Research Report

THE ROLE OF PERCEPTUAL LOAD IN PROCESSING DISTRACTOR FACES

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Abstract—*It has been established that successful ignoring of irrelevant distractors depends on the extent to which the current task loads attention. However, the previous load studies have typically employed neutral distractor stimuli (e.g., letters). In the experiments reported here, we examined whether the perception of irrelevant distractor faces would show the same effects. We manipulated attentional load in a relevant task of name search by varying the search set size and found that whereas congruency effects from meaningful nonface distractors were eliminated by higher search load, interference from distractor faces was entirely unaffected by search load. These results support the idea that face processing may be mandatory and generalize the load theory to the processing of meaningful and more complex nonface distractors.*

A central issue in the study of selective attention concerns the extent to which attention can prevent perception of irrelevant distractors. Although it would seem that whether irrelevant distractors are perceived or not should depend on the type of distractor objects presented, so that some distractors are harder to ignore than others, studies of selective attention have typically presented fairly neutral distractor stimuli such as letters or shapes. In the experiments reported here, we examined whether the perception of distractor stimuli of great biological and social significance, such as human faces, depends on selective attention in the same manner as the perception of other more neutral nonface distractors.

The issue of whether perception of irrelevant distractors can ever be prevented, even for neutral distractor stimuli (e.g., letters), has been debated for many decades. Although there have been many demonstrations of apparently successful distractor rejection, reports of failures to ignore irrelevant distractors have also accumulated (for review, see Lavie & Tsal, 1994). Recently, the conflicting results have been accommodated by a load theory of attention (Lavie, 1995, 2000), in which selective attention can result either in successful exclusion of distractors from perception or in failure to exclude distractors from perception, depending on the level of perceptual load in the relevant task. In this model, perception of distractors can be prevented in situations of high perceptual load (e.g., when many relevant stimuli are presented) that exhaust all available capacity in the perception of relevant stimuli. However, in situations of low perceptual load (e.g., when just one relevant stimulus is presented), spare capacity from relevant processing "spills over" to the irrelevant items, resulting in perception of distractors.

Evidence for this load theory has been obtained in a number of studies using different load manipulations varying either the number of stimuli to be processed (e.g., relevant search set size) or the pro-

cessing requirements for those stimuli (e.g., comparing tasks of easy detection vs. hard discrimination). These studies have examined various behavioral measures of distractor perception (e.g., response competition, negative priming), and in some cases functional imaging has been employed to assess neural correlates of distractor perception in visual cortex (Lavie, 1995; Lavie & Cox, 1997; Lavie & Fox, 2000; Rees, Frith, & Lavie, 1997).

However, as in much previous attention research, the experimental tasks used to test the load theory have typically employed fairly neutral distractor stimuli (e.g., letters). In the present study, we asked whether the perception of irrelevant distractor faces would also depend on the level of load in the relevant task. Because of their special biological and human significance, faces might always be prioritized regardless of their task relevance and the level of attentional load in a current task.

Indeed, ample neuroscientific evidence (e.g., De Renzi, 2000; Kanwisher, McDermott, & Chun, 1997; Perrett, Hietanen, Oram, & Benson, 1992) suggests that face processing is dealt with by dedicated neural systems (but see Gauthier, Skudlarski, Gore, & Anderson, 2000, for a contrary view). These data support claims of a specialized face-processing module (Farah, 1996; Kanwisher et al., 1997). Modules stipulate mandatory and automatic processing in the presence of the correct stimulus (Fodor, 1983), but no study has tested the implication of such claims for the question of whether perception of distractor faces depends on the level of attentional load. To examine this, we devised a new flanker task that allowed us to compare the effects of perceptual load on processing of face versus nonface distractors.

EXPERIMENT 1

In Experiment 1, subjects were required to search for a name among one, two, four, or six letter strings in the center of a display and to indicate by a speeded key press whether it was a politician's or a pop star's name, while ignoring an irrelevant distractor face in the periphery (Fig. 1). We manipulated the distractor's congruency with the target response. The distractor could be either the face of the person named (congruent condition) or the face of a person from the opposite category (incongruent condition; see Fig. 1). If target reaction times (RTs) varied as a function of distractor congruency, this would indicate that the distractor face was perceived and recognized. In order to examine whether perception of distractor faces depends on perceptual load in the relevant task, we assessed the effects of distractor congruency as a function of the set size of the name search. Each subject ran through a practice block of 48 trials, followed by four experimental blocks of 192 trials. Within each block, all conditions were randomly intermixed.

