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Do prosopagnosics have impaired spatial coding within or between objects?

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Do prosopagnosics have impaired spatial coding within or between objects?

by

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A thesis submitted to the graduate faculty
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

Major: Psychology

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2008

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ABSTRACT

Barton and Cherkasova (2005) tested within-object and between-object spatial abilities of patients with prosopagnosia and concluded that prosopagnosia is the result of within-object spatial impairment. The interpretation of these findings is difficult as Barton and Cherkasova's (2005) experimental design involved a major confound of using smaller distances in the within-object task and larger distances in the between-object task. The present study used the same distances on between-object and within-object spatial discrimination tasks in an attempt to replicate the findings of Barton and Cherkasova (2005). Experiments 1 and 2 were designed to test within-object and between-object spatial processing of faces and objects, respectively, in prosopagnosia using the between-object spatial distances from Barton and Cherkasova (2005) while Experiments 3 and 4 tested these impairments using the within-object spatial distances from the original study. The experiments failed to find a difference in between-object and within-object spatial processing in a prosopagnosic.

INTRODUCTION

One important distinction in vision research has been of spatial versus object coding. In order to properly interact with the environment, individuals need to know both the location of objects in the environment (spatial coding) as well as the identity of objects in the environment (object coding). Ungerleider and Mishkin (1982) found a double dissociation between object recognition and the spatial coding of objects in monkeys and hypothesized the neuronal mechanisms responsible for the two types of processing: an occipitotemporal pathway for object recognition and an occipitoparietal pathway for spatial coding. The distinction between object and spatial coding was not a new discovery (Ingle, 1967; Held, 1968); however, previous researchers posited that the brain areas responsible for the two processes were the geniculostriate and tectofugal pathways (Schenider, 1967; Trevarthen, 1968) rather than the occipitotemporal and occipitoparietal pathways.

The hypothesis that cortico-cortical pathways were the neural mechanisms of object and spatial coding was based on studies from brain damaged individuals. Individuals with damage to the temporal lobe are impaired at object recognition tasks (Milner, 1958; Kimura, 1963; Meadows, 1974) whereas individuals with damage to the parietal lobe are impaired at spatial coding tasks (McFie, Piercy, & Zangwill, 1950; Semmes, Weinstein, Ghent, & Teuber, 1963; De Renzi & Faglioni 1967). The visual impairments in individuals with brain damage to the temporal and parietal lobes indicate that there are neuronal connections between the occipital lobe and temporal/parietal lobes and demonstrate the importance of the temporal and parietal lobes in object recognition and spatial coding, respectively.

Flechsig (1896) was the first to describe the emergence of the two cortical pathways from the occipital lobe. One pathway was described as projecting dorsally from the occipital lobe to the posterior parietal lobe (dorsal/occipitoparietal pathway) while the other pathway was described as projecting ventrally from the occipital lobe to the temporal lobe (ventral/occipitotemporal pathway). Ungerleider and Mishkin (1982) posited that the dorsal and ventral pathways are the pathways responsible for object recognition and spatial coding respectively and that these pathways are damaged in individuals suffering from impairments in object recognition and spatial coding due to brain damage to the temporal lobe or parietal lobe. Furthermore, Ungerleider and Mishkin (1982) used ablation studies in rhesus monkeys to demonstrate a double dissociation between the dorsal and ventral pathways. They found that monkeys with damage to the parietal lobe were impaired at spatial discrimination tasks but were not impaired at object recognition tasks. In addition, monkeys with damage to the temporal lobe were impaired at object recognition tasks but performed normally on spatial discrimination tasks. Thus, Ungerleider and Mishkin provided more evidence for the distinction between object and spatial coding, which allowed researchers to gain a better understanding of how humans form visual representations.

Recently, Humphreys (1998) made a further distinction within the domain of spatial coding that demonstrated that spatial coding was comprised of at least two parallel forms of visual representations with one being used for coding the spatial relations between separate objects (between-object representation) and the other being used for coding the spatial relations of the parts of a single object (within-

object representation). A between-object spatial representation is crucial for directing action to objects as well as remembering the location of objects for future reference (Milner & Goodale, 1995). In order to interact with an object in the environment, an individual must encode the location of the object in the environment so that attention can be focused towards that object. A within-object representation is crucial for object recognition because it requires the extraction of the spatial locations of the primitives that make up the representation of an object (Marr, 1982). For example, a within-object spatial representation would allow an individual to tell the difference between a mug and a pail. Both have a cylinder and an attached curved cylinder; however, a pail has the curved cylinder located above the cylinder while a mug has a curved cylinder located to the side of the cylinder.

The importance of spatial coding during object recognition is demonstrated in the use of within-object spatial representations by the object recognition system. Cave and Kosslyn (1993) showed that proper spatial relations among component parts of an object are vital for proper identification of that object. The results of the Cave and Kosslyn study along with the findings of the Humphreys (1998) study show the importance of spatial coding in object recognition, so any theory of object recognition must posit some way of specifying the spatial relations of the primitives that make up the representation of an object.

The Coordinate Relations Hypothesis

The coordinate relations hypothesis (Cooper & Wojan, 2000) is a theory of how the representations used for basic level object recognition and face recognition differ. It posits that there are two separate ways of coding relations in the

representations used for recognition: a categorical relations system and a coordinate relations system. Structural description theories hold that objects are represented in the visual system as a collection of geons (simple volumetric primitives) that correspond to the parts of an object; furthermore, the locations of these geons are characterized using categorical relations such as “side-of”, “above”, and “below” (Biederman, 1987; Hummel and Biederman, 1992). These categorical relations do not encode specific distances, rather the spatial location of parts of objects relative to one another are encoded. In addition to encoding the location of the visual primitives, the categorical relations system is hypothesized to encode the relative orientation of primitives relative to one another using “oblique to”, “parallel to” and “perpendicular to” as well as the relative size of the primitives using “larger than”, “equal to” and “smaller than”. Figure 1 shows an example of how the categorical relations system might represent the visual primitives of the face (which, for the purpose of this paper, are defined as two eyes, a nose and a mouth). In this example, the left eye would be encoded as being to the side-of the right eye, above and to the side-of the nose, and above and to the side-of the mouth.

Categorical Relations



**Left eye side-of the right
eye, above and side-of the
nose, above and side-of
the mouth.**

Figure 1. The spatial location of visual primitives (for example, the left eye) may be encoded by the categorical relation system as shown in this illustration. In addition, the relative size of the left eye might be encoded as equal to the right eye and the relative orientation of the left eye might be encoded as parallel to the right eye.

