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Can prosopagnosics discriminate similar, non-face objects?

by

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ABSTRACT

Casner (2006) tested the ability of a prosopagnosic, LB, to discriminate objects that would require the use of the coordinate relations recognition system posited by Cooper and Wojan. Casner reported that the prosopagnosic, LB, was impaired in coordinate relations tasks, but did not differ significantly from controls in all tasks that only required categorical recognition. However, Farah, Levinson, and Klein (1995) reported on a patient who was not impaired at discriminating eyeglasses, a task for which the coordinate relations hypothesis would predict an impairment. The present study replicated Farah et al.'s paradigm with the prosopagnosic, LB. One experiment found that LB, relative to controls, was significantly impaired when discriminating eyeglasses requiring the use of a coordinate relations recognition system rather than a categorical recognition system, however, the other experiment failed to find such a difference. Two experiments results may have arisen from a strategy that LB developed used.

INTRODUCTION

A number of empirical results suggest that the process of recognizing faces is different from the process of basic-level object recognition. “Basic-level” refers to the categorization level at which people tend to classify a presented object (Rosch & Mervis, 1981). For example, humans have greater difficulty recognizing faces that are inverted than faces that are upright, but no such effect is shown for basic level object recognition; this phenomenon is known as *the face inversion effect* (Valentine, 1989; Yin, 1969). Additionally, humans have greater difficulty recognizing photographic negatives of faces than normal photographs of faces, however, researchers fail to find a significant difference between the recognition of photographic negatives and normal photographs of basic-level objects (Galper, 1970; Galper & Hochberg, 1971). Furthermore, researchers have found that infants will track faces longer than basic-level objects (Maurer & Barrera, 1981).

In addition to behavioral studies, several results from cognitive neuroscience suggest that the human brain processes faces and objects differently. First, a double dissociation has been shown between basic-level object recognition and face recognition. Specifically, some neurological patients (known as prosopagnosics) are impaired in their ability to recognize human faces, but retain the ability to recognize basic-level objects (Farah, 2004). In contrast, researchers have noted a few neurological patients (known as object agnosics) who are impaired in their ability to recognize basic-level objects, but retain their ability to recognize human faces (Humphreys & Rumiati, 1998;

Moscovitch, Winocur, & Behrmann, 1997; Rumiati, Humphreys, Riddoch, & Bateman, 1994).

Second, neuroimaging studies have found a region in the right inferior-temporal lobe, known as the Fusiform Face Area (FFA), that appears to respond selectively to faces (Kanwisher, McDermott, & Chun, 1997; for reviews see Kanwisher & Yovel, 2006; McCarthy, Puce, Gore, & Allison 1997; Sergent, Ohta, & MacDonald, 1992). Additionally, researchers using single-cell recordings on monkeys reported of cells in the temporal lobe that fire exclusively to faces (Tsao, Freiwald, Tootell, & Livingstone, 2006). Third, face recognition shows a strong right-cerebral hemisphere advantage (for a review see Ellis, 1983), however, researchers failed to find a hemispheric advantage for basic-level object recognition (Biederman & Cooper, 1991; Young, Bion, & Ellis, 1980). The results from the aforementioned research suggest that object recognition and face recognition are subserved by (at least) two neurologically distinct recognition systems.

What sorts of tasks are mediated by the face recognition system?

There are a number of empirical results that suggest that the face recognition system is used for recognizing other sorts of objects as well. For example, prosopagnosics often have difficulty discriminating different four legged animals, currencies, plants, and buildings sharing the same general features (Farah, 2004; Mayer, 2007). A number of researchers have developed theories to explain the other sorts of tasks that the face recognition system might subserve.

The biological recognition hypothesis posits that the face recognition system mediates recognition of all biological stimuli, and that the basic-level object recognition system mediates the recognition of non-biological stimuli (Cappa et al., 1998; Caramazza & Shelton, 1998; Chao, Haxby, & Martin, 1999). Support for this theory is provided by the fact that prosopagnosics often lack the ability to recognize different animals. For example, one prosopagnosic who was a farmer could no longer distinguish the faces of his cows after his brain was damaged (Bornstein, Stroka, & Munitz, 1969). Further, neuroimaging studies have found brain regions in the lateral fusiform gyrus that respond selectively to biological stimuli (e.g., animals), while brain regions in the medial fusiform gyrus respond selectively to non-biological stimuli such as houses and tools (Chao et al., 1999). A major problem with this hypothesis is that prosopagnosics are not equally impaired in all animal discrimination tasks. For example, Damasio et al. (1982) tested the ability of two prosopagnosics to discriminate different animals and noted that the prosopagnosics could always discriminate biological stimuli such as “owl,” “elephant,” and “horse” from one another. Damasio et al.’s (1982) patients also reported impairments in recognition of non-biological stimuli such as discriminating different cars and selecting the correct container from a shelf.

The subordinate-level recognition hypothesis posits that the face recognition system mediates subordinate-level recognition and that the basic-level recognition system mediates basic-level recognition (Damasio, 1982; Damasio, & Van Hoesen, 1982; Gauthier et al., 1997; Gauthier, Skudlarski, Gore, & Anderson, 2000). Subordinate-level tasks are tasks that require distinguishing between two members of the same basic-level category (e.g., distinguishing a Dell laptop computer from an Apple laptop computer). Support for this hypothesis is provided by Damasio et al. (1982) who noted that some prosopagnosics were unable to distinguish different cars or different containers from one another. Additionally, neuroimaging studies have reported greater activation in the fusiform face area when subjects perform subordinate-level recognition tasks than when subjects perform basic-level recognition tasks (Gauthier et al., 1997). A problem with the subordinate-level recognition hypothesis is that prosopagnosics are often impaired at basic-level recognition tasks. For example, prosopagnosics often have difficulty recognizing different types of four legged animals that do not belong to the same subordinate class (Mayer, 2007).

The expert recognition hypothesis posits that the face recognition system is used for any task at which the individual is an expert (Diamond & Carey, 1986; Gauthier et al., 2000; Gauthier & Tarr, 1997). This hypothesis presumes that all humans are experts at face recognition and that the same brain regions that are used for face recognition will be used for any perceptual task at which a particular human has become an expert. Diamond and Carey (1986) found that, similar to the face inversion effect, dog experts' memory for photographs of dogs was disrupted by inversion, an effect not demonstrated by non-experts. Some of the most convincing data suggesting that the face recognition system mediates expert recognition is provided by Gauthier's "Greeble" studies (Gauthier & Tarr, 1997; Gauthier, Skudlarski, Gore, & Anderson, 2000). In these studies participants are trained to discriminate a set of novel homogeneous stimuli (see Figure 1) until they reach a certain level of expertise. These studies have demonstrated that Greeble experts show greater activation in the FFA than do novices when identifying Greebles and are less accurate at discriminating inverted Greebles than upright Greebles.

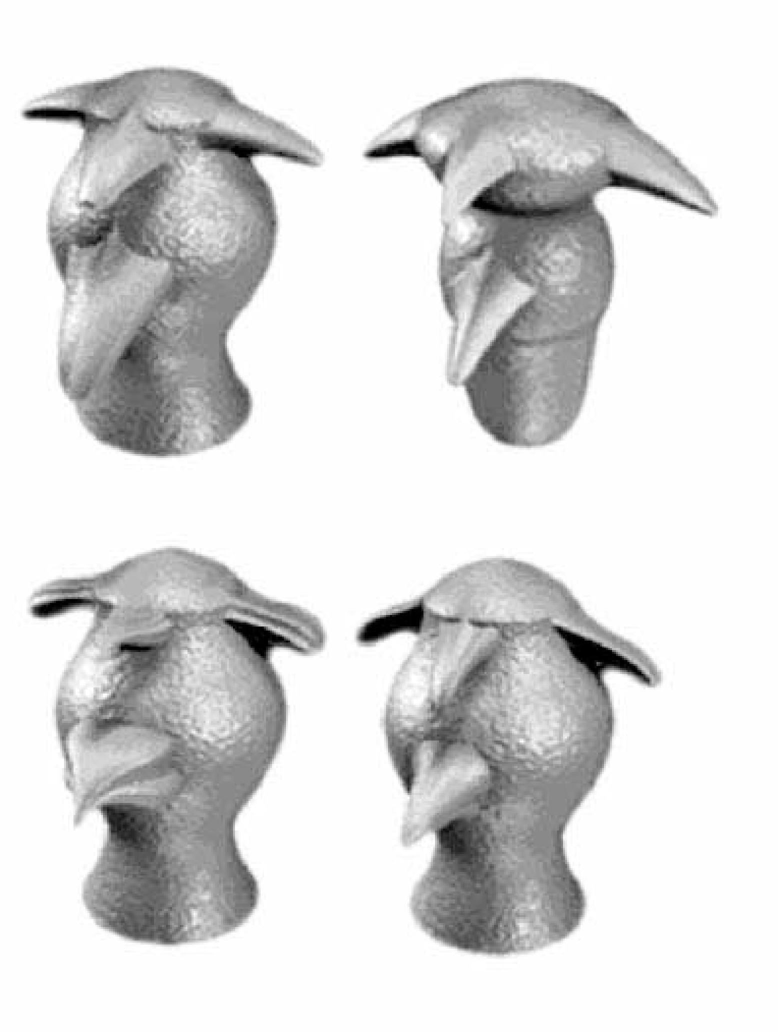

Figure 1. Examples of the novel homogeneous stimuli used in Gauthier's Greeble experiments. Participants were trained on these stimuli until they could accurately discriminate the different Greebles from one another. Greeble experts showed greater activation in their fusiform face are than non-Greeble experts when they viewed Greebles.

The coordinate relations hypothesis

Some theorists have proposed that the human visual system performs basic-level object recognition using a representation that codes an object’s parts and the categorical relations between the parts. Such a representation is called a *structural description* (Biederman, 1987). In theories positing a structural description, the relations among the parts of an object are coded using broad categories rather than specific values. For example, Hummel and Biederman (1992) proposed that the relations among an object’s parts are defined by their relative position (*above, below,* and *side of*), size (*larger than, smaller than,* and *equal to*) and orientation to one another (*parallel to, perpendicular to*, and *oblique to*). For example, according to Hummel and Biederman (1992) the coffee mugs shown in Figure 2 would be coded as a cylinder with a curved cylinder to the side.

Figure 2. Two different coffee mugs that share the same structural description (a cylinder with a curved-cylinder to the side).

The computational advantages of using a structural description to perform object recognition include that it allows for rapid recognition of most objects despite partial occlusion, changes in size, changes in orientation, and rotations in depth that preserve the object's structural description. However, a problem arises for structural description theories when an individual has to differentiate two objects that share the same structural description (such as differentiating the mugs shown in Figure 2). Structural description theories cannot account for the human capacity to distinguish between objects that share the same structural description.

To deal with the limitations of structural descriptions, some theorists have posited representations that use coordinate relations (Bülthoff & Edelman, 1992; Siebert & Waxman, 1992; Ullman, 1989; Ullman & Basri, 1991). Coordinate relations representations code the precise distances of each object primitive (i.e., part) from a fixed reference point or set of fixed reference points. For example, Figure 3 illustrates how a categorical representation (i.e., a structural description) and coordinate relations representation would code the position of my right eye (from the viewers perspective). A categorical relations representation would code my right eye as being, "to the side of left eye, above and to the side of the nose, and above and to the side of the mouth." In contrast, a coordinate relations representation would code my right eye as being 4 units below and 2.66 units to the right of the specified reference point.

