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Face identification in the near-absence of focal attention

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Abstract

In contrast to artificial geometric shapes, natural scenes and face-gender can be processed even when spatial attention is not fully available. In this study, we investigate whether a finer discrimination, at the level of the individual, is possible in the near-absence of focal attention. Using the paradigm, subjects performed face identification on faces of celebrities and relatively unfamiliar individuals, along with a task that is known to engage spatial attention. We find that face-identification performance is only modestly impaired under dual-task conditions. These results suggest that the visual system is well able to make complex judgments of natural stimuli, even when attention is not fully available.

Keywords: Attention; Face identification; Dual-task paradigm; Famous faces

1. Introduction

The processing of naturalistic stimuli has recently come under scrutiny (Braun, 2003; Kayser, Kording, & Konig, 2004; Li, VanRullen, Koch, & Perona, 2002; Rousselet, Fabre-Thorpe, & Thorpe, 2002). In particular, Li et al. (2002) showed that the visual system can categorize natural scenes more efficiently than artificial geometric shapes. They demonstrated that even though subjects could detect the presence of an animal in a scene in the near-absence of attention, they could not discriminate simple stimuli (such as telling a red-green bisected disk apart from a green-red one). They concluded that the attentional demands of a task are not determined by the "complexity" of the stimuli used, but by the type of stimuli used—in this case, natural scenes versus artificial stimuli.

Previously, we investigated the limits of this type of pre-attentive processing of natural stimuli. We sought to determine whether spatial attention would become necessary if the natural targets and distracters were made more similar to each other. Indeed, in contrast to the bisected disk task, where the stimulus space was restricted, and the targets and distracters differed from each other along well-defined feature dimensions, the natural scenes used by Li et al. were very diverse and both the target and distracter ensembles probably populated a high dimensional space. Thus, it remained possible that natural scene processing in the near-absence of attention would break down in more constrained stimulus spaces (and thus presumably more complex discriminations).

To address this issue, we had used a face-gender discrimination task (Reddy, Wilken, & Koch, 2004). The feature dimensions involved in this discrimination are well characterized: eye brows, eyes, jaws, noses, and mouths in order of increasing relevance (Brown & Perrett, 1993; Bruce et al., 1993; Yamaguchi, Hirukawa, & Kanazawa, 1995). Additionally, male and female faces share many common features, including, in particular their global structure; this makes the input space more constrained than other natural scene categorization tasks. Our results demonstrated that subjects could still identify the gender of a face even when spatial attention was not fully available. Additionally, we also observed a face-inversion effect (Brown, Huey, & Findlay, 1997; Sekuler, Gaspar, Gold,

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& Bennett, 2004; Valentine, 1988; Valentine & Bruce, 1988; Yin, 1969).

It thus appears that for pre-attentive processing to break down, even more subtle discriminations will be necessary. Here, we probe the attentional requirements of face identification. Several lines of evidence indicate that identifying a particular face is a finer and more complex discrimination task than telling male and female faces apart. For instance, current models of face recognition posit that, although gender discrimination and face recognition could proceed in distinct modules (Bruce & Young, 1986), (see however Haxby, Hoffman, & Gobbini, 2000), gender discrimination occurs prior to face recognition (Ellis, 1986). Psychophysical data lend credence to this hypothesis since, it has been demonstrated that at least under some conditions gender categorization is performed faster than face recognition (Bruyer, Galvez, & Prairial, 1993; Sergent, 1986). Accordingly, it has been shown that the two systems interact with each other (Rossion, 2002), and that determining the gender of a face can influence its subsequent recognition (Baudouin & Tiberghien, 2002). Additionally, face identification generally exploits higher spatial frequency information than gender discrimination (Schyns, Bonnar, & Gosselin, 2002), although both types of discriminations make use of detailed information around the eyes (Sekuler et al., 2004). Consequently while processing global descriptors is sufficient for the latter, the former is instead based on the finer details of a face (Sergent, 1986).

Thus, face identification constitutes a good candidate to probe the limits of pre-attentive processing of natural stimuli.

2. Methods

2.1. Participants

Five subjects (including the author) were tested in Experiment 1. Four of these subjects and two new subjects were tested in Experiment 2. Four subjects from Experiment 2 were tested in Experiments 3–5. All participants were undergraduate and graduate students at the California Institute of Technology, and gave informed consented. All subjects reported that they had normal or corrected-to-normal visual acuity. For the experiments, subjects were seated approximately 120 cm in front of a Macintosh G4 computer.

2.2. Face database

The face database used in Experiment 1 consisted of pictures of male and female Hollywood celebrities obtained from the web. These were usually high resolution, color shots of the faces of actors and actresses in ''natural'' settings. Eleven (six female) of these celebrities were the target individuals, and there were 24 views of each of these targets. Several views of 43 different celebrities (150 images in all), obtained under comparable conditions, made up the distracter images.

