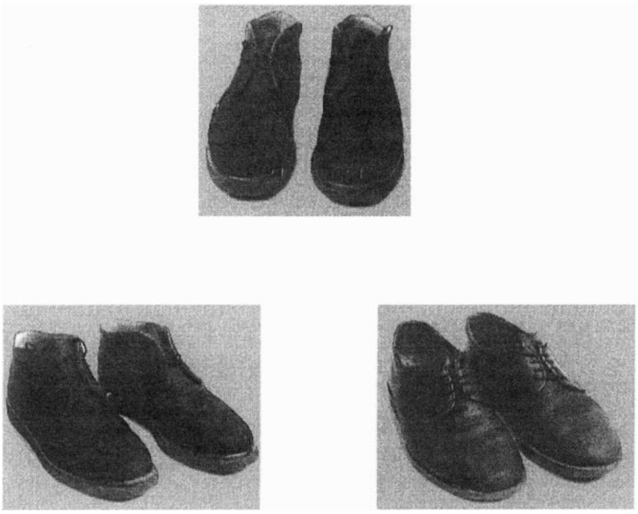
Appendix B

Face-simuli: whole parts matching.



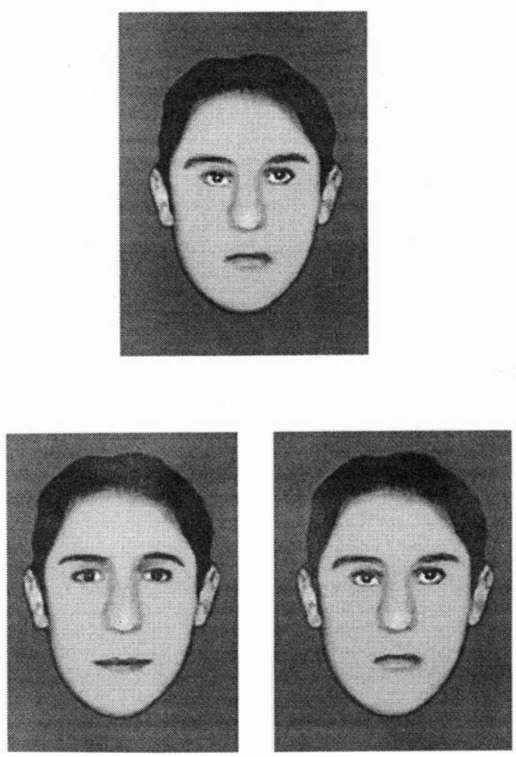
Appendix C

Shoe-simuli: wholes matching.



Appendix D

Face-simuli: wholes matching.



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