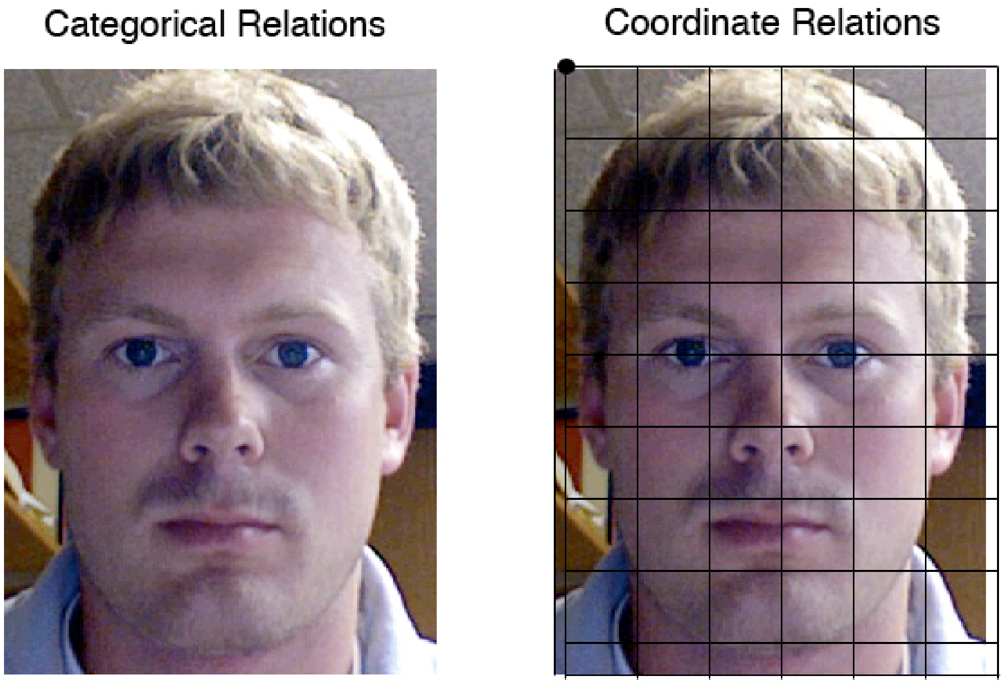

Figure 3. Illustration of how categorical (left picture) and coordinate relations (right picture) would code the position of the left eye of a face. Categorical relations would code the left eye as side of the right eye, above and side of the nose, and above and side of the mouth. In contrast, coordinate relations would code the left eye as 4 units below and 2.66 units to the right of the given reference point.

The *coordinate relations hypothesis* proposes that most basic-level object recognition tasks use a representation of shape that codes the relationships among the parts categorically. In contrast, the face recognition system represents shape using coordinate relations (Cooper & Wojan, 2000). According to the coordinate relations hypothesis, the face recognition system is used to discriminate objects sharing the same structural description (Brooks & Cooper, 2004; Cooper & Wojan, 2000).

There are a number of empirical results that support the coordinate relations hypothesis. The recognition deficits prosopagnosics show with objects other than faces all tend to be on tasks that require the discrimination of objects that share the same structural description (e.g., four-legged animals, buildings, foods, cars). Further, Cooper and Wojan (2000) found that disruptions to the categorical relations among the parts of an object are more disruptive to basic-level object recognition than disruptions in the coordinate relations, while the opposite pattern of results is found for face recognition.

Prosopagnosia: regions of damage, causes, and co-occurring deficits

The purpose of the research being proposed here is to provide a test of the co-ordinate relations hypothesis using a prosopagnosic. Prosopagnosia often results from bilateral temporo-occipital damage (Damasio, Damasio, & Van Hoesen, 1982) although prosopagnosia can also result from unilateral damage to the right hemisphere (De Renzi, 1986; De Renzi, 1994; Wada & Yamamota, 2001). The most common areas damaged in prosopagnosic patients are the lingual gyrus, parahippocampal gyrus, and the fusiform gyrus (see Figure 4 for an illustration).

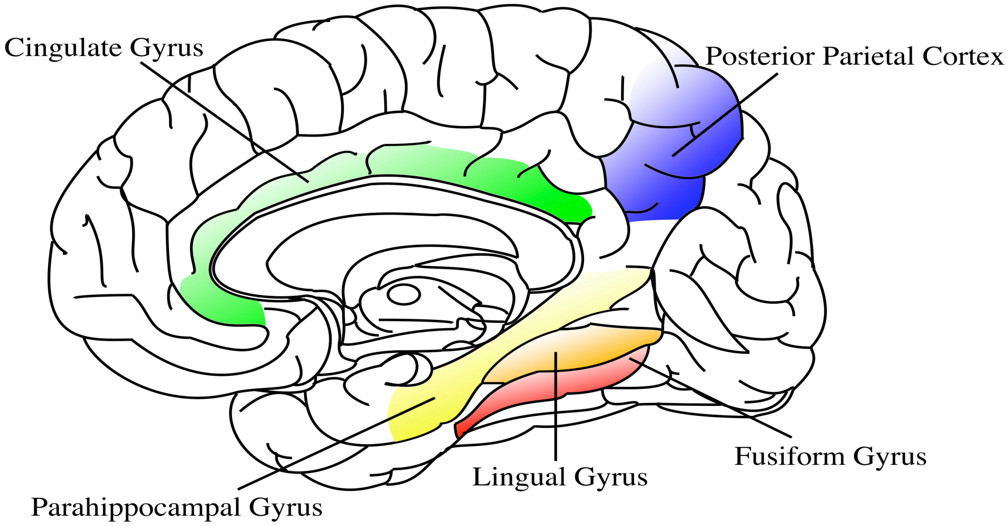

Figure 4. An illustration of the most common areas damaged in prosopagnosic patients (specifically, the parahippocampal gyrus, lingual gyrus, and fusiform gyrus; taken from Casner, 2006).

Prosopagnosia usually results from head trauma (as a result of an accident) or a stroke. Of all the types of strokes associated with prosopagnosia, a posterior cerebral artery infarct is the most common type (Mayer, 2007; Brand et al., 2000). A review of all posterior cerebral artery infarcts suggests that prosopagnosia is very rare. Kumral, Bayulkem, Ataç, and Alper (2004) reviewed the clinical features of more than 140 patients who suffered posterior cerebral artery infarcts and noted only six who had prosopagnosia. As noted in Mayer's review, prosopagnosia often co-occurs with other perceptual deficits, namely, anomia (inability to name objects), hemianopia (loss of one half of the visual field), achromatopsia (colorblindness), and topographic disorientation (inability to navigate through the environment).

Evidence from prosopagnosics supporting the coordinate relations hypothesis

A number of other studies suggest a link between prosopagnosia and an inability to perform tasks requiring coordinate relations. Barton et al. (2004) tested seven prosopagnosics on an array of perceptual tasks in hopes of identifying a perceptual processing impairment contributing to prosopagnosia. Barton et al. concluded that deficits in the perception of luminance, spatial resolution, curvature, line orientation, and contrast sensitivity were unlikely to contribute to prosopagnosia. Interestingly, and consistent with the coordinate relations hypothesis, almost all of the patients were impaired in fruit and vegetable identification tasks and tasks requiring patients to code the distances of four dots from one another.

Casner (2006) tested a prosopagnosic (LB) on three experiments that required LB to discriminate two objects that either shared or did not share the same structural description. The first experiment required LB and controls to indicate whether two animals were the same species or different species. Half of the different species trials consisted of animals that shared the same structural description (e.g., a fox and a wolf). The remaining different trials consisted of animals that did not share the same structural description (e.g., a fox and a goose). Consistent with the coordinate relations hypothesis, but in contrast to the biological hypothesis, LB produced significantly more errors, compared to controls, in trials requiring her to discriminate species that shared the same structural description, but did not reliably differ from controls when discriminating species that did not share the same structural description.

The second experiment required LB and controls to indicate whether two objects within the same subordinate-level category were physically identical. In half of the different trials, the two objects differed in the length of one of the object's parts (e.g., a rectangular table compared to a longer rectangular table), while maintaining the same structural description. In the remaining different trials, the two objects differed in their structural descriptions (e.g., a round table compared to a square table). Consistent with the coordinate relations hypothesis, but in contrast to the subordinate-level recognition hypothesis, LB made significantly more errors than controls when differentiating subordinate-level objects that shared the same structural description, but did not differ from controls when discriminating subordinate-level objects that did not share the same structural description.

The third experiment required LB and controls to indicate whether two nonsense objects were physically identical when they had the same parts but sometimes differed in the relations among the parts. Consistent with the coordinate relations hypothesis, but in contrast to the expert recognition hypothesis, LB made significantly more errors than controls when discriminating nonsense objects that shared the same structural description, but did not differ from controls when discriminating nonsense objects that did not share the same structural description.

Evidence from prosopagnosics that appears contrary to the coordinate relations hypothesis

The coordinate relations hypothesis predicts that all prosopagnosics, in addition to being impaired at face discrimination tasks, should show impairments in object recognition whenever the objects being discriminated share the same structural description. However, there are a few reports in the literature where prosopagnosics appears to show no impairment on recognition tasks for which the coordinate relations hypothesis would predict an impairment (e.g., McNeil & Warrington, 1993; Farah, Levinson, & Klein, 1995).

McNeil and Warrington (1993) tested a prosopagnosic's (WJ) ability to recognize sheep. WJ was a sheep farmer at the time of testing and showed considerable difficulty naming human faces, however, WJ was as accurate as profession-matched controls in recognizing different sheep. The results of this experiment appear to contradict the predictions made by the coordinate relations hypothesis. Specifically, the coordinate relations hypothesis predicts that WJ should show impairments in sheep identification because the sheep being compared would activate the same structural description. If the sheep being compared had distinct markings (i.e., they differed in the surface features rather than shape), it would explain why WJ was able to distinguish the sheep even though they activate the same structural description. In fact, McNeil and Warrington provided figures of the types of sheep WJ could and could not recognize, and it appears that WJ was able to recognize sheep with distinct markings, but showed difficulty recognizing sheep of a solid color (see Figure 5). Thus the results of McNeil and Warrington (1993) may not contradict the coordinate relations hypothesis.

Figure 5. Examples of sheep that WJ could recognize (left photo) and examples of sheep that WJ could not recognize (right photo).

In a similar study, Farah, Levinson, and Klein (1995) tested a prosopagnosic's (LH) ability to discriminate among eyeglasses. Although LH was significantly impaired in face recognition, he did not differ from controls in the ability to discriminate among eyeglasses. Assuming these results reflect the true recognition abilities of LH (see Tarr & Gauthier, 2000 for methodological concerns), the results appear to contradict the predictions made by the coordinate relations hypothesis; because it would seem likely that many of the eyeglasses would share the same structural description. Yet, it is not clear from the description of the stimuli in the article if the eyeglasses used in the study shared the same structural descriptions (e.g., all oval-shaped lens) or if they varied in their structural descriptions (e.g., some oval and some rectangular shaped).

CURRENT STUDY

The purpose of the current set of experiments was to determine whether the results of Farah et al. (1995) would be replicated when controlling for the eyeglasses' structural descriptions. Four experiments tested a prosopagnosic and controls on their ability to discriminate eyeglasses.

Experiment 1

The first experiment was a direct replication of the eyeglass experiment of Farah et al. (1995). Just as in Farah et al., the eyeglasses in Experiment 1 were chosen without maintaining the same structural description across all eyeglasses that were used in this experiment.

