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The influence of feature conjunction on object inversion and conversion effects

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Abstract. The face inversion effect is considered by some as a marker of holistic or configural processing. In an effort to understand the relations between object orientation and the use of configuration for recognition, we explored the extent to which the combination of information across discrete, spatially separated object features contributed to the impact of transforming the orientation of faces and other objects. Subjects performed a matching task on four different sets of faces and novel objects. For two of the sets (diagnostic), the match could be made based on information contained in a single feature. For the remaining two sets (conjunction and disjunction), the information useful for successful matching was divided between two spatially separated features (at the top and at the bottom of the object). For OR disjunctions the top and bottom features provided redundant information such that subjects could rely on either the top or the bottom feature, whereas for AND conjunctions the top and bottom features provided unique information such that subjects needed to use both the top and the bottom features. Experiment 1 assessed the cost of inversion on these stimulus sets with the typical inversion task, where both study and test stimuli were presented in the same orientation. Consistent with previous work, significant inversion effects were found for all of the face sets, but none of the novel object sets. Experiment 2 assessed the cost of 'conversion'—that is, the effect of transforming the orientation of the stimulus between study and test. Consistent with previous work, significant conversion effects were found for all face sets; however, a significant conversion effect was also found for the AND novel set. That only the AND novel set was significant suggests that conversion effects are reliant on combination of information across features, which is compromised when the stimulus configuration is altered between study and test. The results suggest that configural processes, like those purportedly used for face recognition, may be domain-general processes that can also be recruited strategically with other types of objects.

Keywords: face recognition, object recognition, vision

1 Introduction

The ability to identify and recognize objects is essential for successful interactions with one's environment. Among all the kinds of objects, faces may be the most important for humans; thus, many theories assert that the cognitive and neural mechanisms underlying face recognition are separable from other types of objects (Kanwisher, McDermott, & Chun, 1997; Kanwisher & Yovel, 2006; McKone, 2009; Rhodes, Byatt, Michie, & Puce, 2004). One phenomenon that has been historically used as evidence for separable face and nonface object systems is the face inversion effect (McKone & Yovel, 2009; Rossion, 2008; Tanaka & Farah, 1993; Yin, 1969). In one of the earliest reports of a face inversion effect, Yin (1969) tested accuracy on a recognition task with faces and other objects with two variations: one where the orientation of the study and test stimuli were the same (both upright or both inverted) and a second where the orientation of the study and test stimuli were opposite (if studied inverted, then tested upright). Yin found costs in accuracy associated with changing the orientation between study and test, but also found costs when orientation was the same for study and test, but inverted. Importantly, he also found that the costs were much larger with faces than with other objects, which were sometimes negligible.

The latter effect discovered by Yin—that there is a greater cost associated with simply inverting a face at study and test than inverting other objects—has come to be called the face inversion effect and has come to be studied much more than the former effect: the one where orientation is transformed between study and test. The face inversion effect is often considered to be one of the behavioral markers of holistic or configural processing (McKone & Yovel, 2009; Rossion, 2008). That is, the additional cost associated with recognizing an upside-down face compared with other objects is cited as evidence that upright faces recruit holistic or configural processes for recognition, whereas other object classes—including inverted faces—do not. These hypothetical holistic or configural processes are often considered part of a separate recognition system that is instantiated in face-specific neural substrates (Kanwisher & Yovel, 2006; Rhodes et al., 2004). 'Holistic' and 'configural' terms have been widely used in the face literature to mean a variety of different things (Maurer, Grand, & Mondloch, 2002) involving both first-order and second-order relations as well as Gestalt-like processing. In this paper our use of the term 'configural' is closest to that of first-order relations—that is, a process involving the configuration of parts/features (Gauthier & Tarr, 2002).

The view that the privileged status of faces as an environmental stimulus demands that they recruit specialized processes that cannot be co-opted for other kinds of objects has been challenged on several levels. First, neuroimaging studies have shown that the patterns of activation across the whole of the ventral occipitotemporal cortex contribute to the discrimination of many different object classes, including faces. Even the regions with the most extreme category-preferring activation profiles contribute to the analysis of objects not in the preferred category. These findings suggest that object recognition processes are distributed, rather than modular (Haxby et al., 2001; Ishai, Ungerleider, & Haxby, 2000). Perhaps the most important indication of a distributed representation of faces and other objects is that if the most category-preferring activations (say face preferring) are removed from the analysis, that category (faces) can be discriminated using the contributions from the other (nonface preferring) distributed regions. For instance, in regions that prefer chairs over other objects there is significant information that can be used for discrimination of faces, cars, and so forth (Haxby et al., 2001; Ishai et al., 2000).

Further, neuroimaging studies have also shown that the most face-preferring brain sites show significant modulation based on the amount of experience with an object class (Gauthier & Tarr, 1997, 2002; James & James, 2013). These findings suggest that one system is used for recognition of faces and other objects, but that there are quantitative differences in the pattern of recruitment across that system. Rather than a rigid modular system designed around fixed types of objects, these findings suggest a flexible distributed system that can adapt to changes in experience with different types of objects (Bukach, Gauthier, & Tarr, 2006).