For Experiments 2–4, the face database was obtained from the Max-Planck Institute in Tübingen, Germany (http://faces.kyb.tuebingen.mpg.de), and contained seven views of 100 male and 100 female individuals, unknown to our subjects. For these experiments, five viewpoints were used (frontal view, and left and right profiles at 30° and 45°). For all sessions, a set of individuals were chosen randomly to be the targets and distracters.

a

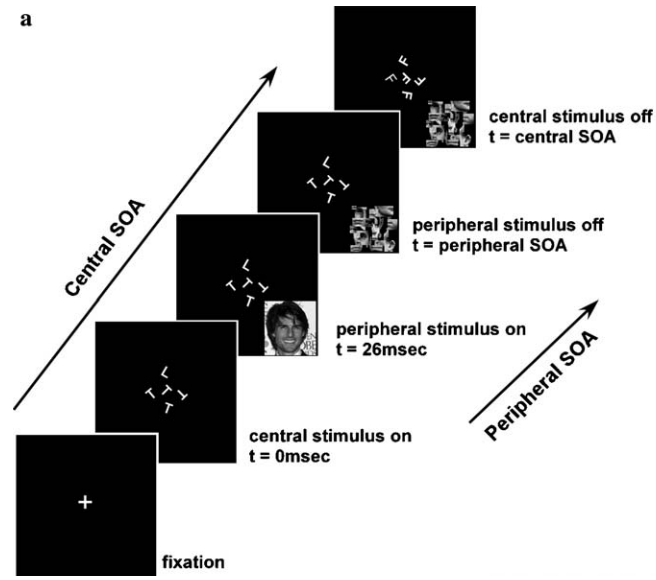

Fig. 1. Face-identification dual-task experiment. Schematic timeline for one trial in the dual-task experiment. At the end of a trial, participants are required to report the identity of the face presented and/or whether the 5 central letters were the same (either 5T's or 5L's) or different (4T's and 1L or 4L's and 1T). All trials are arranged similarly, independent of the specific instructions. Both letters and faces were masked individually. Central SOA (~200 ms) and peripheral SOA (~167 ms) indicate the presentation time for letters and faces, respectively.

2.3. Experiment 1: Face identification with famous faces

The dual-task paradigm was used to test the effects of attentional manipulation on face-identification performance (Fig. 1). The experiment consisted of two separate tasks: an attentionally demanding central letter discrimination task, and a peripheral face-identification task, performed under three conditions: the letter discrimination task or face identification tasks alone, or both tasks together in the dual-task condition. The visual display was identical in all conditions. Each block consisted of 48 trials, with 24 target trials, and 24 distracter trials. An auditory tone was provided as feedback on incorrect trials.

2.3.1. Central letter discrimination task

Each trial began with a fixation cross presented on the screen for 300 ± 100 ms before the onset of the stimulus. At 0 ms, five randomly rotated letters (Ts and Ls, either all the same or one different from the other four) were presented at the center of the display. The letters could occupy nine possible locations within 1.2° of fixation. On this task, subjects had to report if all five letters were identical or not by pressing one of two keys on the keyboard. The letters were each masked by a rotated letter F. The average presentation time for the letters was 197.0 ± 14.3 ms.

2.3.2. Peripheral face-identification task

A face subtending approximately 2.5° of visual angle was centered at a random location along the edge of an imaginary rectangle subtending $8° \times 10°$ of visual angle. The faces were backward-masked by a pattern mask composed of scrambled faces. The face-mask always appeared before the letter-masks. The average presentation time of the faces was 167.8 ± 14.4 ms.

In Experiment 1, the faces presented to subjects were of Hollywood celebrities. Before each block of this task, subjects were given the name of one of the set of target individuals (see above). All 11 target celebrities were known to the subjects. On 24 of the 48 trials in the block, different images of this target celebrity were presented to the subject, while on the other 24 trials other celebrities of the same gender as the target were