Method

Participants

The participants consisted of a prosopagnosic, an age-matched control subject, and a group of undergraduate control subjects. The patient, LB, served as the prosopagnosic in all four experiments. LB is 43 year-old retired junior high math teacher who suffered a posterior artery stroke, causing bilateral inferiortemporal damage and partial unilateral hippocampus damage. LB has subsequently been diagnosed with prosopagnosia, achromatopsia, anomia, topographical disorientation, right upper quadrantanopia, and left homonymous hemianopia (Casner, 2006).

LB retains normal visual acuity in her remaining visual quadrant (lower right quadrant). While LB elicits some memory impairments (e.g., memory for dates and names, and episodic memory impairments), her long-term memory, procedural memory, and motor skills remain intact. LB is not impaired in most forms of basic-level object identification, however, LB did report having difficulty recognizing some types of food, animals, buildings, and money which are all common co-occurring recognition deficits in prosopagnosics (Mayer 2007).

An aged-matched control (FD), reporting corrected-to-normal vision, participated in all four experiments. FD is a 42-year-old male. FD was recruited to determine if LB's perceptual impairments were merely an artifact of age.

Sixteen undergraduate psychology students at Iowa State University who received course credit for their participation were used as controls. All control participants reported normal or corrected-to-normal vision. The control participants consisted of four males and twelve females. The mean age of the control participants was 21.47 (*SD*=1.66).

Apparatus

A 15-inch LCD display with a resolution of 1280 x 854 pixels powered by a Macintosh G4 desktop was used to present the stimuli and collect the data. The experiment was presented using Superlab Pro software. Responses were collected via two keys using a standard Macintosh keyboard that gives ± 0.5 ms response time accuracy.

Forty black and white photographs of male faces were used as stimuli in the experiment. Photographs of faces with facial hair and/or eyeglasses were not used nor were faces with long or strange hair. Additionally, forty black and white photographs of eyeglasses, photographed from a standard perspective, were included. No eyeglasses with visible logos or names were used. Both faces and eyeglasses were divided evenly into sets of “old” items, which appeared in the study and test phases of the experiment, and “new” items, which only appeared during the test phase of the experiment. As in Farah et al. (1995), similar looking eyeglasses were divided evenly between “old” and “new” phases of the experiment.

Procedure

The procedures of Experiment 1 exactly followed that of Farah et al.’s (1995) eyeglass experiment. Presentation of the stimuli during the study phase was self-paced. In the study phase of the experiment, control participants were shown each photograph (20 faces and 20 eyeglasses) for three seconds, with faces and eyeglasses randomly intermixed. Like Farah et al. (1995), the same procedure was used for the prosopagnosic patient except that the patient received more study time. During the study phase, LB viewed all study photographs three times each for six seconds.

Upon completion of the study phase, all participants completed a test phase in which they were instructed to make old/new judgments on a randomly assigned order of all the old and new photographs of faces and eyeglasses (40 faces and 40 eyeglasses). Presentation of the stimuli during the test phase was self-paced. The participants were instructed to press the “z” key if they believed the photograph was presented during the study phase (an “old” item) and to press the “/” key if they believed the photograph was not presented in the study phase (a “new” item). The order of presentation was identical for all participants in the experiment.

Results

A modified *t*-test procedure[1] (for description see Crawford & Howell, 1998) was used to determine if LB's accuracy for distinguishing "old" and "new" eyeglasses and faces differed reliably from the aged-matched control and student controls' accuracy to distinguish "old" and "new" eyeglasses and faces. The modified *t*-test procedure is used when comparing a single subject to a small sample. Due to LB's restricted visual field (i.e., blindness in the left half and upper right quadrant of the visual field; Casner, 2006), LB's reaction time on all experiments tended to be slower than the controls' reaction times. Although in all experiments reaction time will be reported, reaction time was not the principal dependent variable of interest in the current studies. The purpose of reporting reaction time was to test whether any differences in accuracy found between LB and controls were the result of a speed-accuracy trade-off.

Accuracy Data

The accuracy data from Experiment 1 can be seen in Figure 6. Analysis of the age-matched control's accuracy to discriminate "old" and "new" faces compared to the controls' accuracy to discriminate "old" and "new" faces revealed no significant difference, *t*(15)=.36, *p*>.05. The standard error for face comparisons of accuracy, as described by Crawford and Howell (1998), was

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[1] $$t = \frac{X_1 - X_2}{s_2 \sqrt{\frac{N_2 + 1}{N_2}}},$$

7.22. In contrast, analysis of LB's ability to discriminate "old" and "new" faces compared to the controls' accuracy to discriminate "old" and "new" faces revealed that LB was significantly less accurate than controls in discriminating "old" and "new" faces, *t*(15)=3.60, *p*<.05.

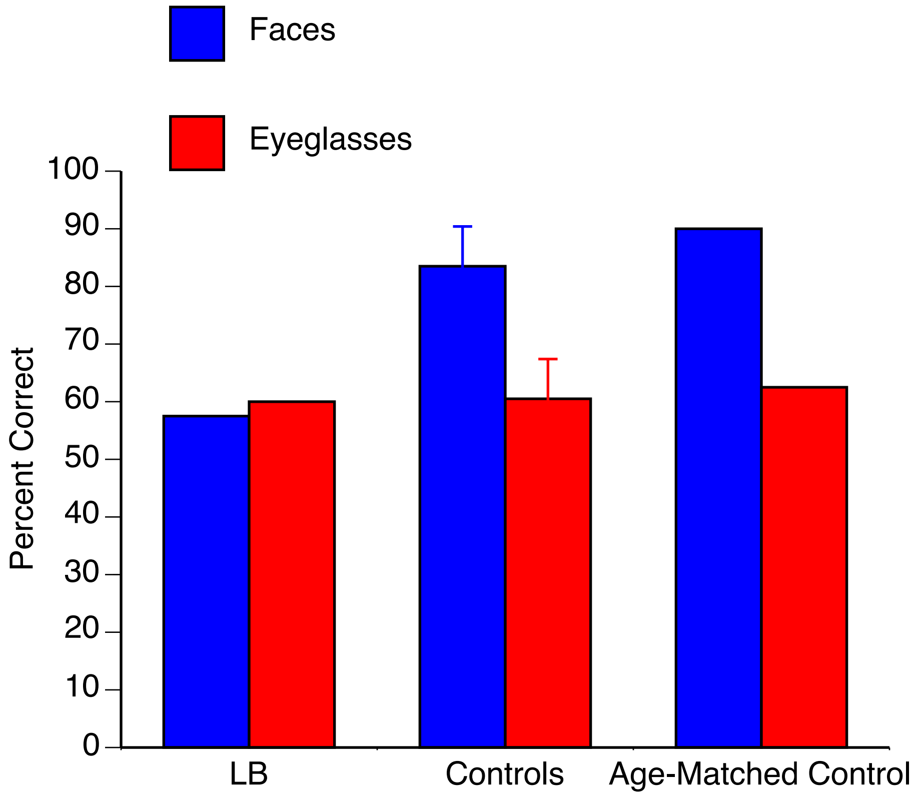

Figure 6. Accuracy data from Experiment 1 (standard error bars are displayed for the controls).

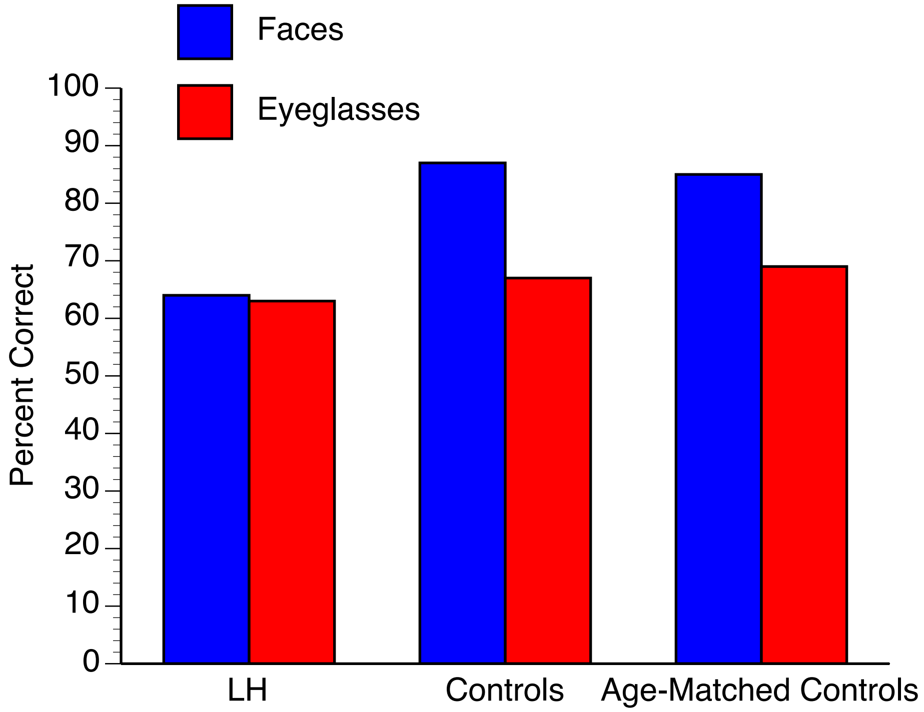

Figure 7. Results from Farah, Levinson, and Klein's (1995) eyeglass experiment.

Analysis of the age-matched control's accuracy to discriminate "old" and "new" eyeglasses compared to the controls' accuracy to discriminate "old" and "new" eyeglasses revealed no significant difference, *t*(15)= .36, *p*>.05. The standard error for eyeglass comparisons of accuracy was 6.91. Similarly, analysis of LB's accuracy to discriminate "old" and "new" eyeglasses compared to the controls' accuracy to discriminate "old" and "new" eyeglasses revealed no significant difference, *t*(15)=.072, *p*>.05. LB's difference in accuracy between discriminating "old" and "new" faces and "old" and "new" eyeglasses, relative to controls, revealed a significant interaction, *t*(15)=3.59, *p*<.05

Reaction Time Data

The mean reaction time to the correct trials for faces for the controls, the age-matched control, and LB were 1920 msec (*s*=388.26), 2106 msec, and 6321 msec respectively. The standard error for face comparisons of reaction time was 400.21. The age-matched control's reaction time for faces did not significantly differ from the controls' reaction time for faces, *t*(15)=.46, *p*>.05. In contrast, LB's reaction time for faces significantly differed from the controls' reaction time for faces, *t*(15)=10.98, *p*<.05.

The mean reaction time to eyeglasses for the controls, the age-matched control, and LB were 2082 msec (*s*=581.79), 2041 msec, and 5675 msec respectively. The standard error for eyeglass comparisons of reaction time was 600.87. The age-matched control's reaction time for faces did not significantly differ from the controls' reaction time for faces, *t*(15)= -.07, *p*>.05. In contrast, LB's reaction time for eyeglasses significantly differed from the controls' reaction time for eyeglasses, *t*(15)=5.98, *p*<.05. LB's difference in reaction time between face and eyeglass stimuli differed reliably from the difference in the controls' mean reaction time between face and eyeglass stimuli, indicating a significant interaction *t*(15)=2.57, *p*<.05. Importantly, the reaction time data indicate no speed-accuracy trade-off in accuracy for both controls and LB.

d' Data

LB's sensitivity (*d*') and response bias (c) while discriminating faces and eyeglasses were calculated and compared to the controls' mean *d*' and *c (*see Table 1) to investigate whether LB's sensitivity and responses bias differed from that of the controls. All analyses comparing the age-matched control's sensitivity and response bias to the controls' mean sensitivity and response bias were not significant. A significant interaction was found when comparing LB's sensitivity to the controls' sensitivity to accurately discriminate "old" and "new" trials across stimulus types, $t(15)= 2.96$, $p<.05$. Consistent with the accuracy data, LB's d' was significantly worse than the controls' mean d' when discriminating "old" and "new" faces, $t(15)= -2.96$, $p<.05$, but did not significantly differ from the controls' mean d' when discriminating "old" and "new" eyeglasses, $t(15)= -.25$, $p>.05$. The standard error for d' comparisons of faces was .60 and the standard error for d' comparisons of eyeglasses was .36. All comparisons of LB's response bias to that of controls were not significant.