The categorical relations system allows objects to be categorized quickly in a view invariant manner. Even if the object is rotated, changes size, or changes orientation in depth up to partial occlusion, the same categorical representation of that object would apply. For example, a categorical representation would very quickly be able to categorize any human face correctly as a face even if the face was not seen from a directly frontal view. Categorical representations have been hypothesized to be located in the dorsal stream, which needs to make use of spatial relations that remain constant under a large variety of configurations of an object (Kosslyn, 1987).

The second system posited by the coordinate relations hypothesis is the coordinate relations system. Whereas the categorical relations system encodes relative locations of visual primitives, the coordinate relations system encodes specific metric distances between the visual primitives in the representation and some fixed reference point and is presumed to be important for face recognition. Figure 2 shows how the coordinate system would code the location of the left eye. In this example, the coordinate relations system would code the location of the left eye as 5 units above and 3.5 units to the right of the reference point.

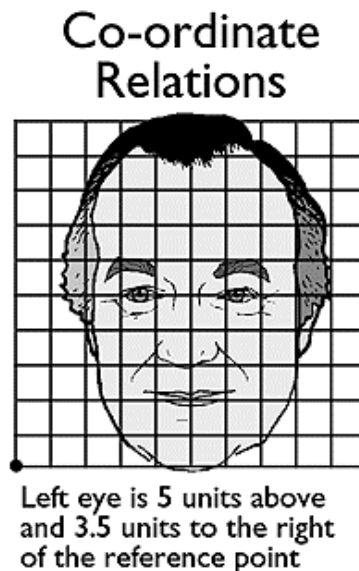


Figure 2. This illustration depicts how spatial location of the visual primitives of the face (in this case the left eye) would be coded by the coordinate relations system.

According to the coordinate relations hypothesis, the coordinate relations system would be utilized anytime an individual is distinguishing two objects with the same categorical representation. For example, if an individual were trying to

distinguish the two coffee mugs in Figure 3, the coordinate relations system would be used because the two coffee cups share the same categorical relations. Both cups are composed of a cylinder with a curved cylinder to the side of the cylinder; however, the cups have subtle differences in their metric sizes which would require the coordinate relations system to distinguish the two cups. The coordinate relations system has been hypothesized to be located in the ventral stream, which is used for discriminating similar objects (Kosslyn, 1987).



Figure 3. Illustration of two coffee mugs that share the same categorical relations but differ in their coordinate relations.

Because the coordinate relations hypothesis holds that there are two recognition systems, coordinate and categorical, an important question is how does an individual decide which recognition system to use? Previous researchers have theorized that a structural description system, such as the categorical relations system posited by Cooper and Wojan (2000), would be much faster than the coordinate relations systems because the coordinate relations system needs to code the precise distance between visual primitives and normalize the input to a standard

size, orientation and position (Ullman, 1989). These additional time consuming tasks that the coordinate relations system must perform result in a slower, less efficient recognition process. Thus, according to the coordinate relations hypothesis, the categorical relations system is more efficient than the coordinate relations system as it does not need to compute exact metric distances. The recognition system utilized during a recognition task depends on the computational demands of a task.

According to the coordinate relations hypothesis, if two objects differ in their structural descriptions, the categorical relations system will be used because it is more efficient; however, if two objects share the same structural descriptions, the coordinate relations system would be used because the categorical relations system would be unable to perform this task.

Prosopagnosia

Neuropsychological studies with prosopagnosic patients are particularly interesting to researchers studying the coordinate relations hypothesis as this hypothesis posits that prosopagnosics should have difficulties performing tasks that require the coordinate relations system (most notably face recognition). Thus, prosopagnosia is a useful tool for examining the coordinate relations system.

Prosopagnosia is classically defined as the inability to discriminate familiar faces despite no impairments in low level visual processing in individuals with otherwise normal intellectual functioning and relatively normal object recognition in categories other than faces (Bodamer, 1947). Individuals with prosopagnosia can use characteristics other than vision to identify people, such as hair style, gait, voice, birth marks, and glasses. Despite impairments in facial recognition, prosopagnosics

are able to make other fine visual discriminations such as those required to read. Prosopagnosia is extremely rare in the general population as well as among individuals with neurological and psychological impairments. For example, a study of 382 patients with posterior cerebral artery lesions only found prosopagnosia among 6% of the patients (Hecaen & Angelergues, 1962).

Brain damage to the posterior cerebral cortex is the cause of prosopagnosia (Damasio et al, 1982). Although encephalitis, tumors, blunt force trauma to the head and surgical lesions can cause prosopagnosia, the most common types of brain damage are arterial infarcts to the posterior cerebral artery or hemorrhage in the infero-medial part of the temporo-occipital area (Mayer & Rossion, 2007). The lesions causing prosopagnosia are located in the inferomedial portion of the temporo-occipital cortex, the fusiform gyrus, the lingual gyrus and the posterior part of the parahippocampal gyrus (Damasio, Damasio, & Van Hoesen, 1982). Using imaging studies with PET and fMRI, researchers have found two small areas, the inferior occipital gyrus (IOG) and the lateral part of the middle fusiform gyrus (MGF), within the large cortical areas lesioned in prosopagnosia that respond preferentially to faces as compared to other object classes (Kanwisher, McDermott, & Chun, 1997; Sergent, Otha, & MacDonald, 1992). Further analysis of these areas has revealed that damage to the right IOG is sufficient to cause prosopagnosia, and it is unclear whether damage to the right MGF is also sufficient to cause prosopagnosia (Schiltz et al., 2005). Among prosopagnosia researchers, there is a general consensus that a lesion to the right hemisphere is necessary to cause prosopagnosia although there

has been one reported case of a prosopagnosic with only a left hemisphere lesion (Mattson, Levin, & Grafman, 2000).

Prosopagnosia has several associated deficits including achromatopsia (Zeki, 1990), topographical disorientation (Habib & Sirigu, 1987; Landis, 2004), and visual field deficits (Grusser & Landis, 1991). Achromatopsia is the inability to discriminate colors and a recent meta-analysis found that 72% of 92 cases of achromatopsia were comorbid with prosopagnosia (Bouvier & Engel 2006). Unilateral or bilateral lesions to the temporo-occipital cortex are sufficient to cause achromatopsia (Zeki, 1990). Topographical disorientation is another common disorder associated with prosopagnosic patients (Habib & Sirigu, 1987). There are two types of topographical disorientation and prosopagnosics typically have problems with both types of topographical disorientation: a vectorial orientation impairment (trouble processing angles and distance) and a loss of environmental familiarity (inability to use landmarks to navigate through the environment) (Landis, 2004). Finally, visual field deficits are common in prosopagnosic patients, especially damage to the left upper quadrant (Bouvier & Engel; Grusser & Landis, 1991). Prosopagnosia has many comorbid disorders because the comorbid disorders (achromatopsia, topographical disorientation and visual field deficits) are caused by damage to adjacent areas in the right cerebral cortex.

