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**Face detection differs from categorization: Evidence from visual search in
natural scenes**

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Abstract

This study examined whether the detection of frontal, $\frac{3}{4}$ and profile face views differs from their categorization as faces. Experiment 1 compared three tasks that required observers to determine the presence or absence of a face but varied in the extent to which they had to search for faces in simple displays and small or large scenes to make this decision. Performance was equivalent for all face views in simple displays and small scenes, but was notably slower for profile views when this required the search for faces in extended scene displays. This search effect was confirmed in Experiment 2, which compared observers' eye movements with their response times to faces in visual scenes. These results demonstrate that the categorization of faces at fixation is dissociable from the detection of faces in space. Consequently, we suggest that face detection should be studied with extended visual displays, such as natural scenes.

Keywords: face, detection, categorization, view

Introduction

The failure to detect faces can lead to the loss of important social information, such as the identity of people in our surroundings or their emotional and attentive state. Our cognitive system seems to guard specifically against such losses, as faces are detected ultra-rapidly (Crouzet, Kirchner, & Thorpe, 2010; Crouzet & Thorpe, 2011) and provide a powerful draw for observers' attention (Langton, Law, Burton, & Schweinberger, 2008; Theeuwes & Van der Stigchel, 2006). These feats emphasize the important status of face detection in social cognition. Despite this, however, this process has received limited attention by psychologists. A convincing theory of human face detection, for example, still does not exist and this topic is rarely considered in grand reviews of face perception (see, e.g., Bruce & Young, 2011; Calder, Rhodes, Johnson, & Haxby, 2011; Hole & Bourne, 2010).

A possible reason for this oversight is that there is variation in the general methods with which face detection has been studied, so the specificity of this process is still not inherently clear. Some research employed paradigms in which faces are cropped from extraneous background and presented in the center of visual displays (e.g., Liu, Harris, & Kanwisher, 2002; Nestor, Vettel, & Tarr, 2008). Other studies have used more complex displays, such as visual search arrays (e.g., Hershler & Hochstein, 2005) and natural scenes (e.g., Bindemann & Burton, 2009).

An empirical question that remains to be resolved is whether this pragmatic divide has theoretical implications for our understanding of face detection. In experimental displays that consist of a single centrally-presented stimulus, the process of detection effectively becomes a categorization task, in

which observers have to determine whether a fixated stimulus is a face or a non-face object. By contrast, extended visual arrays require observers to determine the presence or absence of a face anywhere in a display. Both types of paradigms therefore rely on face versus non-face decisions, but one approach requires the *search* for face stimuli whereas the other does not. Models of object recognition suggest that detection and categorization are distinct processes (e.g., Driver & Bayliss, 1996; Nakayama, He, & Shimojo, 1995). However, this view has also been contested (Grill-Spector & Kanwisher, 2005) and it is unknown whether such a distinction applies to face processing.

One source of evidence to suggest that this distinction might be appropriate comes from tasks in which observers are required to detect the presence of faces at different locations in the visual field (Hershler, Golan, Bentin, & Hochstein, 2010). Under these conditions, face detection performance is comparable to that for non-face targets when these stimuli are presented close to fixation. However, a detection advantage for faces emerges when the targets appear at greater eccentricities and particularly when they are surrounded by further stimuli. These findings therefore provide some initial evidence that different processes are involved in the categorization of centrally-presented faces and the detection of these stimuli across the visual field.

We have **also** obtained **indirect** evidence **for such a distinction** in our own work. **It has already been shown, for example, that familiar face recognition (Troje & Kersten, 1999), gender classification (Bindemann, Scheepers, & Burton, 2009), and emotion recognition (Matsumoto & Hwang, 2011) are all unaffected by differences in view (frontal, $\frac{3}{4}$, and profile) when faces can be located easily onscreen.** By contrast, performance declines in profile view when observers have

to search for faces in visual scenes (Burton & Bindemann, 2009), which hints, again, that detection might be a process that is separable from other face tasks.