Second, behavioral studies converge with the neuroimaging studies to suggest that face recognition is not qualitatively different, but quantitatively (Sekuler, Gaspar, Gold, & Bennett, 2004a). For instance, one study found that inverted faces showed the same behavioral markers of holistic processing as upright faces when subjects were given more time to study them (Richler, Mack, Palmeri, & Gauthier, 2011). Some of the disagreement in both the behavioral and neural literatures may be due, in part, to an issue with definition of terms such holistic and configural. Importantly, the term configural (and the term holistic, to a lesser degree) has been used to refer to cognitive/neural processes (Gauthier & Tarr, 2002; Maurer et al., 2002; McKone & Yovel, 2009; Rossion, 2008; Tanaka & Farah, 1993), but has also been used to refer to a manipulation of the properties of a stimulus (McKone, 2009; Rossion, 2008). However, most of the controversy surrounding the face inversion effect comes only from claims about whether or not it marks the recruitment of a configural *process* and whether or not that hypothetical process is specific to upright faces.

Objects in the real world can undergo rigid-body and nonrigid-body spatial transformations that can change the configuration of the features with respect to the viewer and also with respect to the object. By features, we refer to parts of an object that are relied on for recognition, whether in isolation or when combined (Nestor, Vettel, & Tarr, 2008; Ullman, Vidal-Naquet, & Sali, 2002). Changes in orientation in the picture plane (picture-plane rotation, including the inversion effect) are a particular case of rigid-body transformation where the configuration of features changes with respect to only the viewer. It has been shown convincingly that people can use changes in the configuration of features (changes in spacing) to recognize faces even when there are no changes to the features themselves (McKone & Yovel, 2009). Furthermore, the evidence is clear that there is no cost of inversion for recognizing single isolated face features—that is, features outside the context of a whole face (Arcurio, Gold, & James, 2012; Rhodes, Brake, & Atkinson, 1993). These findings suggest that the use of configuration for recognition may be integral to the cost associated with inversion.

The use of configuration for recognition of faces and other objects must rely on an analysis of combinations of features (Maurer et al., 2002; McKone & Yovel, 2009; Rhodes, 1988). This suggests that combination of information across features may have a primary role in producing the cost of inversion with some types of objects. An important consideration with respect to configuration as a property of objects that can be used for recognition is the degree to which more than one feature is required to successfully recognize the object. If one feature is particularly diagnostic, then it is likely that that feature will be relied on for recognition and not combined with other features. If diagnosticity is spread across features, then one feature will not be relied on exclusively and recognition may improve if information is combined across features. Importantly, in these cases where there are several moderately diagnostic features, it may be that information is not only combined across features to improve recognition, but that the spatial relations among the features can also be exploited to improve recognition. In the other cases, where one feature is highly diagnostic, it is unlikely that combining information from that feature with nondiagnostic features would improve recognition and also unlikely that spatial relations between that feature and nondiagnostic features would improve recognition. Despite the likely importance to theories of object recognition of this hypothesized dependency between feature diagnosticity and the use of configuration to recognize objects, there is little or no research that speaks to the relationship. And, to our knowledge, there is no research that speaks to the influence of this relationship on the cost of inversion.

2 Experiment 1

The current study was designed to assess the influence of feature diagnosticity and feature combination on the cost in behavioral performance associated with inversion. The typical inversion effect was used—that is, the orientation of the study and test stimuli matched. Four object-recognition tasks were developed based on four specific types of stimulus sets. The two diagnostic sets had only a single feature changing, in either the top or the bottom half of the object. Importantly, with these two stimulus sets, a correct response could be made without examining any features besides the diagnostic one. The combination sets had two features changing, one feature in the top and one feature in the bottom. The combinations were of two types: OR disjunctions, where a correct response could be made based on examining *either* the top *or* the bottom feature; and AND conjunctions, where a correct response could be made only after examining *both* the top *and* bottom features. Two groups of four stimulus sets were generated, one group from faces and one from nonface novel objects.

2.1 *Materials and methods*

2.1.1 *Participants.* Forty-two participants (eighteen male; aged 18–22 years) received course credit for participation. Data from two participants were not analyzed, because their accuracy was more than three standard deviations below the mean accuracy for the group. The study was approved by the Indiana University Institutional Review Board. Written informed consent was obtained from all participants prior to the experiment.

2.1.2 *Stimuli.* The experiment included stimuli made from faces and from novel objects. FaceGen 3.2 (http://www.facegen.com) was used to generate 18 face stimuli. Four faces (1–4) were used as the 'background' image, one for each of the four face stimulus sets. The remaining 14 faces (A–N) were used to create the 'features' that were superimposed on the background images to create the four individual stimuli within each stimulus set. All editing of the face stimuli to make stimulus sets was done using Adobe Photoshop. Face features were defined by a circular region centered on each eye/eyebrow region for the 'top' features and on the mouth for the 'bottom' features. Isolated face features were superimposed on the background images in different combinations to create two 'diagnostic' and two 'combination' stimulus sets. For the top diagnostic set, the four stimuli in the set were created by superimposing the four top features from faces A–D onto background image 1. For the bottom diagnostic set, the four stimuli in the set were created by superimposing the four bottom features from faces E–H onto background image 2. For the OR disjunction set, the four stimuli in the set were created by superimposing the four 'top' and the four 'bottom' features from faces I–L onto background image 3. For the AND conjunction set, the four stimuli in the set were created by superimposing the four permutations of the *two* top and two bottom features from faces M–N onto background image 4.