Table 1.

Sensitivity Means (d') and Response Bias Means (c) for LB and Controls from Experiment 1

	LB		Age-matched Control		Control	
	d'	*c*	*d'*	*c*	*d' (s)*	*c (s)*
Faces	.38	.06	2.56	0	2.15 (.58)	.17 (.27)
Eyeglasses	.51	0	.64	.07	.6 (.35)	.17 (.37)
Faces-Eyeglasses	-.13	.06	1.92	-.07	1.55 (.55)	.26 (.35)

Discussion

The results obtained in Experiment 1, and shown in Figure 7, are similar to the results Farah et al. (1995) obtained in their eyeglass experiment. Although LB was significantly more impaired than controls at discriminating "old" and "new" faces, she did not differ from controls in her ability to discriminate "old" and "new" eyeglasses. Caution needs to be exercised before concluding that the results obtained in this experiment support the notion that prosopagnosia is a face-specific impairment. First, the null results obtained for eyeglasses may be an artifact of a floor effect. Specifically, LB and controls were barely above chance in the eyeglass condition; LB and controls may have guessed on all the eyeglass trials except for a few unique eyeglasses that they were able to remember (bringing both LB and the controls' slightly above chance). Second, the results from this experiment do not necessarily contradict the coordinate relations hypothesis. The coordinate relations hypothesis predicts that LB would make significantly more errors when she has to discriminate eyeglasses that share the same structural description, whereas LB will not significantly differ from controls in trials that require her to discriminate eyeglasses that share different structural descriptions. Unfortunately, the current experimental paradigm did not allow a determination of LB's ability to distinguish eyeglasses when they did or did not share the same structural descriptions.

Although the results obtained in Experiment 1 are inconclusive as to whether or not LB suffers from a face-specific impairment, other research suggests that her impairments are not face-specific. For example, Casner (2006) has already demonstrated that LB is impaired in non-face object discrimination tasks that require her to discriminate two objects that share the same structural description. The classes of objects on which Casner tested LB included animals, subordinate-level objects, and nonsense objects. Therefore, it is very possible that the results obtained in Experiment 1 are an artifact of floor effects.

Before one can conclude that LB does not significantly differ from controls in her ability to discriminate eyeglasses, two limitations of Experiment 1 need to be resolved: 1.) The eyeglass task used in this experiment needs to be easier so that controls are well above chance, 2.) The experimental design needs to allow a determination of the type of structural description comparisons being made (i.e., whether the eyeglasses being compared are the same, are different but shared the same structural description, or are different and have different structural descriptions).

Experiment 2

Analysis of Experiment 1 indicated that controls were slightly above chance in discriminating “old” and “new” eyeglasses. Experiment 2 sought to decrease the difficulty of the task used in Experiment 1 by using half the number of faces and eyeglasses that were used in Experiment 1.

Method

Participants

The participants who were in Experiment 1 also participated in Experiment 2.

Apparatus

All materials except the visual stimuli were identical to those that were used in Experiment 1. Twenty black and white photographs of male faces and twenty black and white photographs of eyeglasses were used as stimuli for this experiment.

Procedure

In the study phase of the experiment, control participants were shown each photograph (10 faces and 10 eyeglasses) for three seconds, with faces and eyeglasses randomly intermixed. As in Experiment 1, LB viewed all study photographs three times each for six seconds. Upon completion of the study phase, all participants completed a test phase in which they were instructed to make old/new judgments on a randomly assigned order of all the old and new photographs of faces and eyeglasses (20 faces and 20 eyeglasses). All other procedures were the same as Experiment 1.

Results

Accuracy Data

The accuracy data from Experiment 2 can be seen in Figure 8. The standard error for the face comparisons of accuracy was 6.09. Analysis of the age-matched control's accuracy to discriminate "old" and "new" faces compared to the controls' accuracy to discriminate "old" and "new" faces revealed no significant difference, *t*(15)=.77, *p*>.05. A modified *t*-test indicated that LB was significantly less accurate than controls in discriminating "old" and "new" faces, *t*(15)=3.33, *p*<.05.

Analysis of the age-matched control's accuracy to discriminate "old" and "new" eyeglasses compared to the controls' accuracy to discriminate "old" and "new" eyeglasses revealed no significant difference, *t*(15)=1.62, *p*>.05. Similarly, LB's accuracy for discriminating eyeglasses compared to the controls' accuracy for discriminating eyeglasses did not significantly differ, *t*(15)=1.26, *p*>.05. The standard error for the eyeglass comparisons of accuracy was 8.67. Further, LB's difference in accuracy between faces and eyeglasses did not reliably differ from the difference in the controls' mean accuracy between faces and eyeglasses and indicated no significant interaction, *t*(15)=.88, *p*>.05.

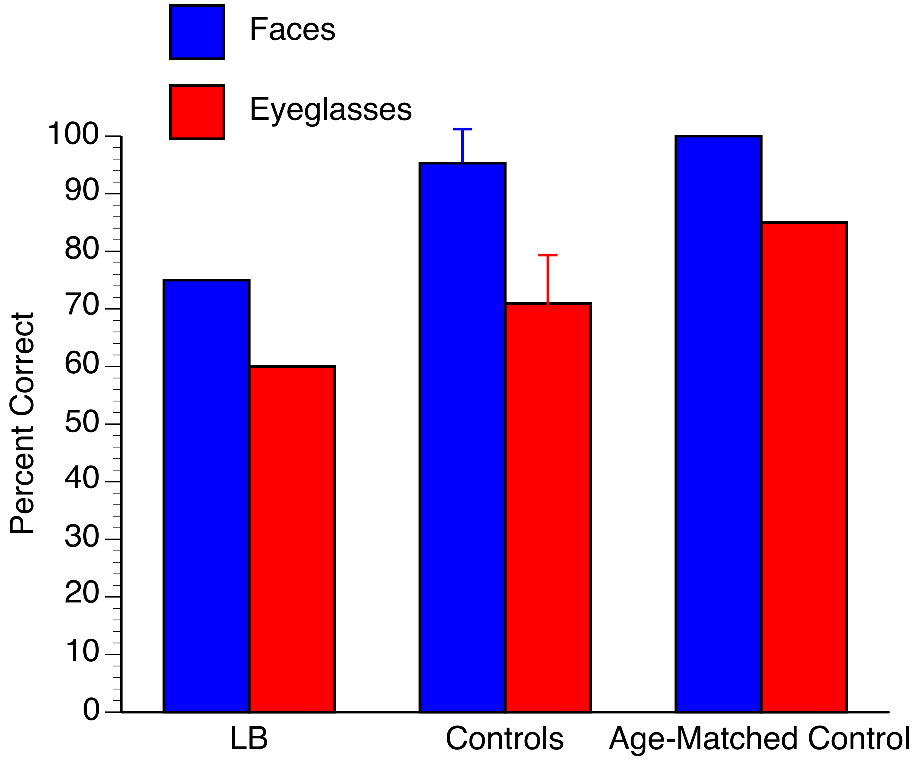

Figure 8. Accuracy data from Experiment 2 (standard error bars are displayed for the controls).

Reaction Time Data

The mean reaction time for correct trials to faces for the controls, the age-matched control, and LB were 1211 msec (*s*=319.11), 1467 msec, and 3286 msec respectively. The standard error for the face comparisons of reaction time was 328.94. The age-matched control's mean reaction time for faces did not significantly differ from the controls' mean reaction time for faces, *t*(15)=.778, *p*>.05. In contrast, LB's mean reaction time for faces significantly differed from the controls' mean reaction time for faces, *t*(15)=6.31, *p*<.05.

Mean reaction time to eyeglasses for the controls, the age-matched control, and LB were 1528 msec (*s*=501.02), 1554 msec, and 2259 msec respectively. The standard error for the eyeglass comparisons of reaction time was 516.45. The age-matched control's mean reaction for eyeglasses did not significantly differ from the controls' mean reaction time for eyeglasses, *t*(15)=.05, *p*>.05. In contrast, LB's mean reaction time for eyeglasses significantly differed from the controls' mean reaction time for eyeglasses, *t*(15)=5.98, *p*<.05. LB's difference in reaction time between face and eyeglass stimuli differed reliably from the difference in the controls' mean reaction time between face and eyeglass stimuli, indicating a significant interaction, *t*(15)=2.57, *p*<.05. Whereas, LB was slightly slower in reaction time when discriminating "old" and "new" faces, as compared to LB's reaction time for eyeglasses, the inverse was true for the controls, *t*(15)=2.5, *p*<.05.

d' Data

As in Experiment 1, LB's sensitivity (*d*') and response bias (*c*) while discriminating faces and eyeglasses were calculated and compared to the controls' mean *d*' and *c (*see Table 2). The standard error for the *d'* comparisons of faces was .47 and the standard error for the *d'* comparisons of eyeglasses was .54. All analyses comparing the age-matched control's sensitivity and response bias to the controls' mean sensitivity and response biases were not significant. No significant interaction was found when comparing LB and the controls' sensitivity to accurately discriminate "old" and "new" trials across stimulus types, *t*(15)= -1.56, *p*>.05. Consistent with the accuracy data, LB's *d*' was significantly worse than the controls' mean d' when discriminating "old" and "new" faces, $t(15)= -3.28$, $p<.05$, but did not significantly differ from the controls' mean d' when discriminating "old" and "new" eyeglasses, $t(15)= -.72$, $p>.05$.

Table 2

Sensitivity Means (d') and Response Bias Means (c) for LB and Controls from Experiment 2

	LB		Age-matched Control		Control	
	d'	*c*	*d'*	*c*	*d' (s)*	*c (s)*
Faces	1.37	-.16	3.29	0	2.91 (.46)	.05 (.25)
Eyeglasses	.8	-1.24	2.12	.22	1.18 (.52)	.25 (.37)
Faces-Eyeglasses	.57	1.08	1.17	-.22	1.73 (.46)	-.2 (.53)

A significant interaction was found when comparing LB's response bias to that of the controls' response biases when discriminating "old" and "new" trials across stimulus types, $t(15)= 2.49$, $p<.05$. Specifically, LB was significantly more biased to indicate that a "new" eyeglass was "old" than were the controls', $t(15)= -3.88$, $p<.05$. In contrast, LB's measure of response bias did not significantly differ from the controls' response bias when making "old" and "new" judgments to faces, $t(15)= .83$, $p>.05$. The standard error for the response bias comparisons of faces was .26 and the standard error for the response bias comparisons of eyeglasses was .38. LB's measure of response bias is consistent with her post-experiment interview in which she indicated she was merely guessing during the eyeglass trials; she thought that almost all of the eyeglasses that were presented in this experiment were "old" (only two times did she indicate that they were “new).