The current study addresses this issue directly, with two contrasting paradigms designed to dissociate these possibilities. We conducted two experiments in which observers were asked to look for faces in different views. In Experiment 1, we used this view manipulation to determine whether the categorization of faces differs from the search for faces in visual scenes. For this purpose, observers were presented with three separate tasks. The first was a categorization task between faces and objects presented at fixation. We compared performance in this paradigm with a detection task, in which observers had to search for faces in visual scenes. We also provided a further task to bridge the gap between these paradigms. In this task, observers were presented with small outtakes from the visual scenes, which were shown in the screen centre and could contain a face or not.

Each of these tasks therefore required observers to determine the presence or absence of a face, but differed in the extent to which they had to search for faces to make this decision. The aim here was to determine whether an effect of face view was present during the categorization of stimuli at fixation or only when observers had to search for faces in first place.

Experiment 1

Method

Participants

Twenty-seven students, with a mean age of 20.0 years ($SD = 1.7$), participated in the experiment for course credit.

Stimuli

This experiment consisted of three separate tasks. Task 1 assessed face categorization in simple visual displays, while task 3 measured face detection in natural scenes. Task 2 was designed to bridge the gap between these paradigms and is therefore described last.

*Task 1: Face categorization in **basic** displays*

The stimuli for task 1 consisted of the faces of 20 models (10 male) and 120 non-face objects. Each person was depicted in three different poses (frontal, $\frac{3}{4}$ profile left/right, and profile left/right), giving a total of 100 different images. The non-face stimuli consisted of a wide range of objects, including household items, furniture and food. All images were cropped to remove extraneous background and scaled to a height and width of 180 pixels presented at a resolution of 72 pixels/inch (for examples, see Figure 1).

Task 3: Face detection in natural scenes

The stimuli for task 3 consisted of photographs of 120 indoor scenes, which were taken from inside houses, apartments, and office buildings. These scenes measured 1,000 (W) x 750 (H) pixels presented at a screen resolution of 72 pixels/inch. For each scene, six versions existed that were identical in all aspects, except for the following differences. Five of the versions contained a face, whereas one version did not. In face-present scenes, faces were either depicted in a frontal, $\frac{3}{4}$ profile left/right or profile left/right view. Applying these

manipulations to each of the scenes resulted in a total of 720 different displays, comprising 120 face-absent scenes and 600 face-present scenes.

Crucially, the faces in these scenes were the same photographs that were used in task 1 (see Figure 2). The location of these photographs was unpredictable across the scenes. In addition, the faces varied in size across scenes, ranging from 0.08% to 1.73% of the total scene area, to ensure that participants could not adopt a simple search strategy based on target size (for further details, see Burton & Bindemann, 2009).

Task 2: Face categorization in small scenes

This task was designed to bridge the gap between the face/non-face categorization paradigm (task 1) and the search for faces in full scenes (task 3). The stimuli therefore consisted of the scene areas that contained the target faces (see Figure 2). These scene segments measured 180 pixels in height and width and were presented in the centre of a plain white background. The scale of these stimuli was preserved, so that the faces were presented at the same size as in the full scenes.

To provide a set of non-face stimuli to make up the task demands, the corresponding areas from the face-absent scenes were used. In total, there were therefore 720 different displays, comprising 120 face-absent and 600 face-present images, in which a face was either shown in a frontal view (120 images), a $\frac{3}{4}$ left or right view (120 images each), or a profile left or right view (120 images each).

Procedure

In each of the tasks, participants were shown 360 randomly intermixed trials, consisting of 240 non-face and 120 face trials. The face trials consisted of 40 stimuli for each of the three view conditions (frontal, $\frac{3}{4}$ view, profile view). For $\frac{3}{4}$ and profile views, these comprised 20 left and 20 right-facing stimuli. In the full and partial scene task, the different face views were rotated around the scene images, so that each face-present scene was only shown once to each participant. Overall, however, the presentation of the scenes was counterbalanced across participants, so that each face view appeared in each scene an equal number of times.