Rhino 4.0 3-D modeling software was used to generate a set of 18 novel objects (for example, see figure 1). Four novel object stimulus sets were generated using the same procedure as the four face stimulus sets, but from the 18 novel objects. The top features were the large lateral indentations located at the top of the object, and the bottom features were the protruding 'handles' on the bottom side of the object. All images were presented as grayscale and subtended 8 by 8 deg.

2.1.3 *Procedures.* The diagnostic face and novel object stimulus sets and combination face and novel object stimulus sets were tested in separate groups of participants ($N = 31$ and $N = 31$, respectively) using the same procedures. One group was exposed to face and novel object diagnostic stimulus sets, and the other one was exposed to face and novel object conjunction stimulus sets. The experiment consisted of 4 blocks of 50 trials each. Each block contained stimuli from only one of the stimulus sets (top diagnostic, bottom diagnostic, OR disjunction, AND conjunction). Each trial began with a study phase where subjects were presented with a single sample stimulus for 330 ms, in either the upright or inverted orientation. The study phase was followed by an interstimulus period of 0.5 s followed by a response screen showing all four stimuli from the set presented in the same orientation as the sample stimulus (figure 2). Subjects were instructed to choose the alternative that matched the sample stimulus from that trial and indicate their choice with one of four keyboard keys associated with the choice. Subjects were given unlimited time to make their response. The first 10 of 50 trials per block were 'practice' trials on which the subjects were given corrective feedback. Because the subjects were not explicitly told which features were important for success, these practice trials allowed the subjects to implicitly learn which features to use to produced correct responses. For the remaining 40 test trials in the block, no feedback was given. Only the test trials were analyzed. The order of blocks of stimulus sets and the order of each stimulus and the stimulus orientation on each trial was randomly assigned across subjects.