CURRENT STUDY

Recently, there has been a large amount of research pertaining to spatial coding impairments in individuals with brain damage to the dorsal and/or ventral streams. Spatial coding deficits were first described in patients with Balint's

syndrome or hemineglect (Humphreys, 1998; Cooper & Humphreys, 2000), and further research has begun looking into the spatial coding deficits observed in prosopagnosia (Barton & Cherkasova, 2005; Barton, Malcolm & Hefter, 2007). Barton and Cherkasova (2005) examined prosopagnosic patients who were previously shown to be severely impaired in the discrimination of the spatial configuration of facial features, but who performed normally on tasks in which changes to the features of a face (such as eye color) did not alter spatial configuration (Barton, Cherkasova, & Press, 2003; Barton, Press, & Kennenan, 2002). These results led researchers to wonder whether the spatial deficits observed in prosopagnosic patients are within-object or between-object spatial processing deficits.

Given that the between-object spatial processing system is thought to be a parietal function, Barton and Cherkasova (2005) hypothesized that prosopagnosics should not be impaired on between object processing tasks because they do not have damage to their parietal lobes; however, these researchers believed that prosopagnosics would be significantly impaired in their within-object processing systems because they have damage to the ventral stream, which is thought to be responsible for within-object coding. The study found that prosopagnosic subjects were significantly impaired on within-face spatial judgments because they performed at chance on a within-face spatial judgment task; however, prosopagnosic subjects were not impaired on the between-face spatial judgments tasks because they performed similarly to controls on that task (Barton & Cherkasova, 2005). The researchers also tested whether the deficits in spatial coding in prosopagnosia

extend to non-face objects and found the group of prosopagnosics to be impaired on within-object spatial judgment tasks (Barton & Cherkasova, 2005). Their conclusion from the study was that prosopagnosics have damage to their within-object processing system, which accounts for their deficits in coding the configuration of facial features and leads to their impairments in face recognition. This result lends credit to the coordinate hypothesis' prediction that impairments in prosopagnosia are not selective for faces, but also extend to other objects; however, there were several problems with their experimental design.

First, Barton and Cherkasova (2005) used different distances in the within-face spatial coding task and the between-face spatial coding task. The distances in the within-face spatial task were much smaller than those in the between-face spatial coding task as shown in Figure 4 which contains Figures 2A and 2B from Barton and Cherkasova (2005). Figure 2A from Barton and Cherkasova (2005) is an example of one within face stimulus presentation in which the subject's task was to determine which face had an altered distance between the nose and mouth. Figure 2B from Barton and Cherkasova (2005) is an example of one between-face stimulus presentation in which the subject's task was to determine which face was more displaced from the other two faces. It is evident that the within face spatial judgment task requires subjects to make smaller spatial discriminations than the between face spatial judgment task. Perhaps Barton and Cherkasova's finding that prosopagnosics have impaired within-object spatial coding can be explained by presuming that prosopagnosics are able to detect big changes better than small changes.

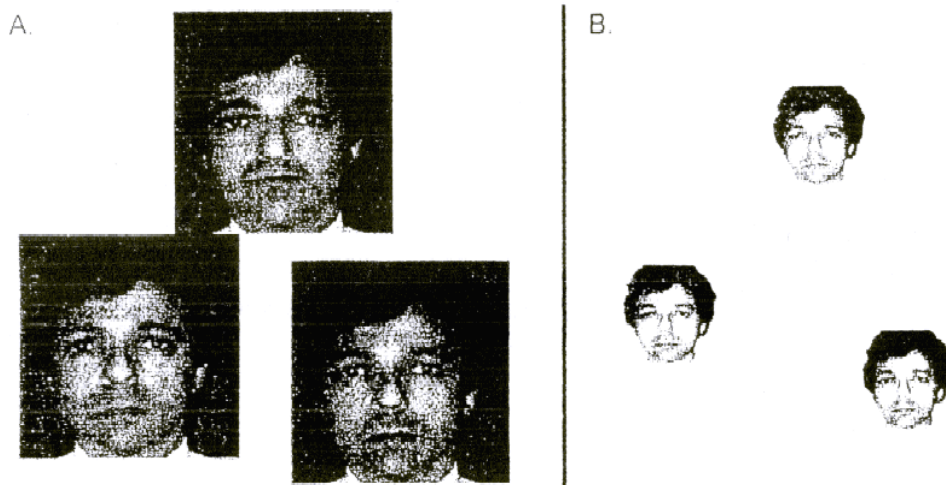


Figure 4. Figures 2A and 2B from Barton and Cherkasova (2005). Figure 2A is an example of one within face stimulus presentation in which the subject's task was to determine which face had an altered distance between the nose and mouth. Figure 2B is an example of one between face stimulus presentation in which the subject's task was to determine which face was more displaced from the other two faces. Figures 2A and 2B illustrate that the spatial distances were larger in the between face spatial judgment task.

Second, the within-object coding task was not relevant to objects typically seen in the environment. Barton and Cherkasova used the abstract dot patterns shown in Figure 5 that are not typically seen on any object in the natural environment, and it is not clear how two separated dots constitute an "object". Figure 4A from Barton and Cherkasova (2005), which is located in Figure 5, is an example of a within object spatial discrimination task used in their study. The subject's task was to determine which pair of dots had a larger distance between them. Barton and Cherkasova (2005) classified the pairs of dots as objects, but pairs of dots are not representative of objects found in the natural environment. Objects may have dot patterns present on their surface such as bowling balls or dice; however, patterns of

separated dots are rarely, if ever, considered to be objects, and it is unlikely that the visual system has evolved to treat them as a single object. Perhaps if they used objects that have known dot patterns already on them, such as bowling balls with three finger holes for the within-object coding task, they would not have found this discrepancy. It is possible that the unnatural stimuli they used are not processed the same way as natural stimuli.