In each of the tasks, a trial began with a fixation cross for 1 second, followed by a stimulus, which was displayed until a response was registered. Participants were briefed about the different face views prior to the experiment and were asked to make speeded responses concerning whether a face was present or not. The running order of the three tasks was counterbalanced across participants.

Results

In all three tasks, the average correct response times were calculated for the three face views. These results are displayed in Table 1 and show that response times were generally comparable for task 1 (face categorization in basic displays) and 2 (face categorization in small scenes) but slower in task 3 (face detection in natural scenes). In addition, performance also appeared to be matched evenly across face views in task 1 and 2, but response times were notably slower for profile faces than frontal and $\frac{3}{4}$ views in task 3.

These observations were confirmed by a 3 x 3 within-subject ANOVA, which showed a main effect of task, $F(2,52) = 94.46, p < 0.001, \text{partial } \eta^2 = 0.78$. Tukey HSD comparisons show that this effect arises from slower response times in task 3 compared to task 1 and 2, both $qs \geq 16.23, ps \leq 0.001, ds \geq 1.70$, while task 1 and 2 did not differ, $q = 1.15$. In addition, ANOVA also showed an effect of face view, $F(2,52) = 3.58, p < 0.05, \text{partial } \eta^2 = 0.12$, and an interaction between both factors, $F(2,52) = 4.44, p < 0.01, \text{partial } \eta^2 = 0.15$. Analysis of simple main effects showed a difference in response times across face views in task 3, $F(2,52) = 11.28, p < 0.001, \text{partial } \eta^2 = 0.30$, but not in task 1 or 2, both $Fs < 1$. A comparison of the face views in task 3 showed that response times were evenly matched for frontal and $\frac{3}{4}$ views, $q = 1.32$, but were slower for profile faces than frontal and $\frac{3}{4}$ views, both $qs \geq 5.05, ps \leq 0.01, \text{both } ds \geq 0.33$.

A 3 x 3 ANOVA of the accuracy of responses also showed a main effect of task, $F(2,52) = 20.50, p < 0.001, \text{partial } \eta^2 = 0.44$, which reflects lower accuracy in task 3 than in task 1 and 2, both $qs \geq 6.64, ps \leq 0.001, ds \geq 0.78$, while task 1 and 2 did not differ from each other, $q = 2.01$. ANOVA also found a main effect of face view, $F(2,52) = 12.52, p < 0.001, \text{partial } \eta^2 = 0.33$, reflecting lower accuracy in the classification of profile faces than frontal and $\frac{3}{4}$ views, both $qs \geq 4.42, ps \leq 0.01, ds \geq 0.22$. By comparison, accuracy for the frontal and $\frac{3}{4}$ view condition did not differ, $q = 2.58$. The interaction of task and view was not significant, $F(2,52) < 1$.

Discussion

This experiment replicates previous research by showing that the detection of profile faces is slower in natural visual scenes than that of frontal

and $\frac{3}{4}$ views (Burton & Bindemann, 2009). Crucially, this was observed in a context that did not show the same effect of view when faces were presented centrally, so that the search component of the detection task was eliminated. Moreover, this was observed with faces that were shown on a plain background (task 1) and in small scenes (task 2). In this latter condition, the faces were an exact match to those in the full scenes in terms of their size, colour and contrast, and the immediate surrounding visual context. The difference between these tasks therefore shows that the categorization of a centrally-presented stimulus as a face and the search for faces in extended visual displays can yield rather different outcomes. This indicates that categorization and detection are dissociable face processes.