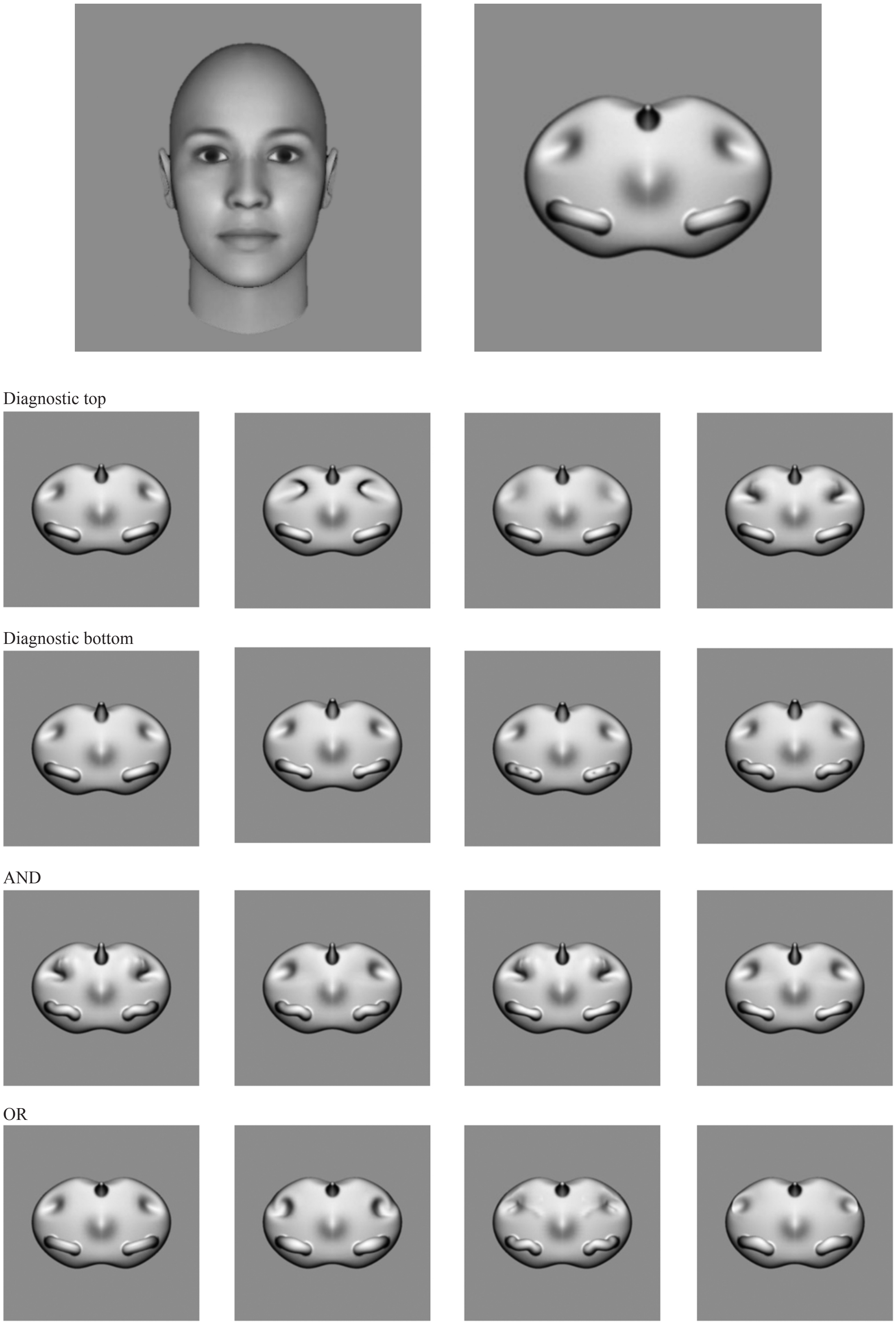

Figure 1. Sample stimuli.

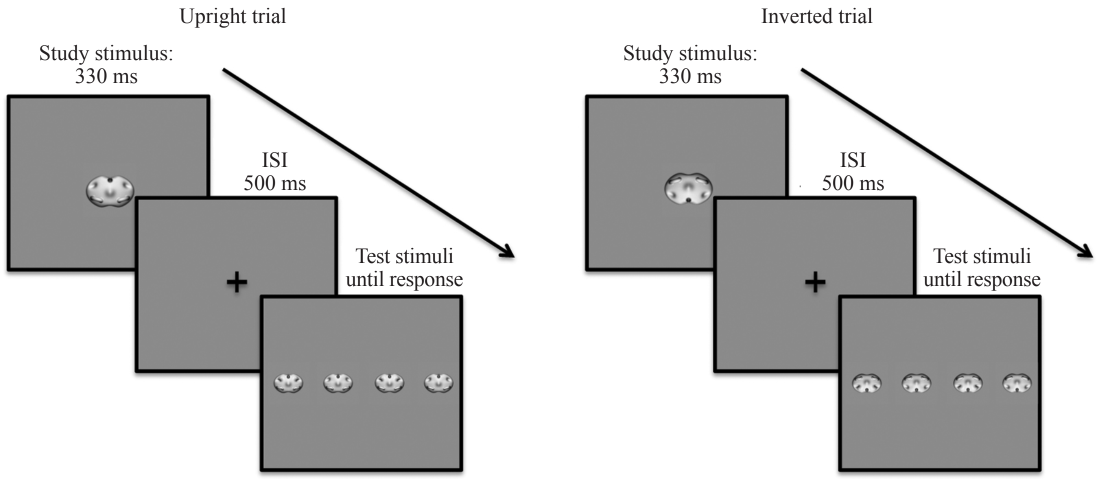

Figure 2. Design schematic for experiment 1.

2.2 *Results and discussion*

Figure 3 shows the identification accuracy for upright and inverted faces and novel objects for the four stimulus sets. A three-way repeated-measures ANOVA was performed on that data with object type and orientation as within-subject factors, stimulus set as a between-subject factor, and accuracy as the dependent measure. The results showed significant main effects of orientation ($F_{1,40}$= 17.45, $p < 0.005$), stimulus set ($F_{1,40} = 52.66$, $p < 0.005$), and object type ($F_{2,40} = 165.83$, $p < 0.005$). There was also a significant two-way interaction between stimulus set and object type ($F_{2,40} = 36.84$, $p < 0.005$) and a two-way interaction between stimulus set and orientation ($F_{2,40} = 20.44$, $p < 0.005$). Planned comparisons testing inversion effects for each stimulus type found significant inversion effects for all four of the face stimulus sets (bottom diagnostic: $t_{20} = 2.91$, $p = 0.008$, top diagnostic: $t_{20} = 4.67$, $p < 0.005$, AND: $t_{20} = 2.684$, $p = 0.014$, OR: $t_{20} = 3.2$, $p = 0.004$), but for none of the object stimulus sets.

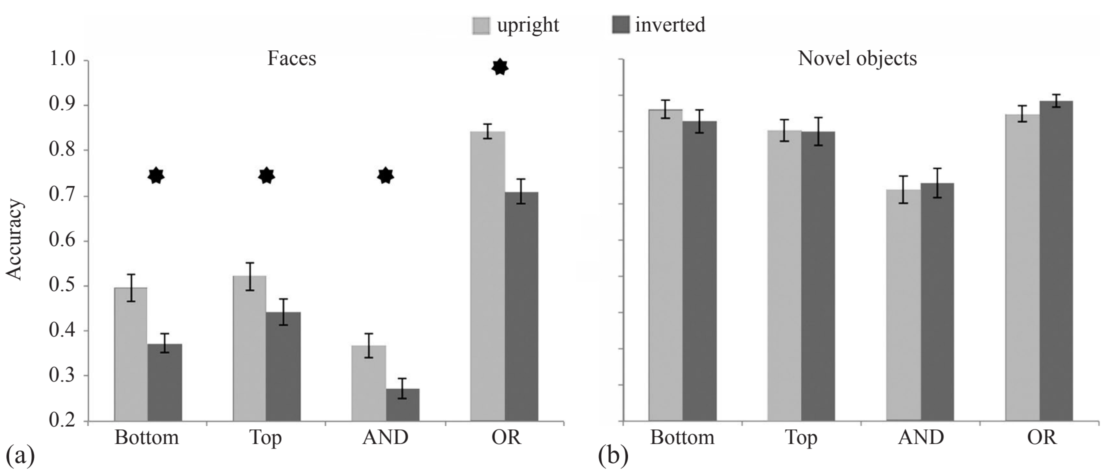

Figure 3. Accuracy as a function of stimulus set and object category. (a) Feature combination stimulus sets (AND and OR) and (b) diagnostic stimulus sets (top and bottom features). Error bars are standard error of the mean.