Figure 2 presents the mean RTs as a function of the experimental variables. A two-way within-subjects analysis of variance (ANOVA; Set Size × Congruency) revealed a robust main effect for set size, $F(3,$

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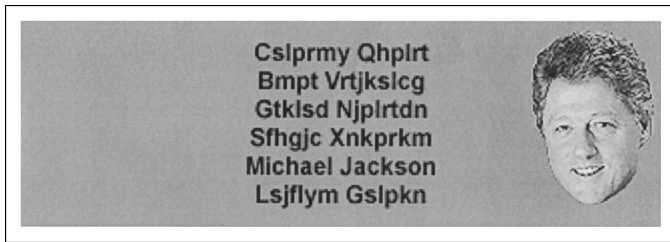
Fig. 1. Example stimulus display from Experiment 1 (incongruent condition with a set size of six). In this experiment, the name-plus-face display was presented until the subject responded. Each display was preceded by a 500-ms fixation point. For all set sizes, the name was equally likely to appear in any of the six positions, and the face was equally likely on the left or right. The face and name on a given trial were selected from a set of six politicians and six pop stars. Viewing distance was 57 cm. The names were typed with Arial font size 12. Each face was placed in an imaginary rectangle that subtended 4.1° by 3.3° and was positioned with its center 5° from fixation.

63) $= 467.88$, $p < .001$, confirming that perceptual load was effectively manipulated. RT was significantly increased by each increase in the search set size ($p < .01$ in all comparisons), and the average search slope was 79 ms per item. This finding clearly indicates the increased demand on attention imposed by increasing set size. There was also a main effect of congruency, $F(1, 21) = 70.15$, $p < .001$, that did not interact with set size ($F < 1$). The congruency effect was significant at each set size ($p < .05$ for all comparisons). Thus, subjects clearly failed to ignore the peripheral distractor faces, despite explicit instruction to do so.

Error rates were significantly increased by set size, $F(3, 63) = 23.9$, $p < .001$, with 5%, 7%, 7%, and 10% errors for set sizes of one, two, four, and six, respectively. There was a trend for a congruency effect (error rates were 8% in the incongruent condition and 7% in the congruent condition), $F(1, 21) = 3.74$, $p = .067$, that did not interact with set size ($F < 1$).

Thus, as in previous perceptual load studies, increasing the relevant search set size clearly increased the demand on attention (for review, see Lavie, 2000). However, unlike in previous studies, load had no effect on the extent to which distractor faces were processed: Distractor faces interfered with target performance at all levels of load.[1]

EXPERIMENT 2

In Experiment 2, we examined whether perceptual load can determine interference from familiar nonface distractors. This question was

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1. In previous load studies, the largest effects of set size on RTs were typically found with a relevant set size of six items. In this study, the largest effect of set size on RTs was already found at set size four (Fig. 2). A close inspection of the data revealed that classification RTs for some of the names (e.g., Ronald Reagan, Michael Jackson) were more strongly affected by increasing the set size from four to six ($M = 153$ ms for this increase in set size) than by increasing the set size from two to four. Distractor interference effects showed the same pattern for these names as for the other names: Interference was found at all set sizes and clearly was not reduced by set size six (for this set size, the average distractor interference for these names was 58 ms).

important in order to establish whether face distractors are special, or whether any meaningful distractor object will be processed regardless of perceptual load in the relevant task, with load effects being confined to more neutral stimuli (e.g., letters). Thus, in Experiment 2, we asked subjects to categorize names of fruits and musical instruments while ignoring their photographs, indicating responses by a speeded key press. Distractor congruency and load were manipulated as before, and all other aspects of the procedure were the same as in Experiment 1 (see Fig. 3).

As can be seen in Figure 4, perceptual load produced again a significant main effect, $F(3, 69) = 391.42$, $p < .001$; the linear search slope was 92 ms per item, confirming the increased demand on attention as relevant search set size increased. As in Experiment 1, there was also a main effect of congruency, $F(1, 23) = 24.6$, $p < .001$; however, unlike in Experiment 1, this effect was qualified by an interaction with load, $F(3, 69) = 2.97$, $p < .05$. Effects of distractor congruency were significant at set sizes one, two, and four ($p < .01$ in all comparisons), but not at set size six ($t < 1$).