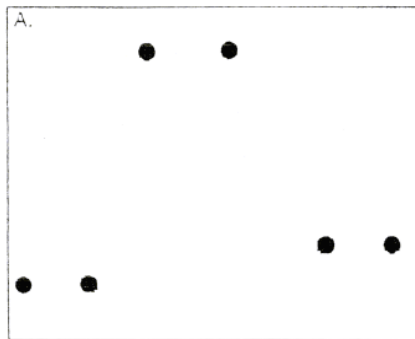


Figure 5. Figure 4A from Barton and Cherkasova (2005) showing the stimuli for the within object spatial discrimination task. The subject's task was to determine which pair of dots has a larger distance between them which would be the top pair of dots in this example.

Confounds present in the experimental design make it difficult to interpret their results. In addition, one study with a prosopagnosic patient (O'Brien, Cooper, Casner, & Brooks, 2006) found no difference between within-object and between-object spatial coding tasks, so it is unclear whether Barton and Cherkasova's (2005) interpretation of their results is accurate. The purpose of the experiments presented in this proposal is to provide more insight into the deficits in spatial coding shown by prosopagnosics by testing within-object and between-object spatial discrimination in

a prosopagnosic while eliminating the experimental confounds that were present in the Barton and Cherkasova study.

Experiment 1

Barton and Cherkasova (2005) found that prosopagnosics were impaired at within-face but not between-face spatial coding; however, a major problem with this study was that the distance manipulation was not the same for the within-face and between-face spatial coding tasks. In the within-face task, the distance was much smaller (4.2 to 33.6 minutes of visual angle) than in the between-face task (42 to 147 minutes of visual angle). Prosopagnosics are known to have impairments in the detection of small distances (Grusser & Landis 1991; O'Brien et al., 2006), so it is possible that the finding of a difference in within-face and between-face spatial coding in prosopagnosics is simply due to their inability to detect small visual changes.

In Experiment 1, the within-face and between-face spatial perception tasks of Barton and Cherkasova (2005) were replicated keeping the distance changes in the two tasks constant. The purpose of this experiment was to fix the confounding factor of different distances in the within-object and between-face object tasks. Participants in Experiment 1 were presented with three faces with three blemishes located either within one face (within-face task) or one blemish located on each face (between-face task). The task was to determine which blemish was altered in its distance from the other two blemishes. The distance between the blemishes was kept constant in the within-face task and the between-face task so distance would not be a confounding variable in this experiment.

Method

Subjects

The subjects for all of the experiments discussed herein were a control group of neurologically intact college students, one individual with prosopagnosia (LB) and a neurologically intact age matched control (FD). All subjects were naïve to the purpose of the experiment. The control group consisted of 15 undergraduate students at Iowa State University with normal or corrected to normal vision and a mean age of 22.06 ($SD=2.26$). Thirteen of the undergraduate students received credit for their participation while the remaining two students were paid \$10 for their participation. The control group consisted of five males and ten females. The age matched control (FD) is 42-year-old male with normal vision. FD participated in the experiment to ensure that LB's performance was not merely an artifact of age.

LB is a 43-year-old female retired junior high math teacher. At 39 years of age, LB suffered a posterior cerebral artery stroke causing bilateral inferotemporal lobe damage and partial unilateral hippocampal damage. LB has been diagnosed with prosopagnosia, achromatopsia (inability to discriminate colors), anomia (inability to name objects), topographical disorientation (inability to follow directions to navigate through the environment), right upper quadrantanopia (blindness in the right upper quadrant of the visual field) and left homonymous hemianopia (blindness in the left half of the visual field) (Casner, 2006). LB has normal visual acuity in her lower right quadrant of visual field and reports visual recognition problems for faces and some types of food, plants, animals, buildings and money. For example, LB loved gardening prior to the stroke. After the stroke, LB was unable to distinguish

weeds from plants, so gardening was no longer feasible. Notice that the majority of LB's co-occurring deficits are due to damage to the posterior cerebral cortex with the exception being anomia, which is due to unilateral hippocampal damage. Recent studies have confirmed LB's diagnosis of prosopagnosia (Kahl, 2008).

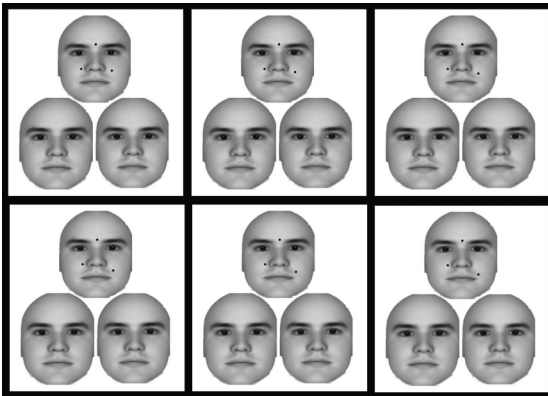
Apparatus

The experiment was presented using a Macintosh G4 desktop computer using Superlab Pro software (Phoenix, AZ). Stimuli were presented on a 20-inch LCD screen with a resolution of 1680 x 1050 pixels. Subjects responded via key press using the built in keyboard that records reaction time with ± 0.5 ms accuracy.

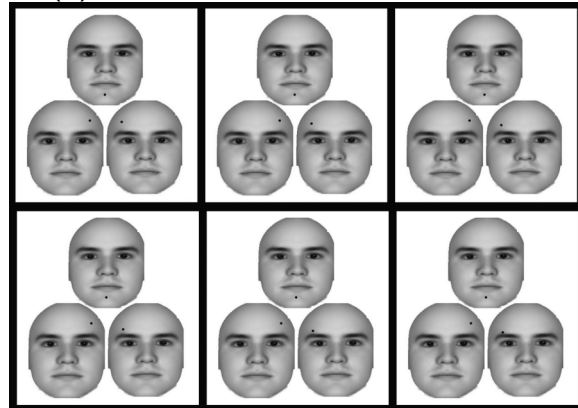
Stimuli

Stimuli for Experiment 1 were grayscale photos of three identical faces. Each face occupied an area of $8.8^\circ \times 8.8^\circ$ of visual angle and the three faces were located in a triangular configuration. There were three blemishes present either within one face or one blemish present on each face. The blemishes were also in a triangular configuration 8.8° apart from each other with one of the two bottom blemishes being displaced from the other two blemishes by 42', 63', 84', 105', 126' or 147' of visual angle. The triangular configuration of the blemishes had the possibility of occurring in six different locations (three locations on the between-face task and three locations on the within-face task). There were a total of 72 images. Examples of the stimuli are located in Figure 6.