The results are consistent with previous research on the typical face inversion effect showing a stronger cost of inversion with faces compared with other objects. The results with the diagnostic face sets extend previous work by demonstrating that changes to the distribution of useable features in a face stimulus does not influence the effect of inversion.

Even though the diagnostic sets encouraged subjects to focus on a single highly diagnostic feature, the effect of inversion was large with faces. While we defined our diagnostic features as a singular unit of two eyes or an entire mouth, participants most likely differentially use subfeatures like individual eyes or corners of the mouth. We speculate that combination of these subfeatures may lead to the inversion effects found in the diagnostic conditions. Clearly, more work is needed to determine the specific features of different sizes—and the hierarchy of those features—that contribute to recognition in general and to inversion effects more specifically.

Not surprisingly, none of the novel object sets showed a cost with the typical inversion task, considering that subjects would not have learned (or have had an innate predisposition for) a particular upright orientation for the novel objects.

3 Experiment 2

In addition to the typical inversion effect, we also wanted to assess Yin's other inversion task, the one that specifically involved a transformation of stimulus orientation between study and test. We felt that this 'conversion' task was important to examine, because it is a task where a *change* in configuration must be overcome for successful recognition. The typical face inversion effect can be explained as a simple processing inefficiency for recognition of a nonstereotypical orientation (Sekuler, Gaspar, Gold, & Bennett, 2004b). Faces are almost always experienced in the upright orientation, producing a large discrepancy in experience between the upright and inverted orientations. Thus, faces are a special type of object for which experience may create large inversion effects (Gauthier & Tarr, 2002). As such, the face inversion effect by itself says little about the use of configural properties or processes for face recognition. However, in addition to the typical face inversion effect, Yin (1969) also found what we refer to as a face 'conversion' effect. To us, this finding is the strongest evidence presented by Yin that configural processing is more important for faces than for other types of objects. Because the conversion effect involves overcoming a transformation of the configuration of the stimulus, object types for which configural information is relied on should show the greatest cost.

As examining the influence of conversion asked a somewhat different research question than that posed by examining the influence of inversion, we conducted a second experiment that examined the influence of feature diagnosticity and combination with the conversion task. We hypothesized that the conversion task would be more sensitive than the inversion task to the effects of feature diagnosticity, because conversion specifically assesses the reliance on configural information.

3.1 *Materials and methods*

3.1.1 *Participants.* Sixty-three participants (twenty male; aged 18–22 years) received course credit for participation. Data from three participants were not analyzed, because their accuracy was more than three standard deviations below the mean accuracy for the group. The study was approved by the Indiana University Institutional Review Board. Written informed consent was obtained from all participants prior to the experiments.

3.1.2 *Stimuli.* The current experiment used the same sets of faces and novel objects as experiment 1. All images were presented as grayscale and subtended 8 by 8 deg.

3.1.3 *Procedures.* The face stimulus sets and novel object stimulus sets were tested in separate groups of participants ($N = 30$ and $N = 30$, respectively) using the same procedures. One group was exposed to face diagnostic and conjunction stimulus sets, and the other one was exposed to novel object diagnostic and conjunction stimulus sets. The experiment consisted of 4 blocks of 30 trials each. Each block contained stimuli from only one of the stimulus sets (top diagnostic, bottom diagnostic, OR disjunction, AND conjunction). For each trial subjects were first presented with a single sample stimulus for 330 ms, in either the upright or inverted orientation. The study phase was followed by an interstimulus period of 0.5 s followed by a response screen showing all four stimuli from the set presented in the upright orientation (figure 4). Subjects were instructed to choose the alternative that matched the sample stimulus from that trial and indicate their choice with one of four keyboard keys associated with the choice. Subjects were given unlimited time to make their response. The first 10 of 30 trials per block were 'practice' trials on which the subjects were given corrective feedback. Because the subjects were not explicitly told which features were important for success, these practice trials allowed the subjects to implicitly learn which features to use to produce correct responses. For the remaining 20 test trials in the block, no feedback was given. Only the test trials were analyzed. The order of blocks of stimulus sets and the order of each stimulus and the orientation on each trial was randomly assigned across subjects.