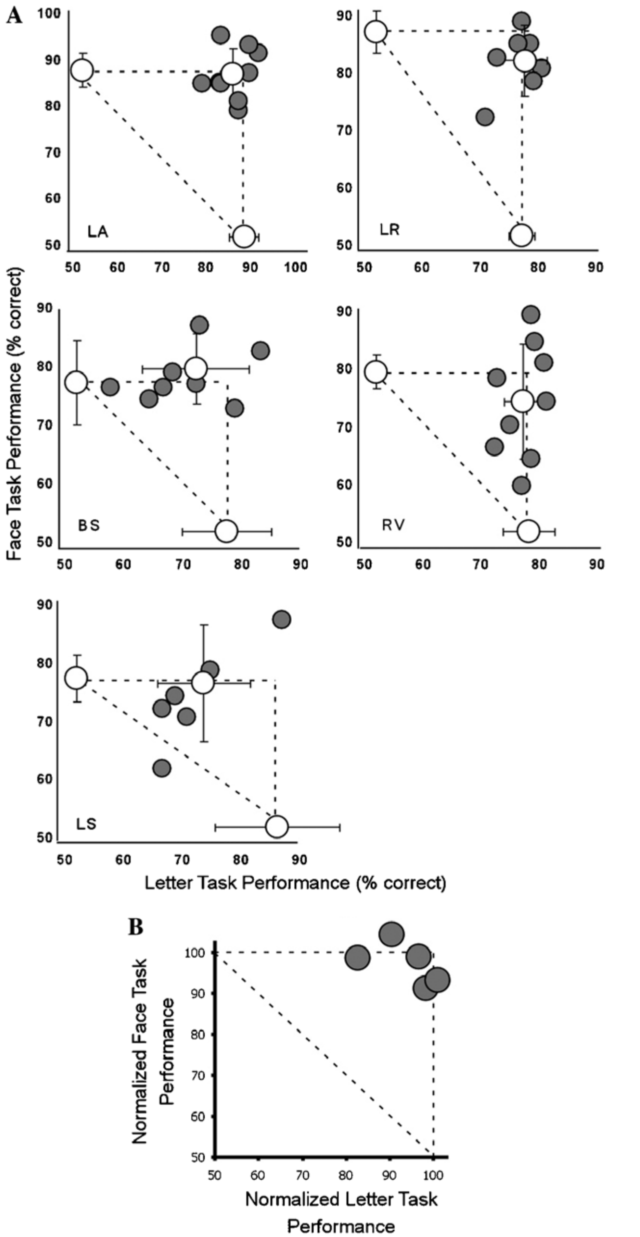

Fig. 2. Results from five participants in the dual-task paradigm with famous faces (Experiment 1). (A) The horizontal axis represents performance on the attentionally demanding central letter task. The vertical axis represents performance on the peripheral face identification task. Each filled circle is the participant's mean performance in the dual-task in one block of 48 trials, while an open circle represents mean performance over all blocks in the three experimental conditions: single central task, single peripheral task and the dual-task. By default, performance of the "to-be-ignored" task is assumed to be at chance level (50%) in the single-task condition. Error bars represent standard deviation. For all participants face-identification performance in the dual-task condition is not significantly worse (t test, $p > 0.05$) than performance in the single-task condition indicating that face-identification suffers only minimally when performed concurrently with an attentionally demanding task. (B) Normalized average performance for each participant in the dual-task paradigm. Each point represents a participants' performance in the dual-task normalized to their single-task performance. Normalized values are obtained by a linear scaling which maps the average single-task performance to 100% leaving chance at 50%. Normalized face-identification performance values lie above 90% of single-task performance, suggesting that participants can perform this task remarkably well in the near-absence of spatial attention.

presented as distracters. The order of the trials was randomized. Subjects reported if the face was the target face or not by pressing one of two keys on the keyboard.

2.3.3. Dual-task condition

In the dual-task condition, subjects had to perform both the central letter discrimination task and the peripheral face-identification task together while fixating at the center. In this experiment, subjects performed at least seven blocks of the dual-task condition, and three blocks each of the central and peripheral tasks.

Normalized dual-task performance values reported in Figs. 2–4 are calculated by a simple linear scaling of the mean value of each participant's performance. The scaling mapped the mean single-task performance to 100%, leaving chance at 50%

$$\text{normalized performance} = 0.5 + 0.5.[(P_2 - 0.5)/(P_1 - 0.5)],$$

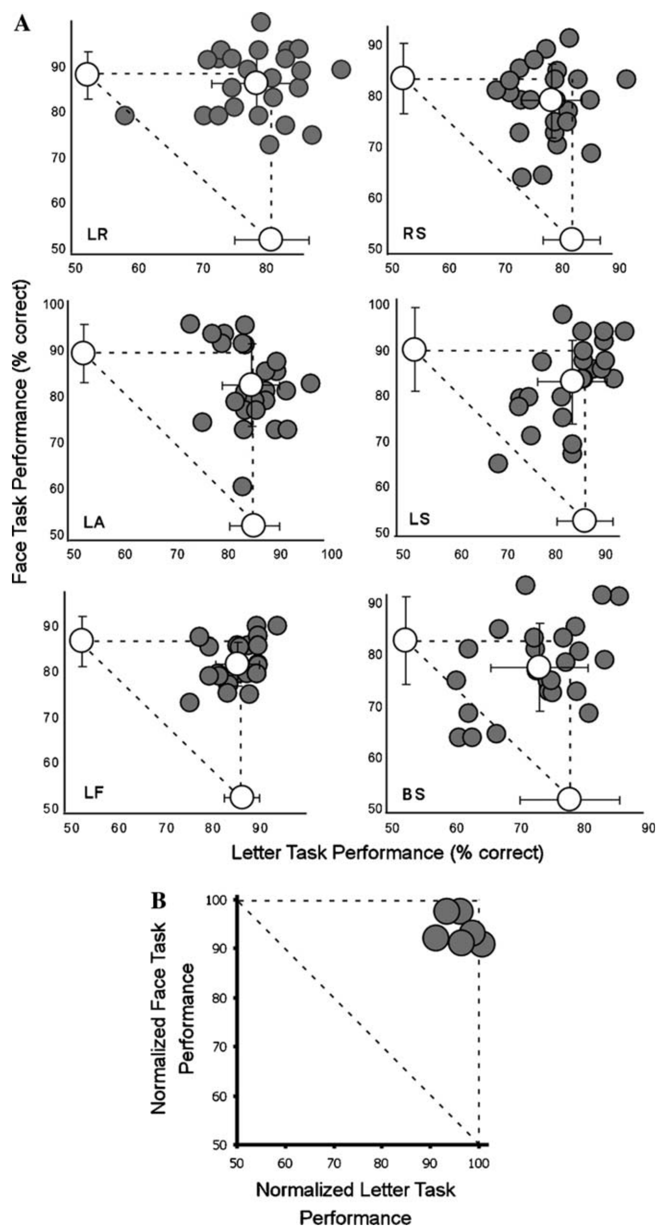

Fig. 3. Results from six participants in the dual-task paradigm with unfamiliar faces (Experiment 2). The format of this figure is the same as Fig. 2. Normalized performance values shown in (B) are >90% for all subjects. Thus, even with unfamiliar faces, subjects are able to identify faces in the near-absence of focal attention.