(a) Within face stimuli



(b) Between face stimuli



(c) Locations 1, 2, and 3 for the within and between face tasks

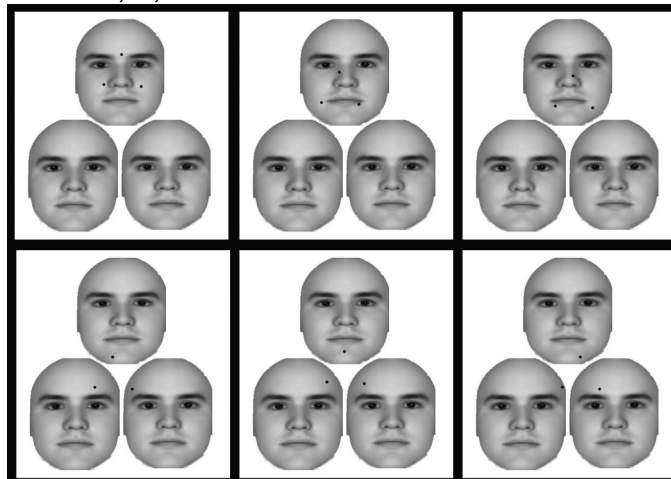


Figure 6. Examples of stimuli presented in Experiment 1. (a) within-face stimuli, (b) between-face stimuli, (c) locations 1, 2 and 3 for the within and between face tasks. The subject's task was to determine whether the lower right or lower left blemish was more distant from the upper blemish, and respond with a key press.

Procedure

The presentation of the stimuli was self-paced. Each trial was initiated by a key-press on the computer keyboard. After a key-press, a cue was presented for 500 ms, followed by one of the stimulus displays for 2000 ms, followed by a blank screen that remained on the screen until the participant responded (the subject was

unable to respond prior to the appearance of the blank screen). The subject's task was to determine which blemish (the lower right or the lower left) was farther from the other two. The subjects was instructed to press the "z" key if the lower left blemish was farther from the other two and press the "/" key if the lower right blemish was farther from the other two.

The experiment consisted of 288 trials that were presented in a randomized order. There were 72 stimulus displays in the experiment: 36 within-face and 36 between-face. The triangular arrangement of blemishes occurred in three locations on the within-face trials and three locations on the between-face trials. Of the 36 images within face and between face; 12 (6 with lower right blemish changed and 6 with lower left blemish changed) were distance changes in location one, 12 in location two, and 12 in location three (see Figure 6). Half of the trials were tests of within-face spatial discrimination and the other half of the trials were tests of between-face spatial discrimination. Each trial was repeated 4 times for a total of 288 trials. Each subject completed 8 practice trials, using stimuli not present in the experiment proper, prior to beginning the experiment.

Results

A modified t-test was used to determine whether LB's mean accuracy rate for within-face and between-face spatial discrimination tasks was reliably different from the control group's mean accuracy rate. This modified t test was proposed by Sokal and Rohlf (1995) and is more accurate than a standard t-test when comparing a single case to a small sample of controls (Crawford & Howell, 1998). The formula for

the t value is the following (s_2 is the standard deviation of the control group's means):

$$t = \frac{X_1 - \bar{X}_2}{s_2 \sqrt{\frac{N_2 + 1}{N_1}}}$$

Due to the nature of the experimental design used by Barton and Cherkasova (2005), which is replicated in this study, reaction time was not collected. In the Barton and Cherkasova (2005) study as well as the current experiment, subjects responded after viewing the stimulus for two seconds. Thus, the reaction time collected was after a two second viewing period and not reflective of the time required for the subjects to complete the experimental task. In addition, LB has brain damage and known visual deficits (left homonymous hemianopia and quadrantanopia) so her results are always slower than controls at any visual task. As a result, reaction time data will not be reported in this study.

The accuracy data from Experiment 1 are represented in Figure 7. Data analysis of the age-matched control's accuracy in performing the between-face spatial discrimination task compared to the control group's accuracy in performing the between-face spatial discrimination task revealed no significant difference, $t(14)=0.061$, $p>0.05$, $se=0.95$. Similarly, LB's accuracy in performing the between-face spatial discrimination task compared to the control group's accuracy in performing the between-face spatial discrimination task revealed no significant difference ($t(14)=0.18$, $p>0.05$, $se=0.95$).

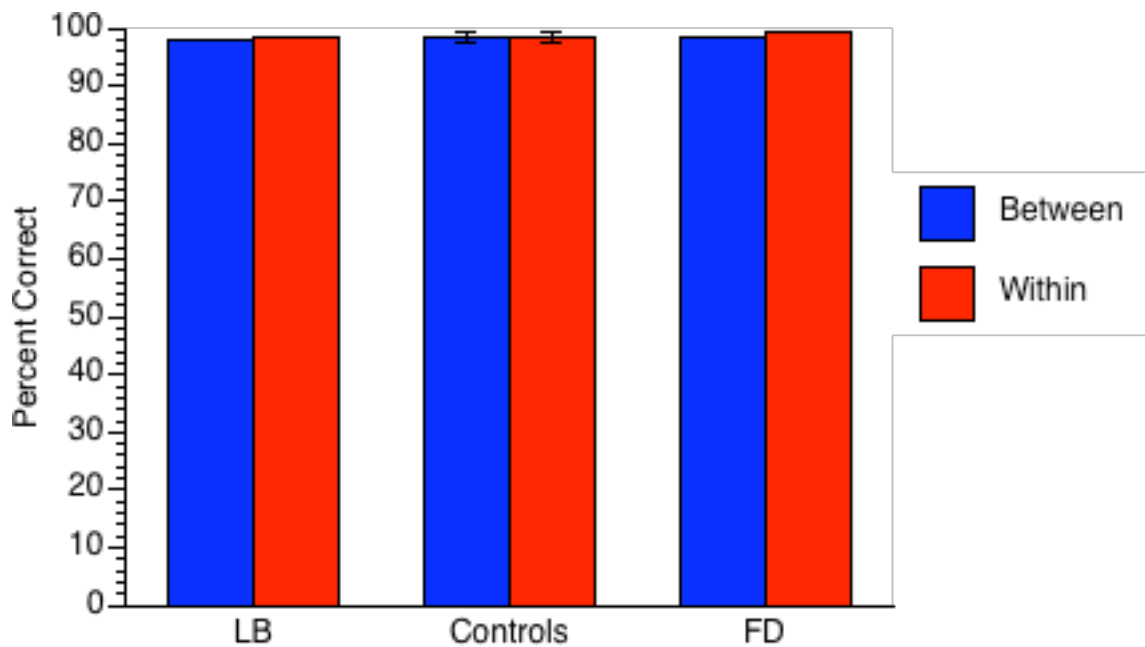


Figure 7. Accuracy data from Experiment 1 (standard error bars are displayed for the controls)