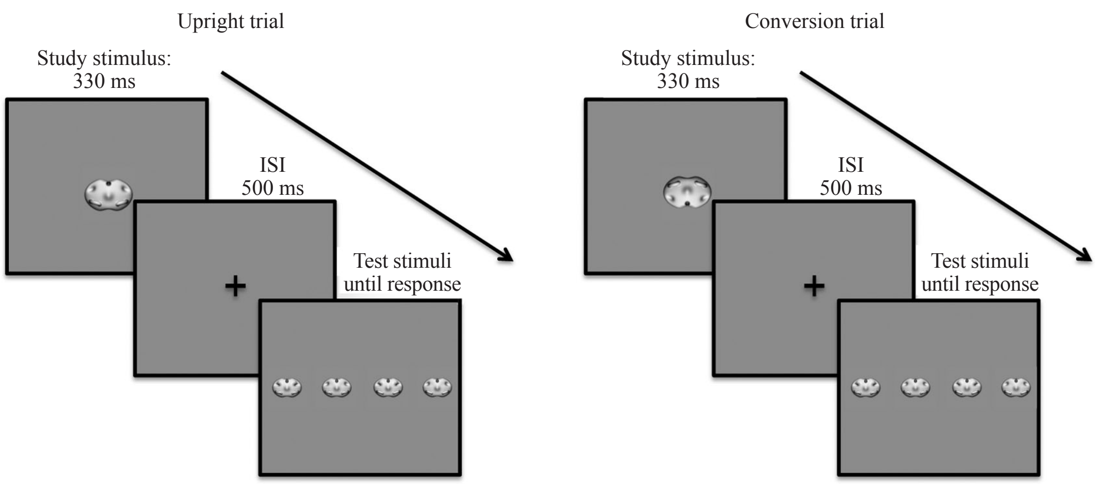

Figure 4. Design schematic for experiment 2.

3.2 *Results and discussion*

Figure 5 shows the identification accuracy for upright and converted faces and novel objects for the four stimulus sets. A three-way repeated-measures ANOVA was performed on those data with stimulus set and orientation as within-subject factors, object type as a between-subject factor, and accuracy as the dependent measure. The results showed significant main effects of orientation ($F_{1,58}$= 82.84, $p < 0.005$), stimulus set ($F_{3,174} = 13.94$, $p < 0.005$), and object type ($F_{1,58} = 175.9$, $p < 0.005$). There was also a significant two-way interaction between stimulus set and object type ($F_{3,174} = 19.95$, $p < 0.005$), a two-way interaction between orientation and object type ($F_{1,58} = 26.91$, $p < 0.005$), a two-way interaction between orientation and stimulus set ($F_{3,174} = 3.09$, $p = 0.02$), and finally a three-way interaction between orientation, experiment, and object type ($F_{3,174} = 4.237$, $p < 0.05$). Planned comparisons testing conversion effects revealed that accuracy was significantly better for the upright than converted orientation for all of the face stimuli (bottom feature diagnostic set: $t_{29} = 2.148$, $p = 0.02$, top feature diagnostic set: $t_{29} = 6.901$, $p < 0.005$, AND set: $t_{29} = 3.695$, $p < 0.005$, OR set: $t_{29} = 4.987$, $p < 0.005$); however, for novel objects the effect was present in only the AND conjunction condition ($t_{29} = 4.87$, $p < 0.005$).

On the surface, the typical inversion task used in experiment 1 and the conversion task used in experiment 2 both measure the impact on recognition of changing the spatial configuration of a stimulus. However, the key difference between the tasks is that conversion changes the configuration between study and test, whereas inversion uses the same configuration as study and test. In this way, costs associated with inversion are a measure of the efficiency

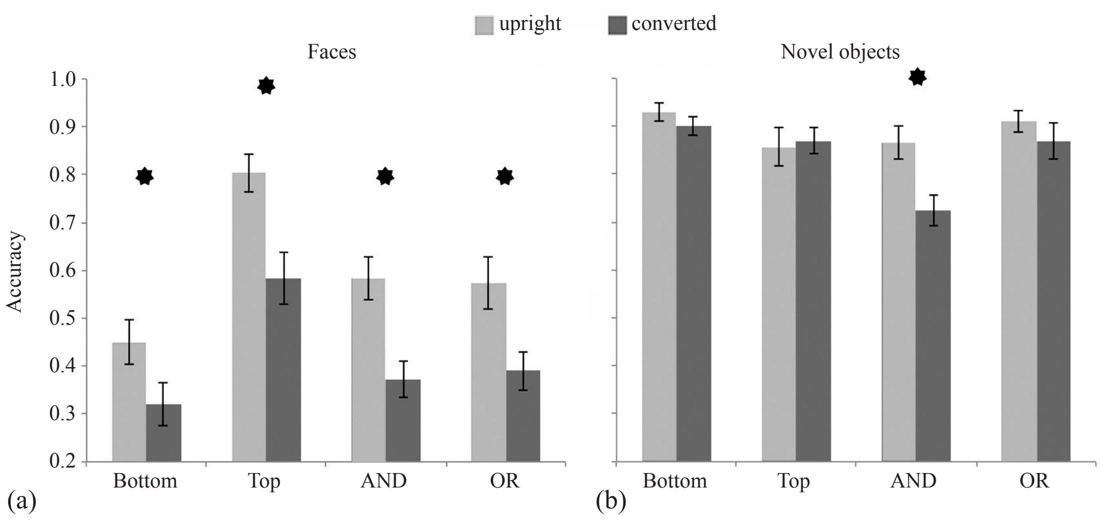

Figure 5. Accuracy as a function of stimulus set and stimulus orientation for face and novel objects. (a) Face stimulus sets and (b) novel object stimulus sets. Error bars are standard error of the mean.