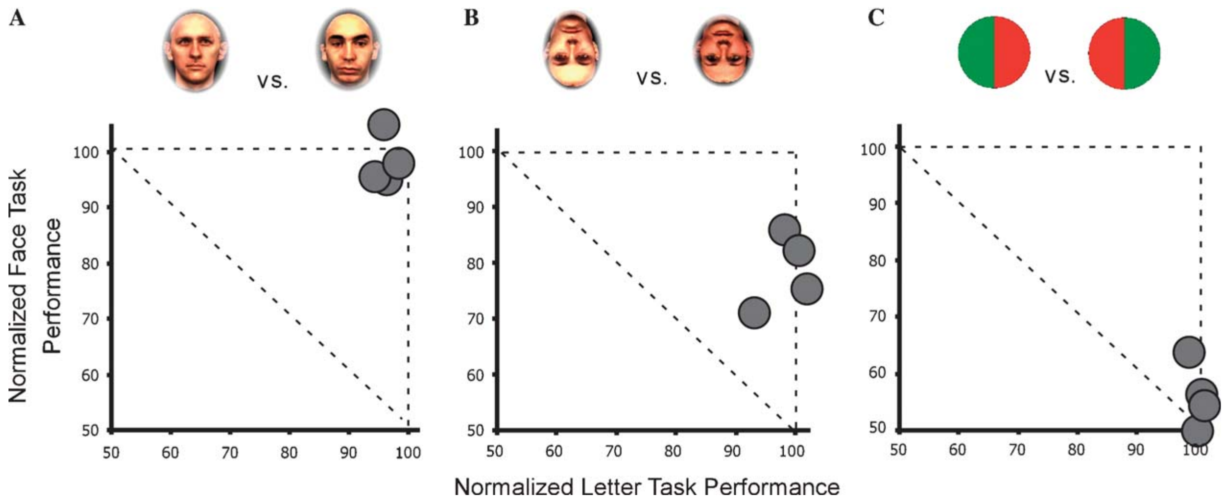

Fig. 4. Normalized performance values for four subjects in three dual-task experiments (Experiments 3–5). (A) Performance values on upright face identification with a new target face on each block of the experiment. The normalized performance is greater than 95% for each subject. (B) Performance values on face-identification with inverted faces. The average normalized performance is 78.4 ± 6.6% for these subjects. A significant ($p < 0.005$) drop in performance is observed for each subject with inverted faces compared to upright face identification. The results indicate that the performance observed with upright faces is not due to a strategy based on low-level differences. (C) Performance values on a disk-discrimination task in the periphery fall to chance levels in the dual-task condition. This indicates that the central letter task does withdraw some attentional resource away from the periphery resulting in a sharp drop in performance on certain tasks.

where P_2 and P_1 refer to performance in the dual-task and single-task conditions, respectively.

2.4. Experiment 2: Face identification with non-famous faces

In a separate dual-task experiment, subjects performed a face-identification task as before, but this time with a set of non-famous faces. Except for the following details, the organization of the experiment was the same as in Experiment 1. In this experiment, a set of 16 individuals from our non-famous set of faces (see above) were randomly chosen as targets. There were 24 distracter individuals. As mentioned before, we used five different views of each of these faces. Each block of trials started with a "familiarization phase" during which subjects were shown all five views of a particular target individual at the start of the block, and told to familiarize themselves with this individual. By self-report, on average, subjects took 30 s to look at the five views of an individual before they started the block by pressing the space bar. In the block that followed, the target individual was presented on 24 of the 48 trials, while distracters of the same gender as the target were presented on the remaining trials. The targets and distracter trials were randomized; at the end of each trial, subjects reported if the face was a target or not by pressing one of two keys on the keyboard. The average presentation time was 179.8 ± 15.8 ms for the letters and 162.3 ± 17.1 ms for the faces. These SOAs were not significantly different from those used in Experiment 1.

Six subjects performed four 1-h sessions of this experiment on four consecutive days. On each day, they performed six dual-task blocks and four blocks of the two single tasks. The target face was never repeated in any blocks of the experiment during a 1 h session. However, since the same target face could be presented on different days, we tested subjects on a set of unrepeated target faces (Experiment 3).

2.5. Experiment 3

The layout and SOAs of this experiment were identical to that of Experiment 2. The only difference was that on each block of trials, a new target individual was presented to subjects. Thus, targets were never repeated across blocks. Four subjects performed at least 11 blocks of the dual-task condition and 5 blocks of the two single-task conditions in this experiment.

2.6. Experiment 4

Four subjects were tested on face identification but with a set of inverted faces for both the familiarization and testing phases. This experiment was only performed with the non-famous faces. Subjects performed at least 12 blocks of the dual-task condition and 8 blocks of the two single-task conditions. In all other respects, the design of the experiment was identical to that of Experiment 2.

2.7. Experiment 5

Four subjects performed a disk-discrimination task in the periphery. Two color patterns—a vertically bisected disk with red and green halves and such a disk rotated by 180°—were shown. The bisected disk was masked by a disk divided into four red and green alternating quadrants. At least 12 blocks of the dual-task condition and 8 blocks of the two single-task conditions were collected for each subject. The average presentation time for the disks was 78.9 ± 19.4 ms.