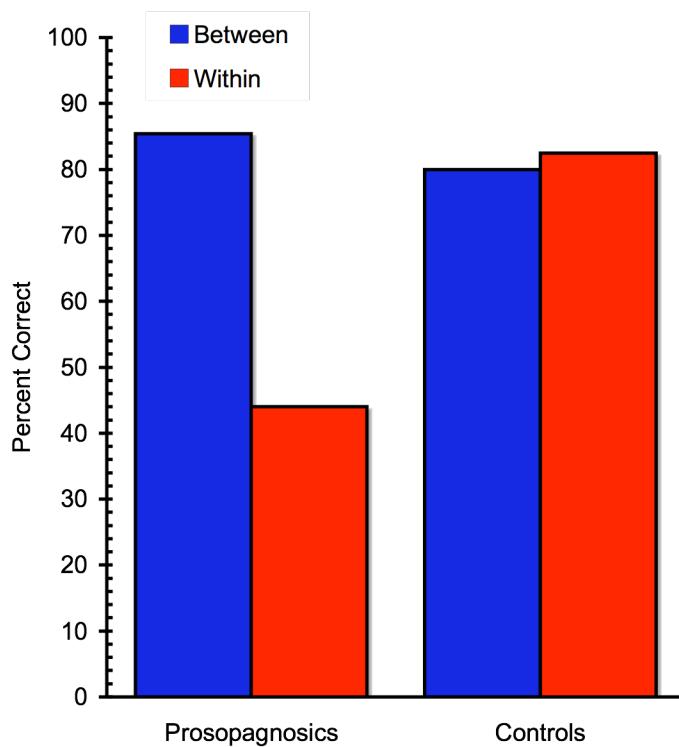


Figure 8. Results from Barton and Cherkasova's (2005) between-face and within-face spatial discrimination experiment.

Data analysis of the age-matched control's accuracy in performing the within-face spatial discrimination task compared to the control group's accuracy in performing the within-face spatial discrimination task revealed no significant difference ($t(14)=0.19$, $p>0.05$, $se=1.05$). A power analysis indicated that the smallest detectable difference was 3.32%. Similarly, LB's accuracy in performing the within-face spatial discrimination task compared to the control group's accuracy in performing the within-face spatial discrimination task revealed no significant difference ($t(14)=0.021$, $p>0.05$, $se=1.05$). LB's difference in performance on the between-face spatial discrimination task and the within-face spatial discrimination task, relative to controls, was calculated with a difference score and revealed no significant interaction ($t(14)=0.021$, $p>0.05$, $se=2.00$).

Further analysis of the age-matched control's accuracy in performing the between-face spatial discrimination task compared to the control group's accuracy was broken down by distance change to reveal no significant difference at 42' ($t(14)=0.56$, $p>0.05$, $se=1.71$), 63' ($t(14)=0.47$, $p>0.05$, $se=0.64$), 84' ($t(14)=0.34$, $p>0.05$, $se=0.64$), 105' ($t(14)=0.27$, $p>0.05$, $se=0.28$), 126' ($t(14)=0.56$, $p>0.05$, $se=0.66$) or 147' ($t(14)=0.27$, $p>0.05$, $se=0.28$). Similarly, LB's accuracy in performing the between-face spatial discrimination task compared to the control group's accuracy broken down by minutes of visual angle revealed no significant difference at 42' ($t(14)=1.17$, $p>0.05$, $se=1.71$), 63' ($t(14)=0.47$, $p>0.05$, $se=0.64$), 84' ($t(14)=0.34$, $p>0.05$, $se=0.64$), 105' ($t(14)=0.27$, $p>0.05$, $se=0.28$), 126' ($t(14)=0.56$, $p>0.05$, $se=0.66$) or 147' ($t(14)=0.27$, $p>0.05$, $se=0.28$).

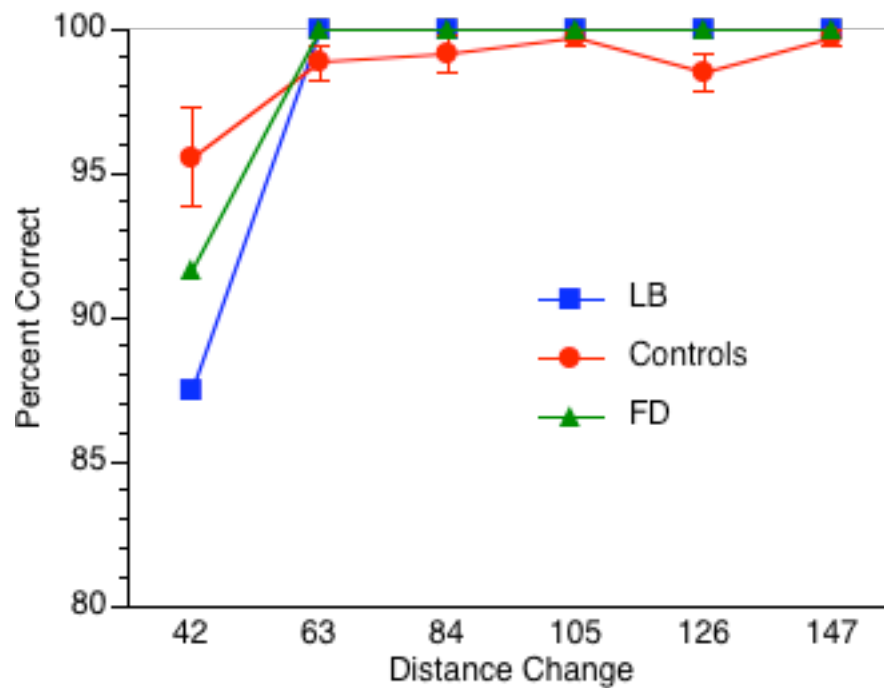


Figure 9. Accuracy data from the between-face spatial discrimination task from Experiment 1 arranged by distance change.