of processing one configuration over the other, but costs associated with conversion are a measure of the degree to which configural properties of the stimulus are used for recognition. With this in mind, the conversion effect with AND conjunction novel objects is particularly revealing. Earlier, we proposed that reliance on configuration would be low for objects with a single highly diagnostic feature and high for objects with multiple diagnostic features, but especially if information needed to be combined across those features for recognition. The results with novel objects parallel this hypothesis: the diagnostic sets showed no influence of conversion, and the AND conjunction set showed a larger conversion effect than the OR disjunction set. These results show that, with novel objects, conversion effects are found only when subjects are forced to combine multiple features.

In light of this finding with novel objects, the conversion effects with face stimuli have interesting implications, more so than when Yin (1969) originally reported such effects. Face stimuli showed a cost of transforming orientation for all stimulus sets—that is, whether or not subjects were forced to combine multiple features, face stimuli produced similar conversion effects. Together with the results with novel objects, these findings with faces suggest that people are combining facial features to recognize faces and that they do this even when features do not need to be combined (OR disjunction set) and even when it is nonoptimal to do so (diagnostic sets). These findings impact theories of face and object recognition by clearly linking face stimuli with the obligatory use of configural information for recognition and by clearly showing that those configural processes are not specific to faces.

4 General discussion

The results of previous studies comparing upright and inverted face and nonface objects clearly show that the human visual system is disproportionately sensitive to the upright orientation of face objects compared with nonface objects. The current study investigated the influence of feature diagnosticity on the costs of inverting the object—studying and testing with the inverted orientation compared with upright—and *converting* the object—studying and testing with different orientations compared with the same. The results suggest two main conclusions.

First, the processing of upside-down faces was less efficient than the processing of upright faces, whether or not the task could be accomplished with a single feature or multiple features. Consistent with previous work, this effect was small or nonexistent with nonface objects.

Like other studies of the inversion effect, these results suggest that faces, because of the idiosyncratic amount and type of experience that people have with them, have a strong stereotypical upright orientation that is more efficiently processed than the inverted orientation.

Second, transforming the orientation of a face between study and test disrupted recognition whether or not the task could be accomplished with a single feature or multiple features. With novel objects, this conversion effect was found with only the AND conjunction stimulus set. The latter finding suggests that feature diagnosticity and the influence it has on combinations of features plays an important role in determining the extent to which configural information is used for object recognition. Importantly, subjects were able to adapt to the recognition goals of different stimulus sets within an experimental session, suggesting that the use of feature combination and configural information is not restricted to faces or other objects of expertise, but can be strategically employed depending on the task demands. However, the results also suggest that recognition of some types of objects (in this case, faces) is less flexible and may involve automatic combination of features.

In addition to the face conversion and inversion effects, historically there are other 'markers' of face specialization, including the composite effect, the part–whole effect, and the differential effects of manipulation of relational versus featural stimulus content (Maurer et al., 2002; Robbins & McKone, 2007; Tanaka & Farah, 1993; Young, Hellawell, & Hay, 1987). In the current study feature diagnosticity was assessed using inversion and conversion tasks, but clearly a more extensive investigation of the influence of feature combination is warranted, possibly by investigating its influence on these other classic behavioral tasks. Such an investigation may find that these tasks all tap a common underlying mechanism (such as feature combination), which may help to unify disparate theories of face processing involving holistic, configural, and feature-based mechanisms.

Although the current study did not use the composite effect, the results are consistent with previous work with that task. A series of studies have demonstrated that the top and bottom halves of composites are combined automatically with face objects, but are combined strategically or context dependently with nonface objects or when face objects are misaligned (Gauthier & Tarr, 2002; Richler, Wong, & Gauthier, 2011; Wong & Gauthier, 2010). Of interest is that these previous studies examined the influence of expertise on composite effects. They found that top and bottom halves were automatically combined for objects of expertise, just like they were with faces (although see Robbins & McKone, 2007). Although the current study did not include nonface objects of expertise, other studies have shown large inversion effects with such objects (Diamond & Carey, 1986; Gauthier & Tarr, 1997; Husk, Bennett, & Sekuler, 2007). Taken together, the previous results and the current results suggest that at least one consequence of expertise is a shift from strategic to automatic recruitment of a domain-general feature combination mechanism (Logan, 1998).

In summary, upside-down faces are processed less efficiently than upright faces. A transformation of orientation was difficult to overcome with face stimuli, presumably because face recognition relies on configural information. When subjects were obliged to combine information across novel object features, there was also a cost associated with transforming orientation with those objects. Together, these results suggest that recognition of faces relies heavily on configural information using domain-general processes that can also be recruited strategically with other types of objects.

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References

Arcurio, L. R., Gold, J. M., & James, T. W. (2012). The response of face-selective cortex with single face parts and part combinations. *Neuropsychologia*, **50**, 2454–2459.