Experiment 2

While the effect of view is only observed in task 3 of Experiment 1, the notion that this effect does, in fact, occur during the *search* process is only inferred from the reaction times on the basis that a similar pattern is not found for centrally-presented faces in tasks 1 and 2. Experiment 2 investigated this issue more directly by recording observers' eye movements during the search for faces in natural scenes. Eye movements are associated closely with the allocation of attention around stimulus displays (Deubel & Schneider, 1996) and provide a sensitive on-line measure for visual search tasks (Liversedge & Findlay, 2000), including the detection of faces (Crouzet et al., 2010). We therefore contrasted the effect of view on the time that is required to first fixate a face in a visual scene, which provides an immediate eye-tracking measure of the duration of the search process, with the time to respond to a face. By comparing

these measures, it is possible to determine **more directly** whether the effect of view arises during visual search for possible face candidates or at a subsequent categorization stage that might take place to confirm that a looked-at stimulus really is a face.

Method

Participants

Eighteen students, with a mean age of 21.7 years ($SD = 3.5$), participated in the experiment for course credit.

Stimuli and procedure

The stimuli and procedure were the same as in task 3 of Experiment 1, except for the following changes. Participants' eye movements were recorded during the detection task. The stimuli were therefore displayed on a 21 inch colour monitor that was connected to an Eyelink 1000 desk-mounted eye-tracking system running at 500 Hz sampling rate. The scenes were presented at a size of 1,000 (W) x 750 (H) pixels at a screen resolution of 66 pixels/inch. Viewing was binocular, but only the participants' left eye was tracked. To calibrate the tracker, the standard 9-point Eyelink calibration procedure was used initially, and repeated every 60 trials.

In the experiment, each trial began with a central fixation dot, which was used to perform an automatic drift correction. A stimulus was then presented until a response was registered. Participants made speeded keypress responses concerning whether a face was present or not. Each participant was given 360

trials, comprising 120 face-present trials (40 each for frontal, $\frac{3}{4}$, and profile view target) and 240 face-absent trials in a randomly-intermixed order.

Results and Discussion

The mean response times and accuracy for all views are shown in Table 2. A one-factor ANOVA of the RT data showed an effect of face view, $F(2,34) = 9.38$, $p < 0.001$, **partial $\eta^2 = 0.36$** , reflecting longer response times for profile faces than frontal and $\frac{3}{4}$ views, both $qs \geq 3.84$, $ps \leq 0.05$, **$ds \geq 0.47$** . In contrast, the difference between frontal and $\frac{3}{4}$ views was not significant, $q = 2.22$. A **corresponding** pattern was found for accuracy. A one-factor ANOVA showed an effect of face view, $F(2,34) = 6.15$, $p < 0.01$, **partial $\eta^2 = 0.27$** , due to lower accuracy in the profile face condition than with frontal and $\frac{3}{4}$ views, both $qs \geq 4.21$, $ps \leq 0.05$, **$ds \geq 0.56$** , while the difference between frontal and $\frac{3}{4}$ views was not significant, $q = 0.16$.

In addition, two measures were extracted from the eye movements, corresponding to the average time that was required to first fixate a face in a visual scene (*time-to-fixation*) and the average number of fixations that were required to do so (*number-of-fixations*). Both measures provide a direct index of the search effort that is required to locate a face and are summarized in Table 2.

A one-factor ANOVA of the time-to-fixation data showed an effect of face view, $F(2,34) = 11.67$, $p < 0.001$, **partial $\eta^2 = 0.41$** , due to longer search times for profile faces than frontal and $\frac{3}{4}$ views, both $qs \geq 5.77$, $ps \leq 0.001$, **$ds \geq 0.72$** , whereas the difference between frontal and $\frac{3}{4}$ views was not significant, $q = 0.27$. A similar pattern was found for number-of-fixations, $F(2,34) = 13.02$, $p < 0.001$, **partial $\eta^2 = 0.43$** , with observers requiring more fixations to locate profile

faces than frontal and $\frac{3}{4}$ views, both $qs \geq 6.01$, $ps \leq 0.001$, $ds \geq 0.85$, while the difference between frontal and $\frac{3}{4}$ views was not significant, $q = 0.44$.