Discussion

Farah et al. (1995) found an interaction between their patient, LH, and controls in the ability to remember faces and eyeglasses. Specifically, LH was significantly impaired in face recognition, compared to controls, but LH did not differ from controls in his ability to discriminate eyeglasses. As a result, Farah et al. posited that prosopagnosia is a deficit in face recognition and not within-category discrimination. In contrast, I failed to find an interaction when comparing LB’s accuracy to the controls’ accuracy across stimulus conditions. The data for Experiment 1 and Experiment 2 suggest that all subjects were at floor in Experiment 1, but when performance was lifted off the floor for the controls in Experiment 2, LB did not significantly improve in Experiment 2 suggesting that LB also shows a deficit for recognizing eyeglasses. Farah et al. may have obtained similar results had they raised their controls mean accuracy further from the floor.

LB’s accuracy and RT data could be interpreted as a speed-accuracy trade-off, and there is reason to believe that perhaps it is. LB’s reaction time was actually faster on the eyeglass trials in which she made the most errors, as compared to her performance on the face trials. Upon completion of this experiment, I interviewed LB and she said that the experiment was terribly difficult, and she felt like she was guessing in the eyeglass condition. Furthermore, LB indicated that she felt that she recognized “a few” of the faces. Therefore, it is possible that LB’s slower reaction time in the face condition reflects longer retrieval for residual familiarity traces of a familiar face that was not present for any of the eyeglasses.

Experiment 3

Experiments 1 and 2 were direct replications of the Farah et al. (1995) study that used an episodic memory task. The problem with using an episodic memory task to test the coordinate relations hypothesis is that one cannot control for the structural descriptions of the eyeglasses being compared because the participants are comparing each stimulus in the test phase to their memory traces for all the stimuli in the learning phase. Experiments 3 and 4 required subjects to perform a discrimination task between two eyeglasses that were presented sequentially. The eyeglasses that participants discriminated in Experiments 3 and 4 sometimes shared the same structural descriptions and other times did not share the same structural description. In Experiment 3, LB and controls decided whether two photographs of eyeglasses that were presented sequentially were physically identical or different. Half of the pairs of eyeglasses being compared were physically identical, while the other half of the eyeglasses differed either metrically or in their structural descriptions (see Figure 9). Based on previous experiments with LB, in which LB discriminating various objects that shared or did not share the same structural description (Casner, 2006), it is predicted that LB will be impaired, relative to controls, when discriminating eyeglasses that share the same structural description, but will not differ from controls in her ability to discriminate eyeglasses that do not share the same structural description.

Method

Participants

The participants who where in the previous experiments also participated in Experiment 3.

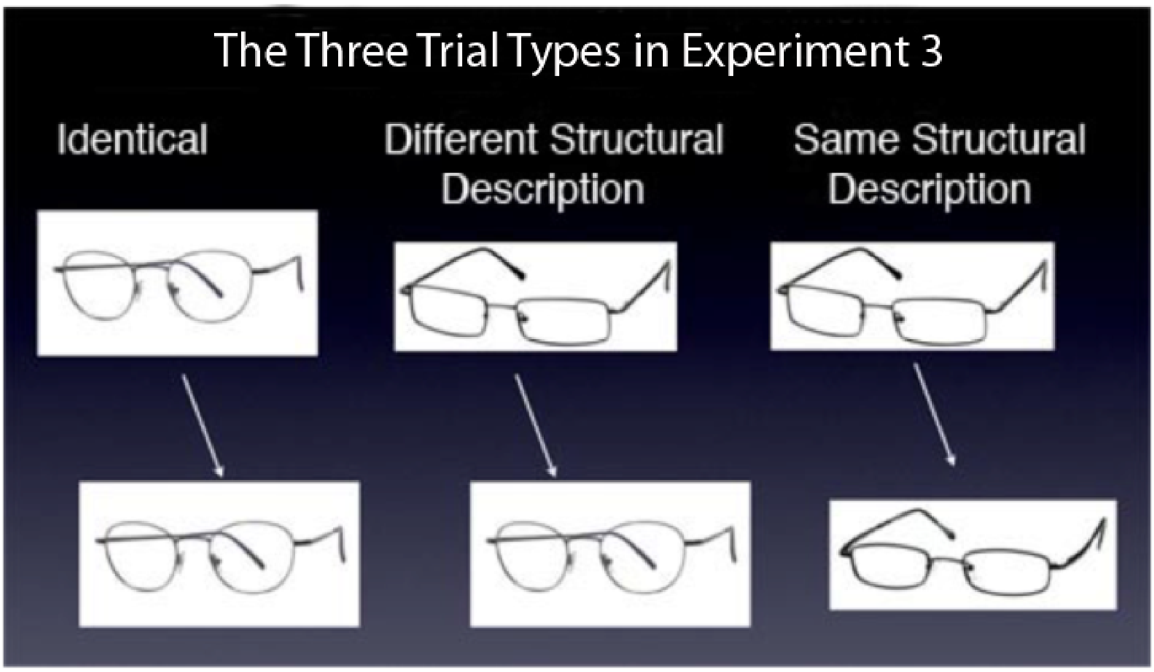

Figure 9. Examples of the three types of trials in Experiment 3. In the different structural description discrimination trial, illustrated above, the rectangular shaped eyeglasses were compared to the oval shaped eyeglasses. In contrast, in the same structural description discrimination trial, illustrated above, both eyeglasses being compared are rectangular shaped.

Apparatus

All apparatus except the visual stimuli were identical to those that were used in Experiment 1. The visual stimuli in this experiment were made up of 16 photographs of eyeglasses all taken from the same viewpoint. Half of the eyeglasses that were obtained were rectangular and the other were round. All eyeglasses that were obtained for Experiment 3 were wire-rimmed.

Procedure

Presentation of the stimuli was self-paced. Participants pressed any key to begin each trial. Upon pressing any key, a fixation cue was presented for 500 msec, followed by the presentation of one pair of eyeglasses for 1000 msec, followed by a pattern mask for 500 msec, followed by a second pair of eyeglasses that remained on the screen until the subject responded (see Figure 10). The second pair of eyeglasses was randomly presented at one of four possible locations on any trial (either 1.5° of visual angle above and 1.5° of visual angle to the right, 1.5° of visual angle above and 1.5° of visual angle to the left, 1.5° of visual angle below and 1.5° of visual angle to the right, or 1.5° of visual angle below and 1.5° of visual angle to the left of the fixation point) and all four locations were presented equally often. Displacing the second set of eyeglasses from the first prevented participants from simply using the height or width of the second pair of eyeglasses as an indicator of whether or not the pairs of eyeglasses were identical. In half of the trials the two eyeglasses presented were physically identical. For the trials in which the eyeglasses were not identical, on fifty percent of the trials the eyeglasses differed only metrically (i.e., round glasses followed by round or rectangular glasses followed by rectangular), while on the other 50% of the trials, the two eyeglasses had different structural descriptions (i.e., rectangular glasses followed by round or round glasses followed by rectangular).

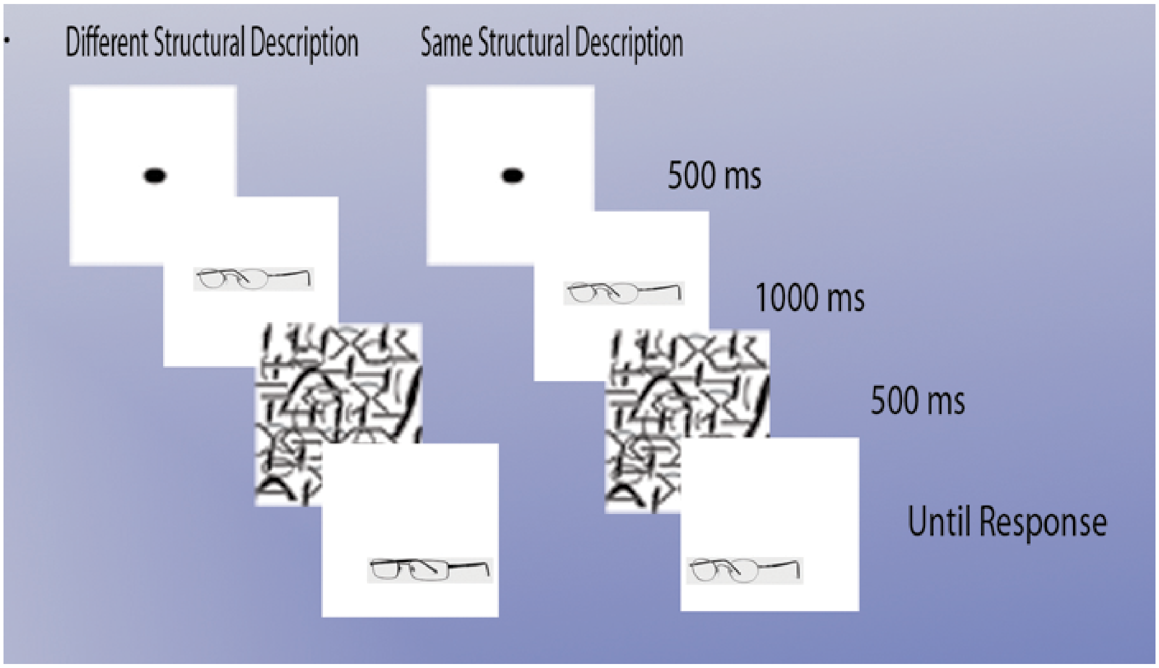

Figure 10. Examples of different trials in Experiment 3. Half of the different trials consisted of two sets of eyeglasses that did not share the same structural description, while the remaining different trials consisted of two sets of eyeglasses that shared the same structural description.

On each trial, the participants' task was to indicate whether the two eyeglasses presented were physically identical (by pressing the "z" key) or different (by pressing the "/" key). Participants were provided with written accuracy feedback following each trial. Participants pressed any key to begin the subsequent trial.

The experiment consisted of 256 trials. On half of the trials the two eyeglasses presented were physically identical (each of the 16 eyeglasses was be shown back-to-back in eight separate identical trials for a total of 128 identical trials). In the remaining trials, each of the 16 eyeglasses were compared to four different eyeglasses that shared the same structural description and to four different eyeglasses that had different structural descriptions. The ordering of the trials was determined randomly, but the order was identical for all subjects. All participants completed a series of ten practice trials prior to the actual experiment. None of the practice images were presented in the actual trials.

Results

As in Experiments 1 and 2, a modified *t*-test was used for all comparisons of LB to the controls. Furthermore, although sensitivity and response bias could technically be measured in Experiments 3 and 4, they were not calculated principally because I was only interested in the different trials of Experiments 3 and 4 (i.e., the two different-trial conditions, same structural description or different structural description).

Accuracy Data

The accuracy data from the different trials of Experiment 3 can be seen in Figure 11. The standard error for the identical eyeglass comparisons of accuracy was 4.24. The age-matched control's mean accuracy for the identical trials did not significantly differ from the controls' mean accuracy for the identical trials, *t*(15)= -.73, *p* >.05. Further, LB's mean accuracy for the identical trials did not significantly differ from the controls' mean accuracy for identical trials, *t*(15)= -.47, *p* >.05.