Bukach, C. M., Gauthier, I., & Tarr, M. J. (2006). Beyond faces and modularity: the power of an expertise framework. *Trends in Cognitive Science*, **10**, 159–166.

Diamond, R., & Carey, S. (1986). Why faces are and are not special: an effect of expertise. *Journal of Experimental Psychology*, **115**, 107–117.

Gauthier, I., & Tarr, M. J. (1997). Becoming a 'Greeble' expert: exploring mechanisms for face recognition. *Vision Research*, **37**, 1673–1682.

Gauthier, I., & Tarr, M. J. (2002). Unraveling mechanisms for expert object recognition: Bridging brain activity and behavior. *Journal of Experimental Psychology*, **28**, 431–446.

Haxby, J. V., Gobbini, M. I., Furey, M. L., Ishai, A., Schouten, J. L., & Pietrini, P. (2001). Distributed and overlapping representations of faces and objects in ventral temporal cortex. *Science*, **293**(5539), 2425–2430.

Husk, J. S., Bennett, P. J., & Sekuler, A. B. (2007). Inverting houses and textures: Investigating the characteristics of learned inversion effects. *Vision Research*, **47**, 3350–3359.

Ishai, A., Ungerleider, L. G., & Haxby, J. V. (2000). Distributed neural systems for the generation of visual images. *Neuron*, **28**, 979–990.

James, T. W., & James, K. H. (2013). Expert individuation of objects increases activation in the fusiform face area of children. *NeuroImage*, **67**, 182–192.

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: a module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience*, **17**, 4302–4311.

Kanwisher, N., & Yovel, G. (2006). The fusiform face area: a cortical region specialized for the perception of faces. *Philosophical Transactions of the Royal Society of London*, **361**(1476), 2109–2128.

Logan, G. D. (1998). What is learned during automatization? II. Obligatory encoding of spatial location. *Journal of Experimental Psychology: Human Perception and Performance*, **24**, 1720–1736.

Maurer, D., Grand, R. L., & Mondloch, C. J. (2002). The many faces of configural processing. *Trends in Cognitive Sciences*, **6**, 255–260.

McKone, E. (2009). Holistic processing for faces operates over a wide range of sizes but is strongest at identification rather than conversational distances. *Vision Research*, **49**, 268–283.

McKone, E., & Yovel, G. (2009). Why does picture-plane inversion sometimes dissociate perception of features and spacing in faces, and sometimes not? Toward a new theory of holistic processing. *Psychonomic Bulletin & Review*, **16**, 778–797.

Nestor, A., Vettel, J. M., & Tarr, M. J. (2008). Task-specific codes for face recognition: How they shape the neural representation of features for detection and individuation. *PLoS ONE*, **3**(12), e3978.

Rhodes, G. (1988). Looking at faces: first-order and second-order features as determinants of facial appearance. *Perception*, **17**, 43–63.

Rhodes, G., Brake, S., & Atkinson, A. P. (1993). What's lost in inverted faces? *Cognition*, **47**(1), 25–57.

Rhodes, G., Byatt, G., Michie, P. T., & Puce, A. (2004). Is the fusiform face area specialized for faces, individuation, or expert individuation? *Journal of Cognitive Neuroscience*, **16**, 189–203.

Richler, J. J., Mack, M. L., Palmeri, T. J., & Gauthier, I. (2011). Inverted faces are (eventually) processed holistically. *Vision Research*, **51**, 333–342.

Richler, J. J., Wong, Y. K., & Gauthier, I. (2011). Perceptual expertise as a shift from strategic interference to automatic holistic processing. *Current Directions in Psychological Science*, **20**, 129–134.

Robbins, R., & McKone, E. (2007). No face-like processing for objects-of-expertise in three behavioural tasks. *Cognition*, **103**, 34–79.

Rossion, B. (2008). Picture-plane inversion leads to qualitative changes of face perception. *Acta Psychologica*, **128**, 274–289.

Sekuler, A. B., Gaspar, C. M., Gold, J. M., & Bennett, P. J. (2004a). Inversion leads to quantitative, not qualitative, changes in face processing. *Current Biology*, **14**, 391–396.

Sekuler, A. B., Gaspar, C. M., Gold, J. M., & Bennett, P. J. (2004b). Inversion leads to quantitative, not qualitative, changes in face processing. *Current Biology*, **14**, 391–396.

Tanaka, J. W., & Farah, M. J. (1993). Parts and wholes in face recognition. *The Quarterly Journal of Experimental Psychology*, **46**, 225–245.

Ullman, S., Vidal-Naquet, M., & Sali, E. (2002). Visual features of intermediate complexity and their use in classification. *Nature Neuroscience*, **5**, 682–687.

Wong, Y. K., & Gauthier, I. (2010). Holistic processing of musical notation: Dissociating failures of selective attention in experts and novices. *Cognitive, Affective & Behavioral Neuroscience*, **10**, 541–551.

Yin, R. K. (1969). Looking at upside-down faces. *Journal of Experimental Psychology*, **81**, 141–145.

Young, A. W., Hellawell, D., & Hay, D. C. (1987). Configurational information in face perception. *Perception*, **16**, 747–759.

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