2.8. Training

To avoid overtraining subjects on the face-identification task, all subjects had been trained in the dual-task paradigm prior to participating in this set of experiments. However, none of them had been trained on the face-identification task. Instead, three subjects had been trained on the animal versus non-animal discrimination task (Li et al., 2002), while the rest had been trained on the face-gender discrimination task (Reddy et al., 2004). The entire training procedure typically lasted between 5 and 10 h on consecutive days for each subject. At the beginning of training, the letters were displayed for 500 ms and the faces or animals for 160 ms before the masks appeared. During training, for each subject, the SOAs were decreased independently for both tasks when performance on a 48-trial block exceeded 90%. Training was complete when subjects' "letter" SOA had stabilized below 250 ms.

3. Results

The dual-task paradigm was used to determine the effects of manipulating focal attention on face-identification performance. In this paradigm, subjects performed a central attentionally demanding letter discrimination task, and a peripheral face-identification task, either alone or concurrently. The role of attention was measured by comparing performance on the face-identification task when it was done alone with performance in the dual-task condition. If face-identification performance requires little or no attentional resources, performance in the dual-task condition should suffer minimally compared to single-task performance. On the other hand, if the peripheral task requires attention, performance should be severely impaired in the dual-task condition (Braun & Julesz, 1998; Braun & Sagi, 1990; Sperling & Melchner, 1978).

The attentionally demanding task consisted of reporting whether five letters (T's and L's) presented at the center of the screen were the same or not. This task is effective in engaging the focus of attention away from the periphery (Lee, Koch, & Braun, 1999; Li et al., 2002); we also demonstrate this in Experiments 4 and 5. Following the onset of the letters, a face appeared at a random peripheral location, and subjects reported if the face was of the individual who had been designated as the target at the beginning of the block (Fig. 1). In each block, the distracters were always of the same gender as the target. In the dual-task condition, subjects performed both tasks, while prioritizing the central letter discrimination task. Although it has been shown recently that peripherally presented faces are processed less efficiently than foveal faces (Makela, Nasanen, Rovamo, & Melmoth, 2001), our results shown below demonstrate that this amount of processing is sufficient to result in good behavioral performance.

In Experiment 1, five subjects were tested on face identification with faces of well-known Hollywood actors and actresses. The average performance (Fig. 2A) on the letter discrimination task in the single- and dual-task conditions were $80.3 \pm 5.4\%$ and $78.2 \pm 5.5\%$, respectively. These values are not significantly different from each other for each subject (one-tailed t test, $p > .05$), indicating that in the dual-task condition the focus of attention was engaged by the letter discrimination task (since otherwise performance would have deteriorated). Average performance on the face-identification task was $83.2 \pm 5.3\%$ when it was performed alone, and $81.1 \pm 4.9\%$ in the dual-task condition. For each of the five subjects, performance on this task in the dual- and single-task conditions was not significantly different (one-tailed t test, $p > .05$). In Fig. 2B, each participant's performance in the dual-task condition is plotted relative to the performance they achieved in the two single-task conditions. As the data show, for each of the five subjects, dual-task performance was above 90% of their performance under single-task conditions. Eye movements would not have played a major role in achieving such performance since the peripheral faces were only presented briefly (<200 ms) on each trial at randomized locations (see Section 2). Additionally, control experiments with an eye tracker on a face-gender discrimination task allowed us to verify that eye movements do not contribute to the performance achieved in the dual-task condition (Reddy, 2005; Reddy, Moradi, & Koch, 2006). These results thus indicate that subjects are able to efficiently identify famous individuals even when spatial attention is not fully available for the task.

Given these results with familiar faces, it is interesting to ask whether this performance extends to lesser known faces as well. It is possible that subjects' ability to identify individuals in the near-absence of focal attention is limited to a small group of famous or familiar people, and that identifying relative strangers would require closer attention. Accordingly, in Experiment 2 we repeated the face-identification experiment, but this time with a set of non-famous faces. This face set contained five views of several unknown individuals, and on different blocks, a particular individual was chosen as the target. Before each block began, all five views of the target were presented to subjects, who were instructed to acquaint themselves with that individual for subsequent identification. On average, this familiarization phase lasted 30 s.

The average performance of six subjects (Fig. 3A) on the letter discrimination task was comparable in the single- and dual-task conditions, signifying that subjects were paying attention to this task in the dual-task condition ($82.7 \pm 3.4\%$ and $80.3 \pm 4.7\%$, $p > .05$, one-tailed t test). On the peripheral task, average performance was $86.4 \pm 3.0\%$ and $82.1 \pm 3.3\%$ under single- and dual-task conditions, respectively. The difference in performance on the face-identification task between the single and dual-task conditions was not significant for four of the six subjects (one-tailed t test, $p > .05$). Fig. 3B shows the performance of each subject in the dual-task condition normalized to their performance in the single-task conditions; on average, face-identification performance in the dual-task condition was above 90% for all subjects. Thus, these results demonstrate that although there is a small decrement in performance in the dual-task condition, it is possible to identify relatively unfamiliar faces in the near-absence of focal attention. Additionally, the data confirm that the results we observed with famous faces were really due to a face-identification process, and were not a result of artifacts introduced by the image set. The images used in Experiment 1 were obtained from the web, and as a result, were not very well controlled for low-level or other cues. For instance, celebrities are well known for their distinctive hairstyles and facial expressions, and subjects could have based their decisions on these cues. Thus, even though the image set allowed us to use a broad range of photographs of people in natural everyday environments, the face identification results could have been disputed. The results of Experiment 2, however, confirm that subjects are able to identify individuals in the near-absence of spatial attention, even when the identification was based only on internal facial features.