This pattern of results is very similar to that found in previous studies of perceptual load using letter stimuli. Lavie and Cox (1997), for example, found that flanker interference from distractor letters was present when relevant search set size involved up to four items, and was eliminated by a set size of six.

Error rates were significantly increased (from 6% to 7%, 7%, and 9%) by increased set size, $F(3, 69) = 10.53$, $p = .001$, and by incongruency (from 6% in the congruent condition to 8% in the incongruent condition), $F(1, 23) = 16.1$, $p < .001$, but the interaction was not significant ($F < 1$).

EXPERIMENT 3

A relevant search set size of six is sufficient to eliminate interference from distractor letters or meaningful nonface objects, but not from distractor faces. In Experiment 3, we asked whether distractor interference from faces can be eliminated by a higher relevant set size. We used the same task as in Experiment 1, but compared congruency effects with set sizes of four, six, and eight in the name search task.

The results are shown in Figure 5. ANOVA of RTs again yielded main effects for congruency, $F(1, 11) = 46.1$, $p < .001$, and load, $F(2, 22) = 45.8$, $p < .001$, but no interaction ($F < 1$): Distractor faces produced significant interference at each set size ($p < .01$ for all comparisons). Thus, distractor faces are perceived even under greater levels of load than are needed to eliminate processing of nonface distractors. Previous research had shown that attentional capacity limits are approached with about five objects (Kahneman, Treisman, & Gibbs, 1992; Pylyshyn, Burkell, Fisher, & Sears, 1994; Yantis & Jones, 1991). The present study thus suggests that unlike other processing of distractor objects, processing of distractor faces may be automatic in the sense of being independent of attentional capacity.

In accordance with the idea that attentional capacity was already exhausted by set size six, the increase to set size eight seemed to have produced mainly data limits, rather than resource limits, as the effects on accuracy were more pronounced than the effects on RTs (error rates increased from 10% at set sizes four and six to 15% at set size eight; RTs increased by 79 ms from set size four to set size six, but only by 28 ms from set size six to set size eight). Like the RTs, error rates showed a main effect of congruency, $F(1, 11) = 5.86$, $p < .05$, that did not interact with set size ($F = 1.08$).
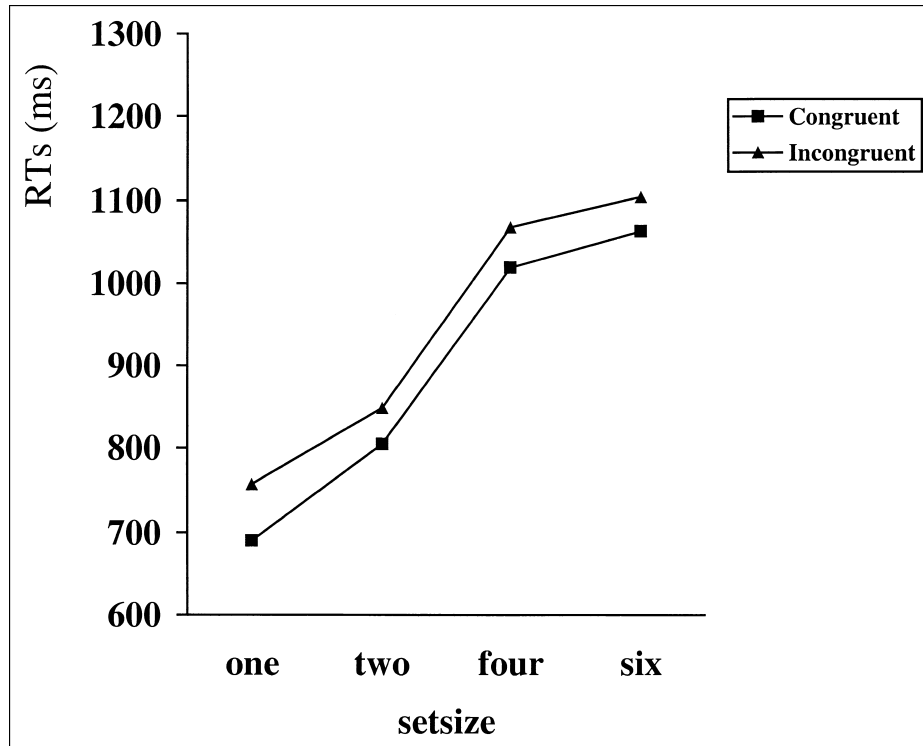
Fig. 2. Mean reaction times (RTs) in the name-classification task of Experiment 1 as a function of set size and congruency.