This experiment therefore provides **more** direct evidence that the effect of face view arises during the *search* for faces in visual scenes. As in Experiment 1, observers were slower to locate profile than frontal and $\frac{3}{4}$ views of faces. Crucially, however, this same effect was found in the time that observers required to first fixate a face in visual scenes. Experiment 2 therefore **indicates** that the view effect **genuinely** is a *search* effect, which arises while observers try to locate faces in visual scenes.

General Discussion

This study examined whether the search for faces in natural scenes differs from the categorization of visual stimuli as face and non-face objects. In Experiment 1, an effect of face view was found when observers searched for faces in extended scenes, but not when small segments of scenes or isolated images of faces and non-face objects were presented in a central location. **Note that these differences are unlikely to reflect general task difficulty. While the full scene stimuli yielded the longest reaction times in Experiment 1, other categorization tasks, such as familiar face recognition, yield similarly long reaction times but do not show view effects (Troje & Kersten, 1999).** Finally, to analyze these findings further, observers' eye movements were recorded during the full scene task in a second experiment. This confirmed that the view effect arises during the search for faces.

Overall, our results **therefore indicate** that the process of detection, whereby faces have to be searched for in visual scenes, differs from the

categorization of face and non-face images. These findings converge with previous experiments that have already hinted at this distinction (Hershler et al., 2010), but provide more direct evidence by contrasting categorization with visual search in natural scenes and by assessing observers' search behavior with eye movements. These results are of theoretical importance for showing that these processes are dissociable. Moreover, our data suggest that if we wish to understand face detection *per se* then this process should be studied with extended visual displays, such as natural scenes.

At present, there are no theories of human cognition that can provide an adequate account of how faces are detected in our visual field (see, e.g., Hershler & Hochstein, 2005; Lewis & Edmonds, 2005; Lewis & Ellis, 2003), despite the fact that is the entry point for all other tasks with faces. Even the cause of the effect of face view, which was used to dissociate face detection from categorization here, has so far resisted explanation (Burton & Bindemann, 2009). Initially, it seemed plausible that the eye regions play an important role in face detection (Lewis & Edmonds, 2003) and contribute to the view effect (Burton & Bindemann, 2009). However, this explanation is perhaps less likely now, considering that eye-gaze cannot be perceived outside focal attention (Burton, Bindemann, Langton, Schweinberger, & Jenkins, 2009). The speed of face detection suggest this process might instead rely on a "quick and dirty" processing strategy that relies on more salient visual cues to locate possible face candidates (Crouzet & Kirchner, 2010).

One possibility for such a strategy could be based on a face-shaped colour-template. This notion is born out of the observation that colour information can be processed very rapidly (e.g., Treisman, 1993) and skin-colour

tones can be an effective first step for detecting likely face candidates (Bindemann & Burton, 2009). This notion receives further support from the finding that faces can be detected rapidly when internal or external visual features are selectively removed as long as an oval face-shape colour-template is retained, but not when this template is disrupted by image scrambling (Hershler & Hochstein, 2005). These findings might explain the effect of view in face detection, which arises primarily from information carried in the top half of a face (Burton & Bindemann, 2009). In profile faces, much of this area is occluded by hair (see Figure 1). If this disrupts the diagnostic oval shape of faces, then this could perhaps produce the detection disadvantage that is found for profile views in natural scenes.

This account is clearly speculative and other theories of face detection have been proposed elsewhere (e.g., Lewis & Edmonds, 2005; Hershler & Hochstein, 2005). These theories do not explicitly deal with variation in the detectability of different face views, but are united in trying to explain this visual process. The main aim of this research is to demonstrate that face detection is indeed an important process in its own right, and is dissociable from the categorization paradigms that are frequently used in face research. We hope that this finding provides an imperative for further progress in this field.

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FIGURE 1. Examples of the face and non-face stimuli for task 1 (a) and task 2 (b), and an example of a face-present scene for task 3 (c) in Experiment 1.