Over the course of Experiment 2, although a particular individual was never the target on more than one block in each session, he or she could have been re-assigned to be the target in another session. On average, for a particular target this would have occurred no more than twice, but it could still be argued that the results observed were biased by the familiarity gained with particular targets. For this reason, in Experiment 3 we re-tested four of our subjects on face identification, but this time with a novel target on each block. Their average performance on the face-identification task was $80.4 \pm 5.1\%$ and $79.7 \pm 3.1\%$ in the single and dual-task conditions, respectively. This difference was not significant for any subject (one-tailed t test, $p > .05$). The normalized data for these subjects (Fig. 4A) demonstrate that even under these conditions, subjects achieve a high-level of performance on this task. Over the group of subjects, the normalized face-identification performance was greater than 95%.

Several studies that investigate face processing have shown that inverted faces are processed less efficiently than upright ones (Sekuler et al., 2004; Yin, 1969). Accordingly, we wanted to verify that under the dual-task paradigm, while performing our peripheral face-identification task, subjects possessed this advantage for upright faces characteristic of real-life face identity processing. We tested subjects on face identification with inverted faces in Experiment 4. As in the previous two experiments, subjects were presented with all five views of the target at the beginning of each block, but this time all the faces were inverted. That is, both during the familiarization and testing phases, subjects were presented with inverted faces. Four subjects from Experiments 2 and 3 were tested with inverted faces in Experiment 4 (Fig. 4B). Their average performance on the face-identification task was $79.8 \pm 4.2\%$ and $67.1 \pm 3.0\%$ in the single- and dual-task conditions, respectively. This difference was significant for all four subjects (one-tailed t test, $p < .005$). Additionally, in comparing performance on upright and inverted faces, we also observed a significant drop in face-identification performance ($p < .005$) for each subject. The normalized face task performance over the group of subjects was $76.4 \pm 4.7\%$. Thus, in agreement with previous studies we also observed an inversion effect with our face-identification task.

These results demonstrate that subjects are able to perform subtle discriminations about the identity of individuals in the near-absence of spatial attention. However, in all these experiments, an obvious concern arises about the efficacy of the central letter discrimination task in engaging the focus of attention away from the periphery. This concern can be addressed by verifying that, for those tasks that are known to require attention, performance suffers in the dual-task condition. We ensured this was the case in our dual-task condition by testing four subjects on a bisected disk-discrimination task which has been shown to require attention (Braun & Sagi, 1990; Braun & Julesz, 1998; Li et al., 2002; Reddy et al., 2004). Subjects' performance (Fig. 4C) was severely impaired (one-tailed t test, $p < .0005$), in contrast to their performance on face-identification (Fig. 4A). Over the group of subjects, the average performance on this task was $53.5 \pm 2.6\%$ in the dual-task condition, compared to $80.2 \pm 5.7\%$ observed in the single-task condition. These results confirm that under our dual-task condition, the central letter discrimination task does remove some attentional resource from the periphery, resulting in performance decrements in tasks known to require attention.

4. Discussion

The results of these experiments extend previous findings on the processing of natural stimuli in the near-absence of focal attention (Li et al., 2002; Reddy et al., 2004; Rousselet et al., 2002), by demonstrating that face identification is possible when spatial attention is not fully available. Given that finer discriminations are required for face identification compared to the natural tasks used in previous studies, it is surprising that processing does not break down completely when the attentional focus is shifted away from the faces. As we mentioned earlier, the goal of these experiments was to ascertain the extent to which we are able to process natural stimuli in the near-absence of spatial attention. We had speculated that the face-identification task would reveal the limits of pre-attentive natural stimuli processing. Surprisingly, our results indicate that the visual system is not overwhelmed by discriminations of this caliber. While earlier work had indicated that super-ordinate levels of categorization (Mervis & Rosch, 1981) for natural stimuli (e.g., animal vs. non-animal) are unimpaired in the near-absence of spatial attention (Li et al., 2002), we now show that this finding extends to categorization at the individual level. It remains thus to be seen what type of discrimination task involving faces (if any) may be impaired in the near-absence of attention. Alternatively, a more efficient strategy to characterize what distinguishes the tasks that do or do not require focal attention may be to apply techniques such as "Bubbles" or reverse correlation (Gosselin & Schyns, 2004).

In our data, we observed a modest drop in performance in identifying faces in the dual-task condition compared to the single-task condition (which was significant for only two subjects with the relatively unfamiliar face set in Experiment 2). However, it should be remembered that some decrement in performance is expected when subjects perform two tasks simultaneously. These decrements do not necessarily reflect competition for an attentional resource, but could be ascribed to other factors, such as having to remember two sets of instructions, or produce two motor responses instead of one (Allport, 1980; Duncan, 1980; Pashler, 1984, 1994). In addition to comparing performance in the single- and dual-task conditions of each task, it can also be informative to compare performance levels across tasks. From our data it appears that in comparison to face-identification on upright faces (where normalized performance was greater than 90%), performance on inverted faces was significantly lower (76.4%). Further, in contrast to processing with natural stimuli, the near-absence of focal attention was a severe limitation to performance on discrimination of artificial geometric shapes (53.5%), even though they appear to be computationally simpler.