EXPERIMENT 4

Is it possible that the different patterns of results for face versus nonface distractors is due to the fact that the face-name task involved discrimination of subordinate categories (politicians vs. pop stars) whereas the nonface-name task involved discrimination of basic-level categories (fruits vs. musical instruments)? In Experiment 4, we examined interference from nonface distractors in a name task that involved discrimination of subordinate categories. Subjects were asked to classify wind versus string instruments while ignoring the instruments' photos. Congruency effects were calculated as a function of name search set size (one, two, or four).[2]

The results showed main effects of congruency, $F(1, 11) = 5.9$, $p < .05$, and load, $F(2, 22) = 205.1$, $p < .001$, as well as a significant interaction, $F(2, 22) = 8.1$, $p < .01$. Congruency effects were found at set sizes one and two ($p < .05$ in both comparisons), but were eliminated by set size four (Fig. 6). Clearly, the pattern found for face distractors cannot be attributed to the requirement to make subordinate-category discriminations in the face-name task.

GENERAL DISCUSSION

The present results show that the level of perceptual load in the processing of relevant stimuli critically determines interference from familiar nonface distractors, but not from face distractors. Whereas interference from meaningful nonface distractors was eliminated by a set size of six, or even by a set size of four when the name task required subordinate categorization and was thus more difficult, interference from distractor faces was not modulated by any increase in the search set size.

The finding that increasing perceptual load in the relevant task eliminated the interference from meaningful nonface distractors is exactly as expected from previous perceptual-load studies. Using simple letter stimuli, these studies have all found similar effects of perceptual load on distractor interference and negative priming (Lavie, 1995; Lavie & Cox, 1997; Lavie & Fox, 2000). The present findings thus allow us to generalize the load theory to the processing of meaningful nonface distractor stimuli.

The discovery that processing irrelevant distractor faces is unaffected by the level of load in the relevant task provides, to the best of
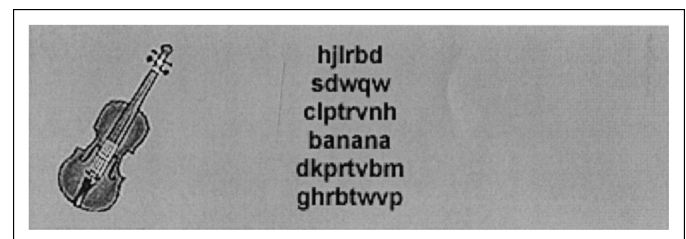

Fig. 3. Example stimulus display from Experiment 2 (incongruent condition with a set size of six). The nonface objects and names were drawn from a set of six fruits and six musical instruments.