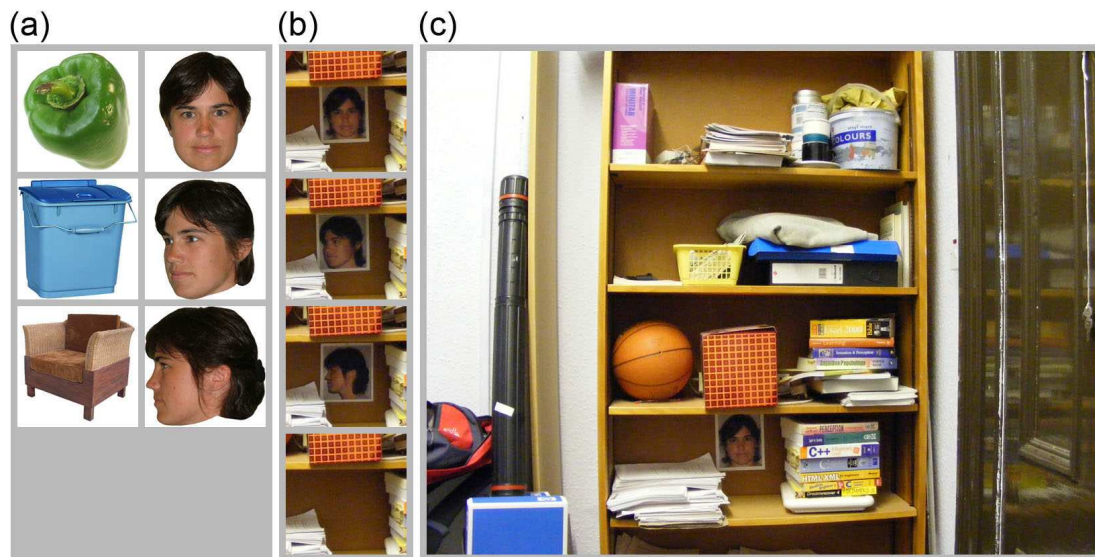


TABLE 1. A summary of the mean reaction times and accuracy for the three tasks in Experiment 1. Parentheses show the standard deviation of the mean. The data for “No Face” responses is reported for completeness but was not included in the analysis.

<i>Reaction Times (in msec)</i>				
	Face View			No Face
	<i>Frontal</i>	<i>3/4</i>	<i>Profile</i>	
Task 1 (Categorization)	533 (137)	514 (129)	504 (111)	538 (151)
Task 2 (Categorization)	539 (115)	545 (123)	555 (108)	554 (121)
Task 3 (Search)	929 (250)	900 (246)	1043 (428)	1580 (888)

<i>Accuracy (%)</i>				
	Face View			No Face
	<i>Frontal</i>	<i>3/4</i>	<i>Profile</i>	
Task 1 (Categorization)	94.8 (3.9)	95.9 (5.2)	94.4 (5.0)	98.7 (2.0)
Task 2 (Categorization)	92.4 (10.3)	93.4 (9.3)	90.3 (9.7)	97.4 (6.5)
Task 3 (Search)	82.7 (16.1)	83.8 (15.4)	79.6 (14.6)	96.4 (8.5)

TABLE 2. A summary of the response and eye movement measures in Experiment 2. Parentheses show the standard deviation of the mean. The data for “No Face” responses is reported for completeness but was not included in the analysis.

	Face View			No Face
	<i>Frontal</i>	<i>3/4</i>	<i>Profile</i>	
Reaction time	847 (103)	881 (132)	940 (118)	1680 (425)
Accuracy	92.5 (4.0)	92.4 (6.7)	88.8 (6.1)	99.1 (0.8)
Time to fixation	593 (108)	588 (114)	704 (188)	-----
Number of fixations	2.4 (0.5)	2.4 (0.4)	2.8 (0.5)	-----