Does this ability to make fine discriminations on natural stimuli also extend to other classes of natural objects, or is it only specific to faces? For instance, could one discriminate between two similar breeds of dogs in the near-absence of attention? It could be argued that the results we observe here would not generalize to other natural categories since various studies have claimed that dedicated areas in the brain exist that preferentially process face stimuli, and that faces are thus of special importance to the visual system (Grill-Spector, Knouf, & Kanwisher, 2004; Kanwisher, McDermott, & Chun, 1997; Kanwisher, 2000; Puce, Allison, Asgari, Gore, & McCarthy, 1996; Puce, Allison, Gore, & McCarthy, 1995; Yovel & Kanwisher, 2004). However, it has also been suggested that faces are so well represented in the brain primarily because human beings are experts in face processing and that similar representations should also be observed for other well known categories. In support of this claim, Gauthier and colleagues have shown that the areas underlying face processing also participate in the processing of other objects of expertise, for instance cars for car experts (Gauthier, Tarr, Anderson, Skudlarski, & Gore, 1999; Gauthier & Logothetis, 2000; Gauthier, Skudlarski, Gore, & Anderson, 2000; Tarr & Gauthier, 2000; Gauthier, Curran, Curby, & Collins, 2003). Thus, it is possible that these regions would similarly facilitate the processing of highly familiar natural categories, and that complex discriminations in the near-absence of attention would be possible for these objects as well.

In fact, the disparity between performance on natural object and artificial geometric shape discrimination in the dual-task condition could be directly linked to how familiar the visual system is with these different categories of stimuli. Indeed, in contrast to natural scenes and faces, artificial geometric stimuli such as bisected red-green disks are rarely encountered in everyday life. The different degrees of familiarity for different object categories might be mirrored by a continuum of "attentional requirements" in which faces would lie at one extreme. This could explain why very subtle discriminations within the category of face stimuli (such as recognition of individuals, even when relatively unfamiliar) can be done pre-attentively, whereas, to answer the question posed above, if subjects do not routinely engage in discriminating breeds of dogs, then the corresponding task might require attention. This speculation is not entirely unreasonable, since if the brain is adapted for everyday stimuli, the processing of oft-encountered natural categories of stimuli should be favored over unusual geometric shapes (Kayser et al., 2004; VanRullen, Reddy, & Koch, 2004).

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References

Allport, D. A. (1980). Attention and performance. In G. Claxton (Ed.), *Cognitive psychology: New directions* (pp. 43–67). London: Routledge & Kegan Paul.

Baudouin, J. Y., & Tiberghien, G. (2002). Gender is a dimension of face recognition. *Journal of Experiment Psychology—Learning Memory Cognition, 28*(2), 362–365.

Braun, J. (2003). Natural scenes upset the visual applecart. *Trends in Cognitive Sciences, 7*(1), 7–9.

Braun, J., & Julesz, B. (1998). Withdrawing attention at little or no cost: Detection and discrimination tasks. *Perception Psychophysics, 60*(1), 1–23.

Braun, J., & Sagi, D. (1990). Vision outside the focus of attention. *Perception Psychophysics, 48*(1), 45–58.

Brown, V., Huey, D., & Findlay, J. M. (1997). Face detection in peripheral vision: Do faces pop out? *Perception, 26*(12), 1555–1570.

Brown, E., & Perrett, D. I. (1993). What gives a face its gender? *Perception, 22*(7), 829–840.

Bruce, V., Burton, A. M., Hanna, E., Healey, P., Mason, O., Coombes, A., et al. (1993). Sex discrimination: How do we tell the difference between male and female faces? *Perception, 22*(2), 131–152.

Bruce, V., & Young, A. (1986). Understanding face recognition. *British Journal of Psychology, 77*(Pt 3), 305–327.

Bruyer, R., Galvez, C., & Prairial, C. (1993). Effect of disorientation on visual analysis, familiarity decision and semantic decision on faces. *British Journal of Psychology, 84*(Pt 4), 433–441.

Duncan, J. (1980). The locus of interference in the perception of simultaneous stimuli. *Psychological Review, 87*(3), 272–300.

Ellis, H. D. (1986). Processes underlying face recognition. In R. Bruyer (Ed.), *The neuropsychology of face perception and facial expression* (pp. 1–27). Hillsdale, NJ: Lawrence Erlbaum.

Gauthier, I., Curran, T., Curby, K. M., & Collins, D. (2003). Perceptual interference supports a non-modular account of face processing. *Nature Neuroscience, 6*(4), 428–432.

Gauthier, I., & Logothetis, N. K. (2000). Is face recognition not so unique after all? *Cognitive Neuropsychology, 17*(1–3), 125–142.

Gauthier, I., Skudlarski, P., Gore, J. C., & Anderson, A. W. (2000). Expertise for cars and birds recruits brain areas involved in face recognition. *Nature Neuroscience, 3*(2), 191–197.