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2. Pilot testing showed that a set size of six produced too many errors in this experiment, and that distractor effects were already reduced by a set size of four.
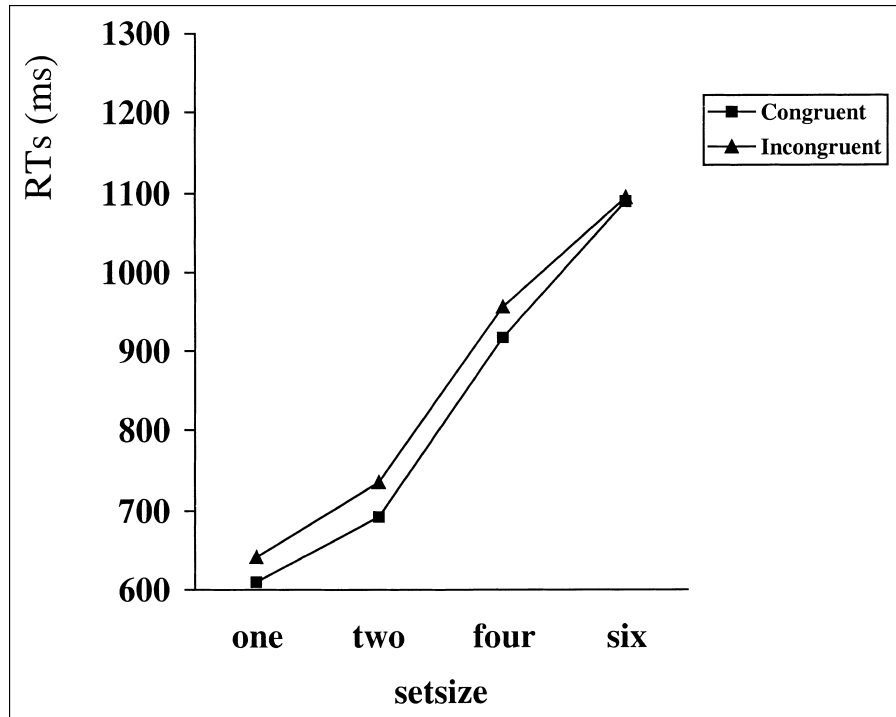
Fig. 4. Mean reaction times (RTs) in the name-classification task of Experiment 2 as a function of set size and congruency.
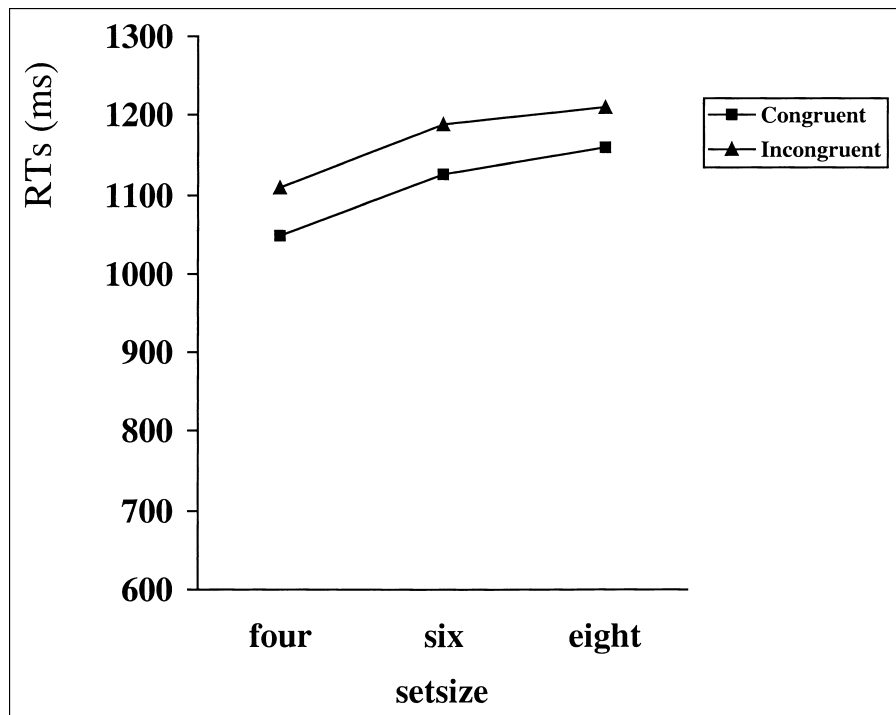

Fig. 5. Mean reaction times (RTs) in the name-classification task of Experiment 3 as a function of set size and congruency.
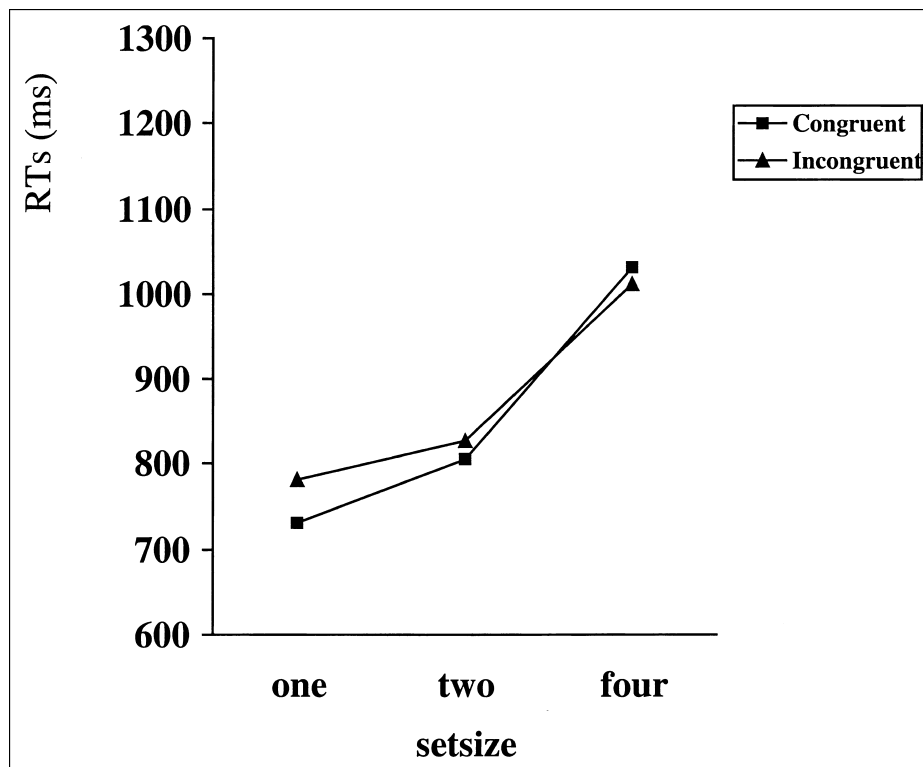
Perceptual Load and Distractor Faces