Analysis revealed that the age-matched control's difference in mean accuracy between the different structural description and same structural description trials was not significantly different from the controls' difference in mean accuracy between the different structural description and same structural description trials, *t*(15)= .86, p>.05. The standard error for the same structural description trials was 4.94 and the standard error for the different structural description comparisons of eyeglasses was 3.65. Comparisons of the age-matched control's mean accuracy relative to controls' in the different structural description discrimination trials, *t*(15)= .88, p>.05, and same structural description discrimination trials, *t*(15)= .29, p>.05, failed to reach significance. Analysis revealed that LB's difference in mean accuracy between the different structural description and same structural description trials was significantly greater than the difference in the controls' mean accuracy rate between the different structural description and same structural description trials, *t*(15)= 2.18, p<.05. Comparisons of LB's mean accuracy relative to controls' in the different structural description discrimination trials, *t*(15)= -1.31, p>.05, and same structural description discrimination trials, *t*(15)= -1.25, p>.05, failed to reach significance.

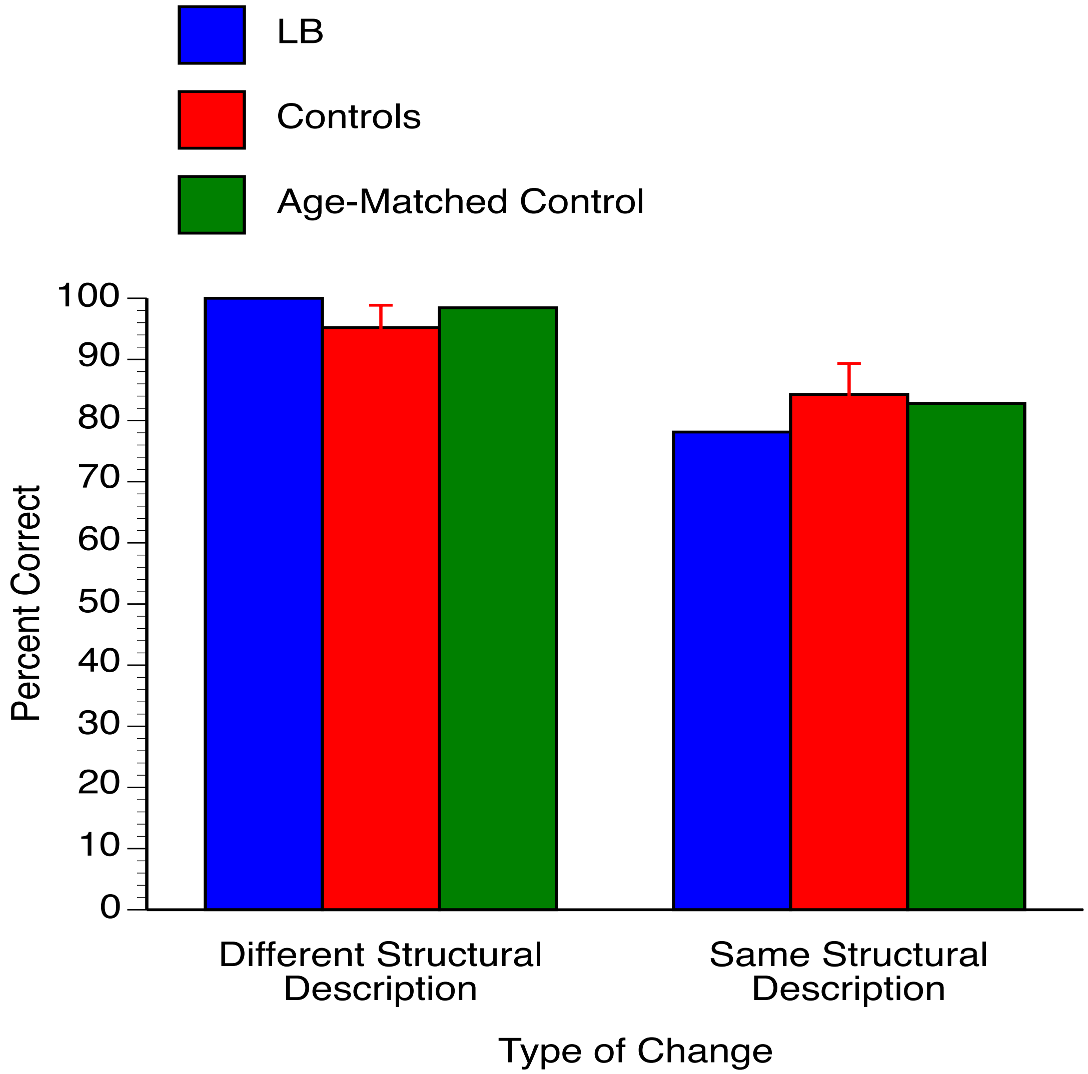

Figure 11. Accuracy data from the different trials of Experiment 3 (standard error bars are displayed for the controls).

Reaction Time Data

The mean reaction time for the correct identical, different structural description, and same structural description trials for the controls, the age-matched control, and LB are reported in Table 3. All comparisons of the age-matched control's mean reaction time to that of the student controls' mean reaction time were not significantly different. Analysis of LB's difference in mean reaction time between the same structural description and different structural description discrimination trials was significantly different than the difference in the controls' mean reaction time between the same structural description and different structural description discrimination trials $t(15)$ 2.12, $p<.05$. Analysis of LB's mean reaction time for the same structural description trials was not significantly different from the controls' mean reaction time for the same structural description trials, $t(15)$ 1.89, $p>.05$. Further, LB's mean reaction time for the different structural description trials was not significantly different from the controls' mean reaction time for the different structural description trials, $t(15)$ 1.58, $p>.05$. The mean reactions times for LB and the controls' tended to be slower for the same structural description trials than the different structural description trials—suggesting that the observed pattern in the error data was not due to a speed-accuracy trade-off.

Table 3

Mean Reaction Time (msec) *for Identical, Different, and Same Structural Discrimination Trials for LB and Controls from Experiment 3*

	LB	Age-matched Control	Control
	M	*M*	*M (SE)*
Identical	626	1677	857 (216.61)
Different Structural Description	1187	580	834 (223.70)
Same Structural Description	1336	631	871 (246.44)

Discussion

As the coordinate hypothesis predicts and consistent with previous studies examining LB's visual deficits (Casner, 2006), LB had greater impairment on the same structural description trials than the different structural description trials relative to controls. Of the three experiments performed thus far, Experiment 3 is the only experiment that allowed me to directly control for structural descriptions of the eyeglasses that are being compared at the time of response. When the eyeglasses did not share the same structural description, consistent with Farah et al. (1995) and the coordinate relations hypothesis, LB's accuracy did not differ from the controls. Nonetheless, Farah et al. (1995) posited that prosopagnosics are not impaired in within-category discrimination tasks; however, our results suggest that prosopagnosics can be impaired in within-category discrimination tasks requiring prosopagnosics to discriminate within-category objects that share the same structural description. Consequently, the coordinate relations hypothesis predicted the results obtained in Experiment 3, whereas the hypothesis of Farah et al. did not.

Experiment 4

In Experiment 3, because the stimuli were drawn from photographs, it is possible that participants were making their discriminations by using aspects of the stimulus other than the shapes of the lenses (e.g., differences in illumination or texture). In order to control for any extraneous variables (other than lens shape) that may have been used to differentiate the eyeglasses in Experiment 3, Experiment 4 used line drawings of eyeglasses. In this experiment the only variable that changed within the two types of different trials was the shape or size of the lenses (see Figure 12).

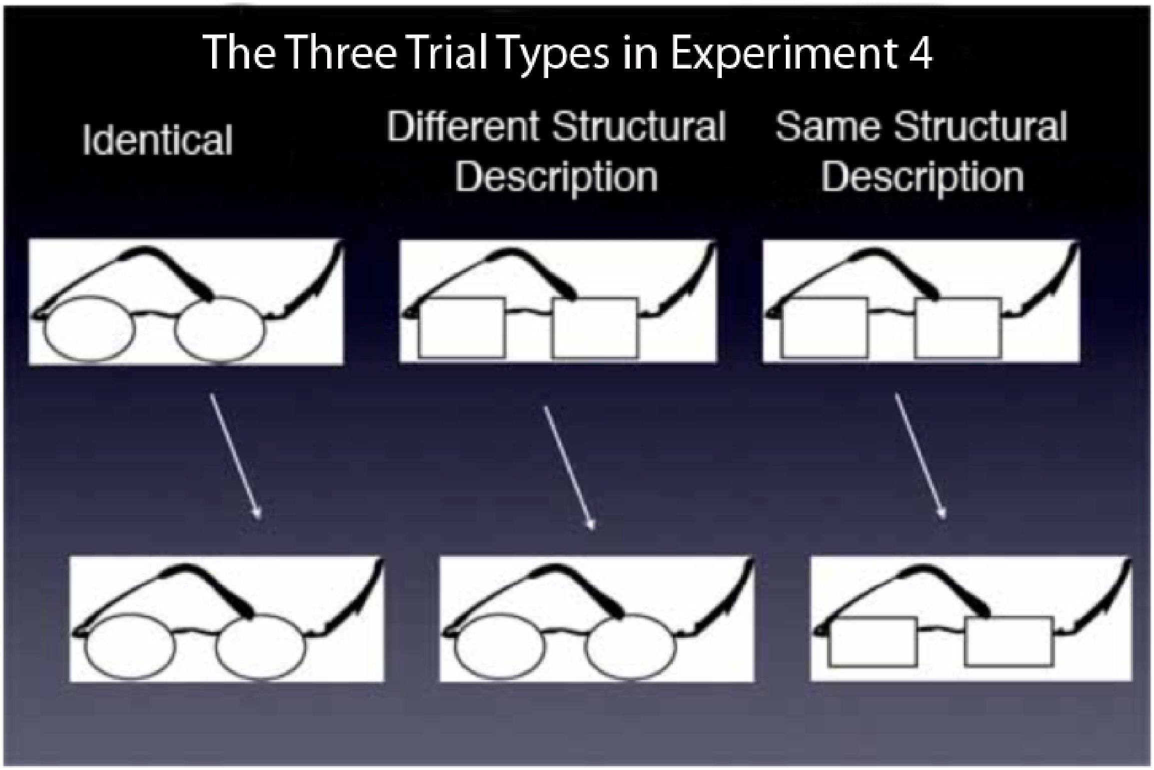

Figure 12. Examples of the three types of trials used in Experiment 4. In the different structural description discrimination trial shown above, the rectangular shaped eyeglass lens is compared to an oval shaped eyeglass lens. In contrast, in the same structural description discrimination trial shown above, both eyeglass lenses being compared are rectangular shaped and differ only in their size.

Method

Participants

The participants who were in the previous experiments also participated in Experiment.

Apparatus

All materials except the visual stimuli were identical to those that were used in Experiment 3. Figure 12 illustrates the different structural descriptions and metric changes that were used in this experiment. A total of 24 grayscale line drawings of eyeglasses were used (6 structural descriptions X 2 ear pieces X 2 metric variations).