Gauthier, I., Tarr, M. J., Anderson, A. W., Skudlarski, P., & Gore, J. C. (1999). Activation of the middle fusiform 'face area' increases with expertise in recognizing novel objects. *Nature Neuroscience, 2*(6), 568–573.

Gosselin, F., & Schyns, P. G. (Eds.). (2004). *Rendering the use of visual information from spiking neurons to recognition.* (Vol. 28): Cognitive Science.

Grill-Spector, K., Knouf, N., & Kanwisher, N. (2004). The fusiform face area subserves face perception, not generic within-category identification. *Nature Neuroscience, 7*(5), 555–562.

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences, 4*(6), 223–233.

Kanwisher, N. (2000). Domain specificity in face perception. *Nature Neuroscience, 3*(8), 759–763.

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*(11), 4302–4311.

Kayser, C., Kording, K. P., & Konig, P. (2004). Processing of complex stimuli and natural scenes in the visual cortex. *Current Opinion in Neurobiology, 14*(4), 468–473.

Lee, D. K., Koch, C., & Braun, J. (1999). Attentional capacity is undifferentiated: Concurrent discrimination of form, color, and motion. *Perception Psychophysics, 61*(7), 1241–1255.

Li, F. F., VanRullen, R., Koch, C., & Perona, P. (2002). Rapid natural scene categorization in the near absence of attention. *Proceedings of the National Academy Sciences of the United States of America, 99*(14), 9596–9601.

Makela, P., Nasanen, R., Rovamo, J., & Melmoth, D. (2001). Identification of facial images in peripheral vision. *Vision Research, 41*(5), 599–610.

Mervis, C. B., & Rosch, E. (1981). Categorization of natural objects. *Annual Review Of Psychology, 32*, 89–115.

Pashler, H. (1984). Processing stages in overlapping tasks—Evidence for a central bottleneck. *Journal of Experimental Psychology—Human Perception and Performance, 10*(3), 358–377.

Pashler, H. (1994). Dual-task interference in simple tasks—data and theory. *Psychological Bulletin, 116*(2), 220–244.

Puce, A., Allison, T., Asgari, M., Gore, J. C., & McCarthy, G. (1996). Differential sensitivity of human visual cortex to faces, letterstrings, and textures: A functional magnetic resonance imaging study. *Journal of Neuroscience, 16*(16), 5205–5215.

Puce, A., Allison, T., Gore, J. C., & McCarthy, G. (1995). Face-sensitive regions in human extrastriate cortex studied by functional mri. *Journal of Neurophysiology, 74*(3), 1192–1199.

Reddy, L. (2005). *Attention and the processing of natural stimuli: Psychophysics, fmri and single unit recordings in the human brain*. Pasadena, CA: California Institute of Technology.

Reddy, L., Moradi, F., & Koch, C. (2006). Top-down biases win against focal attention in the fusiform face area. *Journal of Cognitive Neuroscience*, under review.

Reddy, L., Wilken, P., & Koch, C. (2004). Face-gender discrimination is possible in the near-absence of attention. *Journal of Vision, 4*(2), 106–117.

Rossion, B. (2002). Is sex categorization from faces really parallel to face recognition? *Visual Cognition, 9*(8), 1003–1020.

Rousselet, G. A., Fabre-Thorpe, M., & Thorpe, S. J. (2002). Parallel processing in high-level categorization of natural images. *Nature Neuroscience, 5*(7), 629–630.

Schyns, P. G., Bonnar, L., & Gosselin, F. (2002). Show me the features! Understanding recognition from the use of visual information. *Psychological Science, 13*(5), 402–409.

Sekuler, A. B., Gaspar, C. M., Gold, J. M., & Bennett, P. J. (2004). Inversion leads to quantitative, not qualitative, changes in face processing. *Current Biology, 14*(5), 391–396.

Sergent, J. (1986). Microgenesis of face perception. In H. D. Ellis, M. A. Jeeves, F. Newcombe, & A. Young (Eds.), *Aspects of face processing*. Dordrecht, The Netherlands: Nijhoff.

Sperling, G., & Melchner, M. J. (1978). The attention operating characteristic: Examples from visual search. *Science, 202*(4365), 315–318.

Tarr, M. J., & Gauthier, I. (2000). Ffa: A flexible fusiform area for subordinate-level visual processing automatized by expertise. *Nature Neuroscience, 3*(8), 764–769.

Valentine, T. (1988). Upside-down faces: A review of the effect of inversion upon face recognition. *British Journal of Psychology, 79* (Pt 4), 471–491.

Valentine, T., & Bruce, V. (1988). Mental rotation of faces. *Memory & Cognition, 16*(6), 556–566.

VanRullen, R., Reddy, L., & Koch, C. (2004). Visual search and dual-tasks reveal two distinct attentional resources. *Journal of Cognitive Neuroscience, 16*(1), 4–14.

Yamaguchi, M. K., Hirukawa, T., & Kanazawa, S. (1995). Judgment of gender through facial parts. *Perception, 24*(5), 563–575.

Yin, R. K. (1969). Looking at upside down faces. *Journal of Experimental Psychology, 81*(1), 141–145.

Yovel, G., & Kanwisher, N. (2004). Face perception: Domain specific, not process specific. *Neuron, 44*(5), 889–898.