Fig. 6. Mean reaction times (RTs) in the name-classification task of Experiment 4 as a function of set size and congruency.

our knowledge, the first exception to the typical effects of perceptual load on distractor processing. Consideration of the special biological and social significance of faces suggests why this might be the case. It may be adaptive not to ignore irrelevant faces, unlike other task-irrelevant stimuli, regardless of how demanding the current task is. Even if faces are not task relevant, they have the potential to carry important new information, such as vital social cues, that it may be detrimental to ignore.

The present results provide perhaps the strongest direct behavioral evidence for the suggestion that face processing may be automatic and mandatory (Farah, 1995). Although this notion received some support from neuroscientific studies demonstrating dedicated neural systems for face processing, behavioral evidence of automatic and mandatory face processing is inconclusive. Faces do not tend to pop out in visual search (Brown, Huey, & Findlay, 1997; Kuehn & Jolicoeur, 1994; Nothdurft, 1993; Suzuki & Cavanagh, 1995). However, faces cannot be ignored when presented as search nontargets (Suzuki & Cavanagh, 1995), and in a change-blindness paradigm, changing faces capture attention more than other types of changing objects (Ro, Russell, & Lavie, 2001).

An irrelevant famous face was also found to produce response-competition effects in a central name-categorization task (Young, Ellis, Flude, McWeeny, & Hey, 1986). However, in that study, the irrelevant distractor face and relevant names were grouped together (the name was presented in a "speech bubble" extending from the face's mouth). As such grouping is known to facilitate distractor processing (e.g., Baylis & Driver, 1992), these results are not informative about the extent to which face processing may be mandatory.

Our study provides a more direct test of whether face processing may be described as automatic, and perhaps even mandatory. We explicitly manipulated the extent to which a relevant task loaded attentional capacity in a situation optimal for ignoring the irrelevant distractor faces (the faces were presented in the periphery, clearly segregated from the target names). Thus, the finding that interference from irrelevant distractor faces, unlike other nonface distractors, did not depend on the extent to which the relevant task loaded attentional capacity suggests that face processing is automatic in the sense that it does not depend on general capacity limits.

We note that this does not imply that face processing is entirely capacity free. It may have face-specific capacity limits. This suggestion is consistent with neuroscientific evidence for a dedicated neural system for faces and with two recent studies. Palermo and Rhodes (2002) found a performance cost in a divided-attention condition (relative to a full-attention condition) when attention was shared between upright faces, but not when attention was shared between an upright face and inverted or fractured faces. Jenkins, Lavie, and Driver (2003) found that flanker effects from a distractor face can be diluted only by the presence of another distractor face, but not by the presence of another nonface distractor. The notion of face-specific capacity limits can be examined in the present paradigm by presenting faces instead of names in the relevant search task, thus manipulating load on face processing specifically.

Finally, although our study does not directly address a recent controversy about whether face perception is special, it does address whether faces play a special role in attention. Expertise with other object categories may well result in perceptual performance (Gauthier &

Tarr, 1997) and neural correlates (Gauthier et al., 2000) similar to those found for faces, suggesting that face perception may not be special. However, such a conclusion is by no means contradictory to our conclusion that faces are a special stimulus for attention. We have shown that irrelevant faces are particularly distracting, producing interference even under conditions of high attentional load that have been shown to eliminate interference from various nonface distractors. Whether these findings are due to the particular sociobiological significance of faces or can be acquired for other stimuli after sufficient training may well be an issue worth further investigation.