Further analysis of the age-matched control's accuracy in performing the within-face spatial discrimination task compared to the control group's accuracy was broken down by distance change to reveal no significant difference at 42' ($t(14)=0.077$, $p>0.05$, $se=1.96$), 63' ($t(14)=0.47$, $p>0.05$, $se=0.64$), 84' ($t(14)=0.26$, $p>0.05$, $se=0.83$), 105' ($t(14)=0.27$, $p>0.05$, $se=0.56$), 126' ($t(14)=0.36$, $p>0.05$, $se=0.60$) or 147' ($t(14)=0.27$, $p>0.05$, $se=0.56$). Similarly, LB's accuracy in performing the between-face spatial discrimination task compared to the control group's accuracy broken down by distance change revealed no significant difference at 42' ($t(14)=0.61$, $p>0.05$, $se=1.96$), 63' ($t(14)=0.47$, $p>0.05$, $se=0.64$), 84' ($t(14)=0.26$, $p>0.05$, $se=0.83$), 105' ($t(14)=0.27$, $p>0.05$, $se=0.56$), 126' ($t(14)=0.36$, $p>0.05$, $se=0.60$) or 147' ($t(14)=0.27$, $p>0.05$, $se=0.56$).

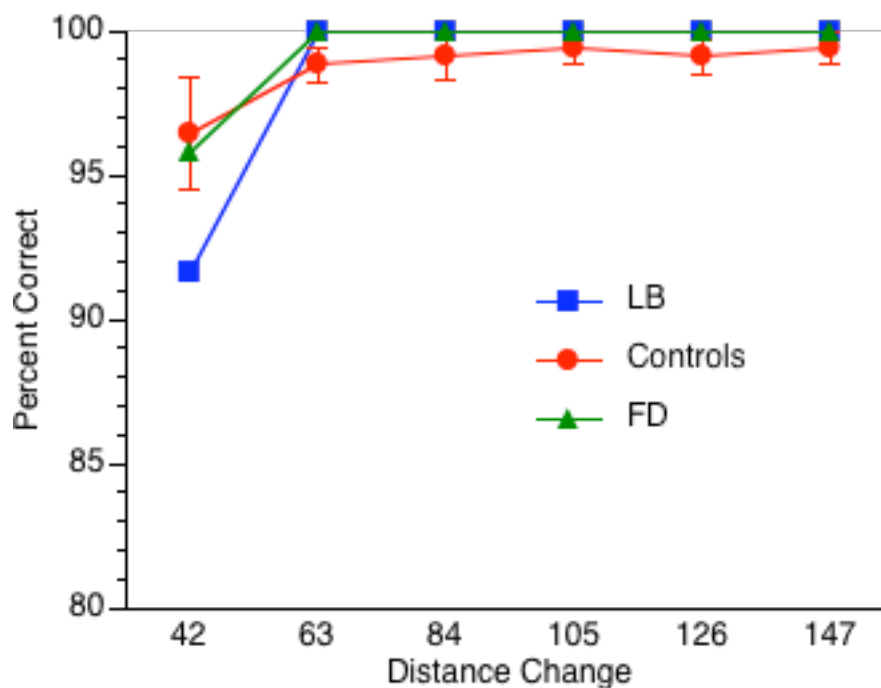


Figure 10. Accuracy data from the within-face discrimination task from Experiment 1 displayed by distance change.

In addition, a within subjects ANOVA was performed on the subjects data combined for both tasks. The results show that there was a significant effect of distance change on performance ($F(5,89)=11.94$, $p<0.001$) thus demonstrating that the experiment was sufficiently powerful to find effects in the data.

Discussion

The results obtained in Experiment 1 do not indicate a difference in performance on between-face and within-face spatial discrimination tasks in prosopagnosia. LB did not differ significantly from controls on her performance on the between-face spatial discrimination task or on the within-face spatial discrimination task. However, there is the possibility that these results are due to a ceiling effect. LB, the control group, and FD had high accuracy rates of 97.92%,

98.61%, and 98.38%, respectively, on the between-face spatial discrimination task and 98.61%, 98.52% and 99.30% on the within-face spatial discrimination task, respectively. Although the experiments were powerful enough to find effects of distance, due to the low difficulty level of this task it is difficult to confirm whether prosopagnosia is a deficit of within-face spatial discrimination tasks as suggested by Barton and Cherkasova (2005).

The results provide evidence that the methods used by Barton and Cherkasova (2005) were flawed. In their original study, the between-face spatial discrimination task distances were 42', 63', 84', 105', 126', and 147' of visual angle while the within-face spatial discrimination task distances were 4.2', 12.6', 16.8', 21.0', 25.2', 29.4', and 33.6' of visual angle. The accuracy rates obtained in the Barton and Cherkasova (2005) study are illustrated in Figure 8, and show that the controls performed similarly on the between-face and within-face spatial discrimination task while the prosopagnosics performed worse on the within-face spatial discrimination task than the between-face spatial discrimination task. The interpretation of the results offered by Barton and Cherkasova (2005) was that prosopagnosics are impaired on the within-object spatial discrimination tasks because they have damage to the ventral stream where the within-object spatial discrimination tasks are performed. While this interpretation is consistent with the coordinate relations hypothesis that within-face spatial discrimination tasks occur in the ventral stream via the coordinate relations system, these results could not be replicate when the confounds of spatial distances from Barton and Cherkasova (2005) were corrected in the current study.

In the current study, there was no difference in LB's performance on the between-face spatial discrimination task and the within-face spatial discrimination task. This pattern of results suggests that the results obtained in Barton and Cherkasova (2005) are due to the use of small distances on the within-face spatial discrimination task but large distances on the between-face spatial discrimination task. Prosopagnosics are known to have difficulties in discriminating small distances (Grusser & Landis 1991; O'Brien et al., 2006), so the results obtained in Barton and Cherksova (2005) are most likely due to the discrepancy in distances between the two tasks rather than the prosopagnosics being impaired on within-face spatial discrimination tasks but not between-face spatial discrimination tasks.

Figures 9 and 10 provide the accuracy data from Experiment 1 broken down by distance changes on the between-face spatial discrimination task and the within face spatial discrimination task. These data show that the 63' to 147' of visual angle distance changes had performance at ceiling while the performance at 42' of visual angle distance change began to decline. At 42' of visual angle, LB, the control group, and FD were 87.5%, 95.54% and 91.67% accurate on the between-face spatial discrimination task, respectively, and 91.67%, 96.43% and 95.83% accurate on the within-face spatial discrimination task, respectively. The ANOVA results indicated that there was a significant effect of distance change. This result indicates that there is a drop off of performance at a smaller distance changes such as those used in Barton and Cherkasova's (2005) within-face spatial discrimination task. These discrepancies did not appear in the between-face spatial discrimination task because the prosopagnosics were able to make spatial discriminations for the large

distances Barton and Cherkasova (2005) used in these tasks; however, these discrepancies did appear in the Barton and Cherkasova (2005) within-face spatial discrimination task as the prosopagnosics were unable to make spatial discriminations at the smaller distances used in that task.