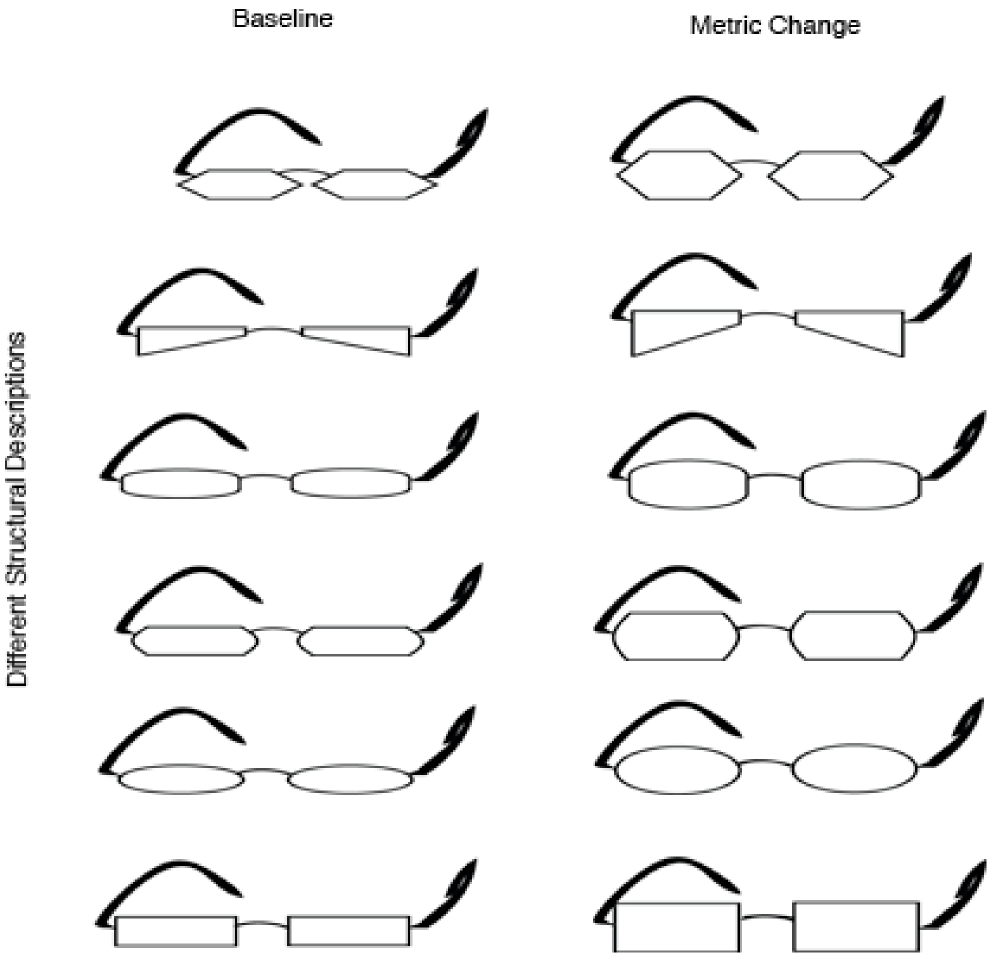

Figure 13. Examples of the six different structural descriptions that were used for this experiment and their corresponding metric changed versions.

Procedure

All procedures in Experiment 4 were identical to the procedures used in Experiment 3 unless noted otherwise. The experiment consisted of 192 trials. In half of the trials (96) the two pairs of eyeglasses were physically identical. In the remaining trials, each of the 24 eyeglasses were compared to a different pair of eyeglasses that shared the same structural description but differed metrically and to a different pair of eyeglasses that had a different structural description (see Figure 14). Upon completion of all 48 different trials, the different trials were repeated a second time (96 total different trials). The ordering of the trials was determined randomly, but the order was identical for all subjects. All participants completed a series of eight practice trials prior to the actual experiment. None of the practice images were presented in the actual trials.

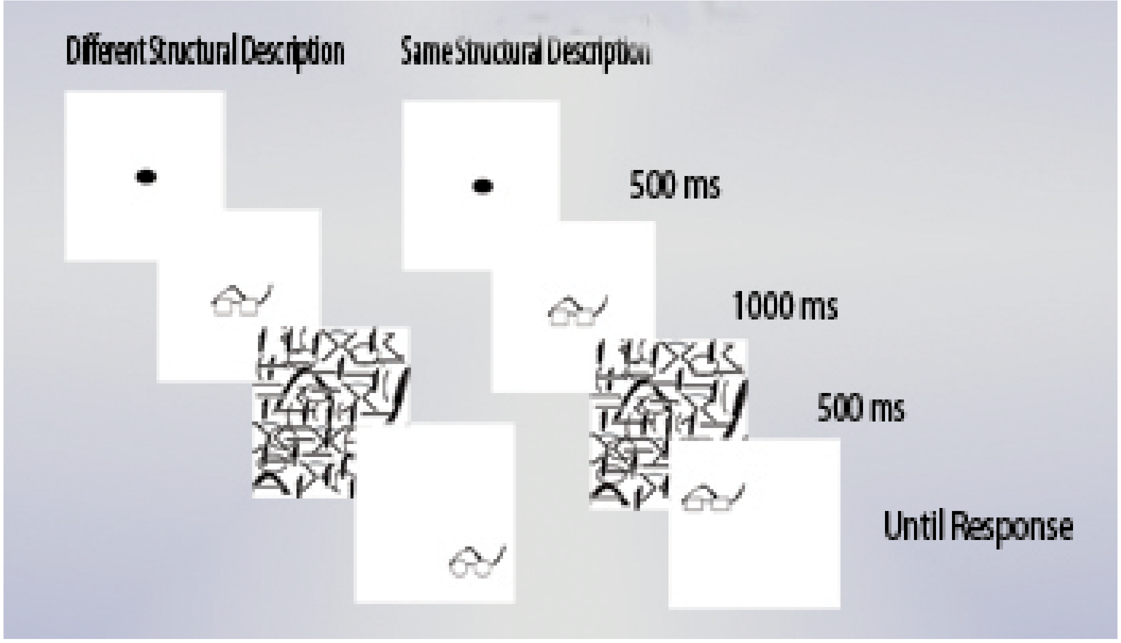

Figure 14. Examples of different trials in Experiment 4. Half of the different trials consisted of two sets of eyeglasses that did not share the same structural description, while the remaining different trials consisted of two sets of eyeglasses that share the same structural description.

*Result*s

Accuracy Data

The accuracy data from the different trials of Experiment 4 can be seen in Figure 15. The standard error for the identical eyeglass comparisons of accuracy was 5.04. The age-matched control's mean accuracy for the identical trials did not significantly differ from the controls' mean accuracy for the identical trials, *t*(15)= -.579, *p*>.05. Further, LB's accuracy for the identical trials did not significantly differ from the controls' accuracy for identical trials, *t*(15)=1.54, *p*>.05.

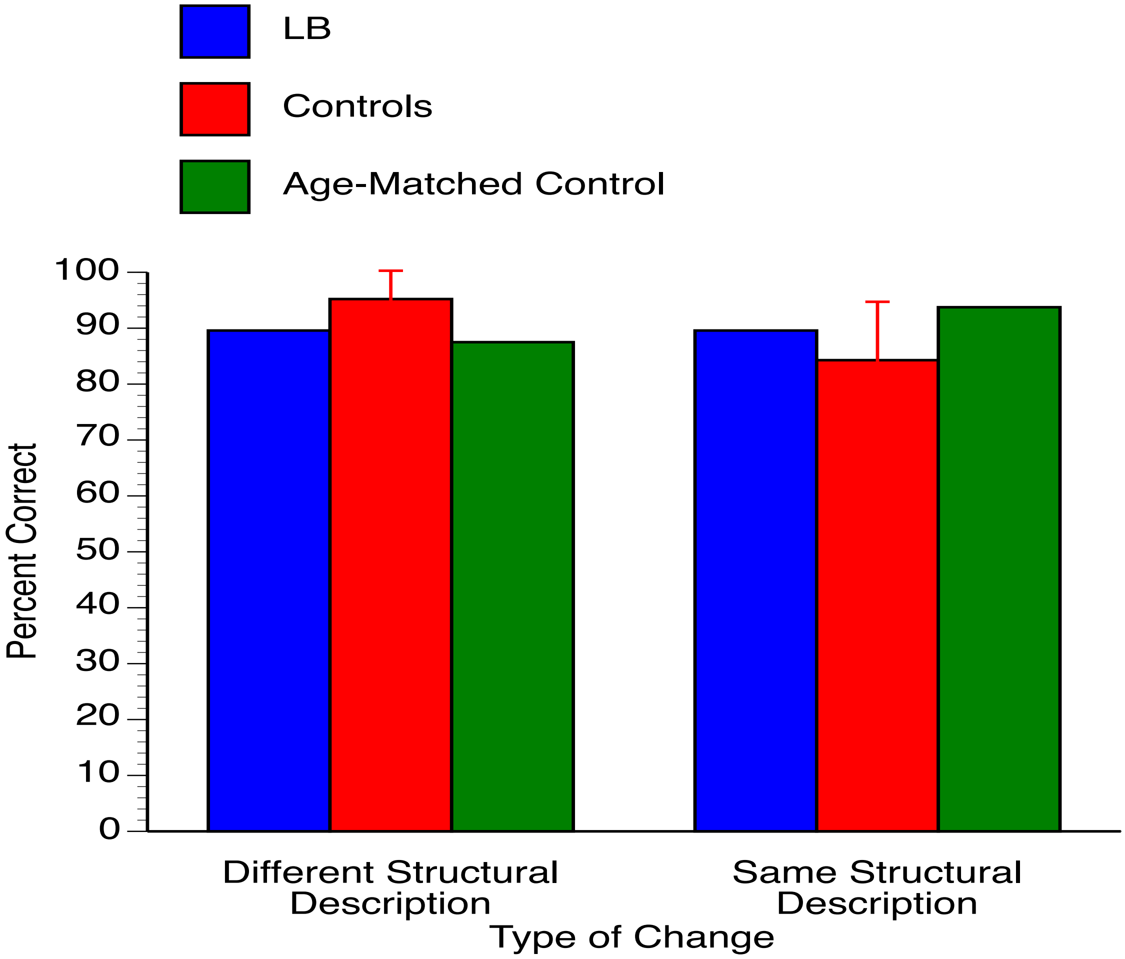

Figure 15. Accuracy data from the different trials of Experiment 4 (standard error bars are displayed for the controls).

Analysis revealed that the age-matched control's difference in mean accuracy between the different structural description and same structural description trials was not significantly different from the controls' difference in mean accuracy between the different structural description and same structural description trials, *t*(15)= -1.34, p>.05. The standard error for the same structural description trials was 10.44 and the standard error for the different structural description comparisons of eyeglasses was 5.07. Comparisons of the age-matched control's mean accuracy relative to controls' in the different structural description discrimination trials, *t*(15)= 1.52, p>.05, and same structural description discrimination trials, *t*(15)= -.97, p>.05, failed to reach significance. Analysis revealed that LB's difference in mean accuracy between the different structural description and same structural description trials was not significantly different from the controls' mean accuracy difference between the different structural description and same structural description trials, *t*(15)= .73, p>.05. Comparisons of LB's mean accuracy relative to controls' in the different structural description discrimination trials, *t*(15)= -1.11, p>.05, and same structural description discrimination trials, *t*(15)= .51, p>.05, failed to reach significance.

Reaction Time Data

The mean reaction time for the correct identical, different structural description, and same structural description trials for the controls, the age-matched control, and LB are reported in Table 4. All comparisons of the age-matched control's mean reaction time to the student controls' mean reaction time were not significantly different. Analysis of LB's difference in mean reaction time between the same structural description and different structural description discrimination trials was not significantly different than the difference in the controls' mean reaction time between the same structural description and different structural description discrimination trials, *t*(15) 1.21, *p*>.05. Analysis of LB's mean reaction time for the same structural description trials was significantly different from the controls' mean reaction time for the same structural description trials, *t*(15) 2.91, *p*<.05. Further, LB's mean reaction time for the different structural description trials were not significantly different from the controls' mean reaction time for the different structural description trials, *t*(15) 2.07, *p*>.05.