REFERENCES

Baylis, G.C., & Driver, J. (1992). Visual parsing and response competition: The effect of grouping factors. *Perception & Psychophysics*, *51*, 145–162.

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

De Renzi, E. (2000). Prosopagnosia. In M.J. Farah & T.E. Feinberg (Eds.), *Patient-based approaches to cognitive neuroscience* (pp. 85–96). Cambridge, MA: MIT Press.

Farah, M.J. (1995). Dissociable systems for visual recognition: A cognitive neuropsychology approach. In S.M. Kosslyn & D.N. Osherson (Eds.), *Visual cognition: An invitation to cognitive science* (2nd ed., Vol. 2, pp. 101–119). Cambridge, MA: MIT Press.

Farah, M.J. (1996). Is face recognition "special"? Evidence from neuropsychology. *Behavioural Brain Research*, *76*, 181–189.

Fodor, J.A. (1983). *The modularity of mind: An essay on faculty psychology*. Cambridge, MA: MIT Press.

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*, 191–197.

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

Jenkins, R., Lavie, N., & Driver, J.S. (2003). Ignoring famous faces: Category specific dilution of distractor interference. *Perception & Psychophysics*, *65*, 298–309.

Kahneman, D., Treisman, A., & Gibbs, B. (1992). The reviewing of object files: Object specific integration of information. *Cognitive Psychology*, *24*, 175–219.

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.

Kuehn, S.M., & Jolicoeur, P. (1994). Impact of quality of the image, orientation, and similarity of the stimuli on visual search for faces. *Perception*, *23*, 95–122.

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal of Experimental Psychology: Human Perception and Performance*, *21*, 451–468.

Lavie, N. (2000). Selective attention and cognitive control: Dissociating attentional functions through different types of load. In S. Monsell & J. Driver (Eds.), *Attention and performance XVIII* (pp. 175–194). Cambridge, MA: MIT Press.

Lavie, N., & Cox, S. (1997). On the efficiency of visual selective attention: Efficient visual search leads to inefficient distractor rejection. *Psychological Science*, *8*, 395–398.

Lavie, N., & Fox, E. (2000). The role of perceptual load in negative priming. *Journal of Experimental Psychology: Human Perception and Performance*, *26*, 1038–1052.

Lavie, N., & Tsal, Y. (1994). Perceptual load as a major determinant of the locus of selection in visual attention. *Perception & Psychophysics*, *56*, 183–197.

Nothdurft, H.C. (1993). Faces and facial expressions do not pop out. *Perception*, *22*, 1287–1298.

Palermo, R., & Rhodes, G. (2002). The influence of divided attention on holistic face perception. *Cognition*, *82*, 225–257.

Perrett, D.I., Hietanen, J.K., Oram, M.W., & Benson, P.J. (1992). Organization and functions of cells responsive to faces in the temporal cortex. *Philosophical Transactions of the Royal Society of London Series B: Biological Sciences*, *335*, 23–30.

Pylyshyn, Z., Burkell, J., Fisher, B., & Sears, C. (1994). Multiple parallel access in visual attention. *Canadian Journal of Experimental Psychology*, *48*, 260–283.

Rees, G., Frith, C.D., & Lavie, N. (1997). Modulating irrelevant motion perception by varying attentional load in an unrelated task. *Science*, *278*, 1616–1619.

Ro, T., Russell, C., & Lavie, N. (2001). Changing faces: A detection advantage in the flicker paradigm. *Psychological Science*, *12*, 94–99.

Suzuki, S., & Cavanagh, P. (1995). Facial organization blocks access to low-level features: An object inferiority effect. *Journal of Experimental Psychology: Human Perception and Performance*, *21*, 901–913.

Yantis, S., & Jones, E. (1991). Mechanisms of attentional selection: Temporally modulated priority tags. *Perception & Psychophysics*, *50*, 166–178.

Young, A.W., Ellis, A.W., Flude, B.M., McWeeny, K.H., & Hey, D.C. (1986). Face-name interference. *Journal of Experimental Psychology: Human Perception and Performance*, *12*, 466–475.