Table 4

Mean Reaction Time (msec) *for Identical, Different, and Same Structural Discrimination Trials for LB and Controls from Experiment 4*

	LB	Age-matched Control	Control
	M	*M*	*M (SE)*
Identical	2903	1640	1865 (216.61)
Different Structural Description	2353	1634	1914 (211.69)
Same Structural Description	2466	1634	1876 (202.55)

Discussion

In contrast to Experiment 3, LB did not produce significantly more errors in the same structural description trials than the different structural description trials relative to controls. These results are peculiar when one considers a previous eyeglass experiment using the same experimental paradigm and very similar line drawings of eyeglasses (see Figure 15 for previous results from Kahl, Cooper, O'Brien, & Scolaro, 2007). In this experiment, Kahl et al. found a significant interaction, in which LB made significantly more errors for the same structural description trials than the different structural description trials relative to controls. Upon completion of Experiment 4, I interviewed LB and asked her about her thoughts on the experiments. LB informed me that she developed a strategy for the eyeglasses in which she ignored the eyeglass as a whole and fixated only the lenses of the eyeglasses being compared. Unfortunately, I did not anticipate such a strategy when creating the stimuli and therefore did not change any other part of the eyeglasses being compared other than the lens frames. In order to resolve this anomaly all subsequent experiments that are performed with LB need to be designed in such a manner that prevents her from fixating on one part of an object.

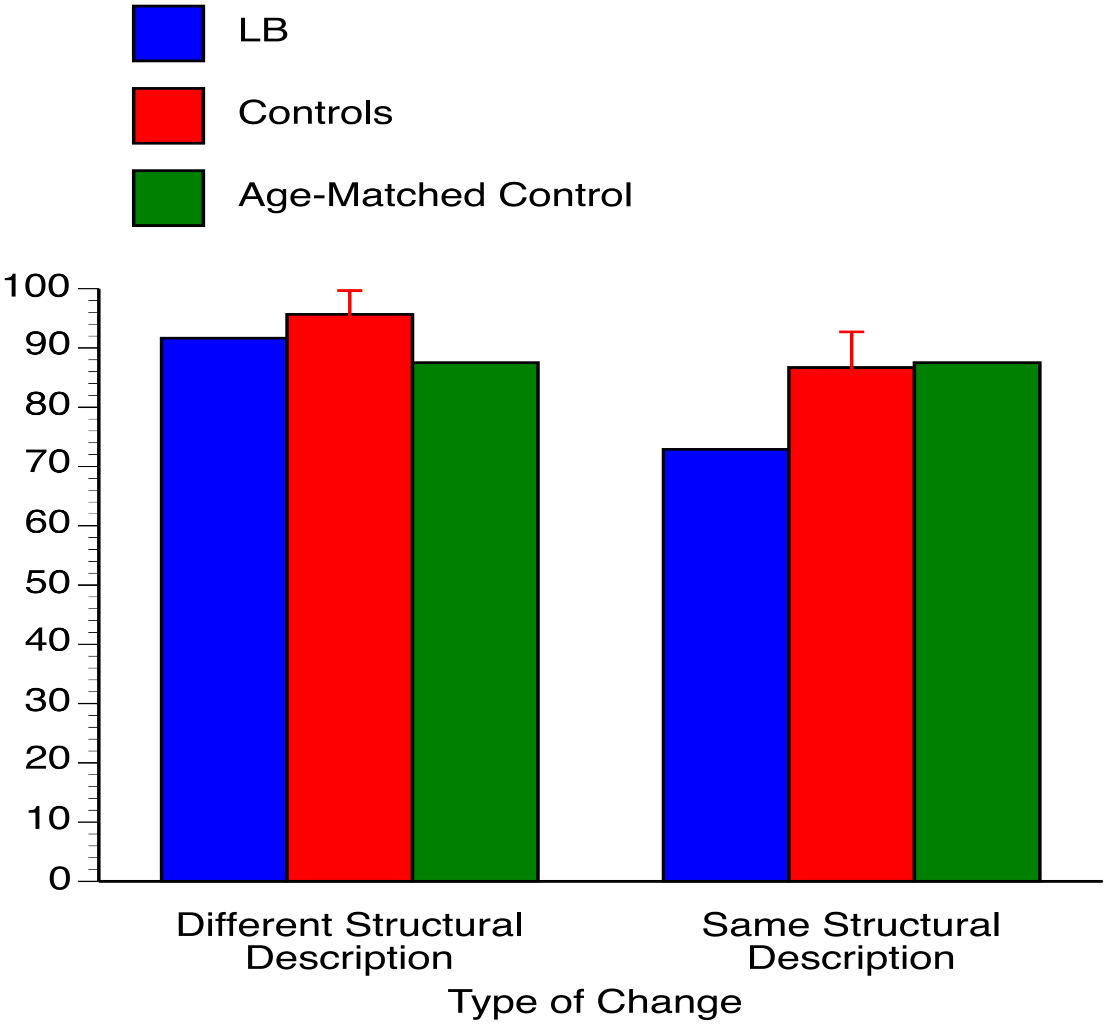

Figure 16. Accuracy data obtained in an earlier experiment (Kahl, Cooper, O'Brien, & Scolaro, 2007) using the same type of eyeglass stimuli (standard error bars are displayed for the controls).

GENERAL DISCUSSION

Four experiments were conducted to test a prosopagnosic, LB, relative to controls in her ability to discriminate eyeglass and face stimuli. Experiment 1 attempted to directly replicate Farah et al.'s (1995) eyeglass experiment. The results obtained from this experiment paralleled the results Farah et al. obtained. The results showed that LB's mean accuracy was only differed from the controls' mean accuracy in the face condition; she did not differ from the controls in her ability to discriminate "old" and "new" eyeglasses. However, the results obtained in Experiment 1 and Farah et al. may have been an artifact of a floor effect. Therefore, Experiment 2 was designed to raise the control subjects' performance off the floor. In contrast to Experiment 1, Experiment 2 failed to find a significant interaction between stimulus type and subject group. Experiment 2's results suggest the results of Experiment 1 and the results obtained by Farah et al. may be a consequence of a floor effect on the controls.

The experimental paradigm of Experiments 1 and 2 placed a greater demand on long-term memory, requiring participants to store multiple face and eyeglass stimuli in memory until the stimulus in memory was presented during the test phase of the experiment. Consequently, I could not determine what the structural descriptions of the eyeglasses were that participant had in memory, from the learning phase, at the time of the participants' response to test phase stimuli.

Unlike Experiments 1 and 2, Experiments 3 and 4 used a different experimental paradigm that controlled for the structural descriptions of the eyeglasses being compared. Experiment 3 revealed that LB made significantly more errors in the same structural description condition than the different structural description condition relative to both the age-matched control and the student control group. These results are consistent with previous studies (Casner, 2006; Kahl et al., 2007) in which LB made significantly more errors than controls on tasks that required her to discriminate two objects that shared the same structural description compared to when they did not share the same structural description.

Inconsistent with previous studies, and the coordinate relations hypothesis, LB's mean accuracy did not significantly differ from the controls in either the same or different structural description conditions of Experiment 4. However, upon completion of Experiment 4, LB indicated the she began fixating only on the lens frames instead of the entire eyeglass when discriminating different eyeglasses. As a result of this strategy, LB did not have to use a structural description (i.e., parts AND relations) to determine whether or not two eyeglasses that were presented were the same or different. Future experiments with LB will need to ensure that LB does not use such a strategy.

Support for the Coordinate Relations Hypothesis

A number of the present study's findings are consistent with the coordinate relations hypothesis. First, Experiment 2 demonstrated that when the controls' mean accuracy from Experiment 1 was raised above the floor, LB's accuracy did not change. In other words, LB showed a deficit with remembering eyeglasses that was comparable to her deficit with remembering faces. Although this result does not directly support the coordinate relations hypothesis (e.g., the structural descriptions of the eyeglasses being compared was not controlled for), it does contradict Farah et al.'s results in which she found a significant interaction; they reported that LH made significantly more errors in the face condition than the eyeglass condition relative to controls. Second, Experiment 3 demonstrated that LB made significantly more errors discriminating eyeglasses with the same structural description than eyeglasses that had different structural descriptions relative to controls.

Results Contrary to the Predictions Made by the Coordinate Relations Hypothesis

Although a number of the current studies' results support the predictions made by the coordinate relations hypothesis, one cannot dismiss the results that contradicted the predictions made by the coordinate relations hypothesis. First, the results obtained in Experiment 1 were virtually identical to the results of Farah et al. (1995) with the prosopagnosics showing a greater deficit in remembering face then remembering eyeglasses, and suggested that prosopagnosia is a face specific deficit—not a deficit in discriminating objects sharing the same structural description. However, as demonstrated by the results reported in Experiment 2, in which the controls were raised off the floor, the results obtained in Experiment 1 appear to be an artifact of a floor-effect. Further, if one looks at the accuracy of the controls for the eyeglass condition in Farah et al.'s experiment (Figure 7), it is possible that their reported interaction was an artifact of floor effects as well. Evidence to support this prediction is provided by Levine and Calvanio (1989) who had previously tested Farah et al.'s patient LH, and who reported that LH could only identify objects having unique distinguishable features (e.g., basic-level objects that did not share same visual features such as a chair and a hammer).

Second, contrary to the predictions made by the coordinate relations hypothesis, LB's mean accuracy in discriminating pairs of eyeglasses that shared same structural description were not different from LB's mean accuracy in discriminating pairs of eyeglasses with different structural descriptions in Experiment 4. Note, however, that this result contrasts with that of Experiment 3 in which LB showed significantly more difficulty discriminating eyeglasses that shared the same structural description than discriminating eyeglasses that did not. Furthermore, the results also contradict the earlier findings of Kahl et al. (2007). Based on a post-experiment interview with LB, Experiment 4's inconsistencies with Experiment 3 and the findings of Kahl et al. may be the result of the strategy that LB began using in the latter experiment, in which she fixated on only the lenses' of the eyeglasses being compared and ignored all other parts.

LB's ability to discriminate lenses of similar shapes in Experiment 4 appears to contradict the coordinate relations hypothesis; however, given the strategy LB reported adopting, there are a few possible explanations for her performance that would not contradict the coordinate relations hypothesis. First, based on the results of Experiments 1 and 2, LB's face recognition system is not completely damaged. Therefore, she could be using the vestiges of her face recognition system to perform the eyeglass discrimination tasks. Second, it is possible that LB only detected a change in the size of the visual field that the lens occupied and that she did not process the eyeglass or lens as an object. Unfortunately, none of the current experiments allow us to test these hypotheses, but in any case, the results reported in Experiment 4 do not necessarily contradict the coordinate relations hypothesis.

Future Directions

Overall, the results from the current study, suggest that the deficits found in prosopagnosics are not face-specific. Converging evidence (suggesting that prosopagnosia is not a face-specific disorder) is provided by Gauthier, Behrmann, and Tarr (1999) who tested two prosopagnosics' (SM and CR) ability to discriminate faces and non-face objects that were compared at different levels of categorization (i.e., subordinate-level and basic-level categorization). Gauthier et al. found that both prosopagnosics were impaired in discriminating objects that were visually similar—regardless of category. The current study tested Farah et al.'s (1995) hypothesis that prosopagnosia is a face-specific deficit and a number of the results reported here suggest that prosopagnosia is not a face-specific deficit, rather it is an impairment in discriminating objects that share the same structural description.

Subsequent studies examining the types impairments associated with prosopagnosia can benefit by considering the structural descriptions of the stimuli that are being used. One implication of the current set of experiments is that therapy for prosopagnosics might benefit from encouraging the prosopagnosic to use visual features that would be discriminable by the structural description recognition system.

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