Experiment 2

One of the most interesting findings from the Barton and Cherkasova (2005) study was the finding that prosopagnosics have impairments on within-object spatial discrimination tasks indicating that their deficits may not be selective to faces. This finding is consistent with the coordinate relations hypothesis, which holds that prosopagnosics have damage to their coordinate relations system so that they are impaired on any task that requires the coordinate relations system (discriminating objects or faces with the same categorical relations). The within-object and between-object experimental designs used in the Barton and Cherkasova (2005) article did have a major problem because they used an abstract dot pattern for the between-object and within-object coding tasks (see Figure 8). These abstract dot patterns are not representative of natural objects that humans interact with on a daily basis, so it is difficult to say whether or not the findings were due to prosopagnosics having impairments on tasks other than faces. It is possible that the prosopagnosics are simply unable to discriminate spatial distances between abstract dot patterns. The purpose of Experiment 2 was to determine if the spatial discrimination impairments in prosopagnosia extend to objects other than faces.

Method

Subjects

The subjects used were the same subjects from Experiment 1.

Apparatus

The apparatus used was the same apparatus from Experiment 1.

Stimuli

Stimuli for Experiment 2 were grayscale photos of three identical balls. Each ball occupied an area of $8.8^\circ \times 8.8^\circ$ of visual angle and the three balls were located in a triangular configuration. There were three dots presented in a triangular configuration either within one ball or there was one mark on each of the three balls. The balls were in a triangular configuration 8.8° apart from each other with either the lower right or the lower left dot being displaced from the other two dots by $42'$, $63'$, $84'$, $105'$, $126'$ or $147'$ of visual angle. The triangular configuration of the dots had a possibility of occurring in six different locations (three locations on the between-face task and three locations on the within-face task). There were a total of 72 images. Examples of the stimuli are located in Figure 11.

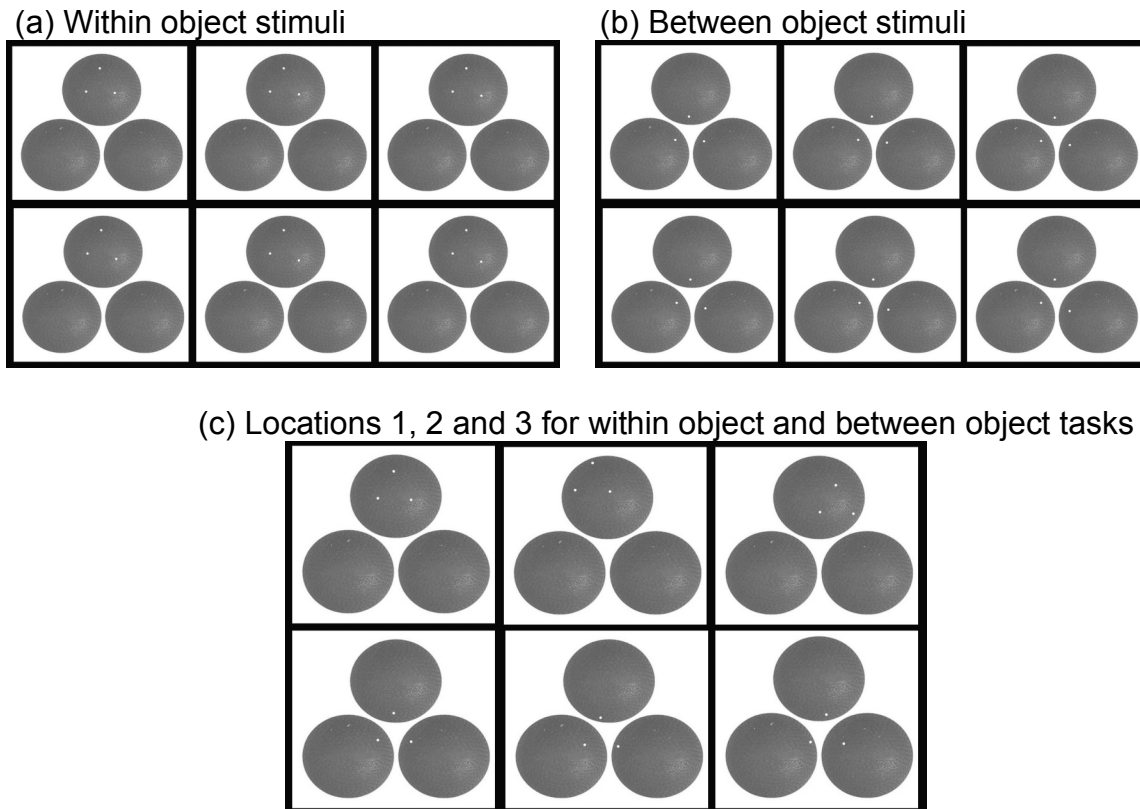


Figure 11. Examples of the possible stimuli presented in the within object and between object task. (a) within object stimuli, (b) between object stimuli, (c) examples of locations 1, 2, and 3 for the within object and between object tasks. The subject's task is to determine which dot, the lower left or the lower right, is more distant from the other two dots.

Procedure

Each trial was initiated by a key press on the computer keyboard. After a key press, a cue was presented for 500 ms, followed by one of the stimuli for 2000 ms, followed by a blank screen, which remained on the screen until the subject responded. The subject's task was to determine which dot (the lower left or the lower right) was farther from the other two. The subjects were instructed to press the "z"

key if the lower left dot was farther from the other two and press the “/” key if the lower right dot was farther from the other two dots.

The experiment consisted of 288 trials that were presented in a randomized order. There were 72 stimulus displays in the experiment: 36 within-object and 36 between-object. The triangular arrangement of dots occurred in three locations on the within-object trials and three locations on the between-object trials. Of the 36 images within-object and between-object; 12 (6 with lower right dot changed and 6 with lower left dot changed) were distance changes in location one, 12 in location two, and 12 in location three (see Figure 9). Half of the trials were tests of within-object spatial discrimination and the other half of the trials were tests of between-object spatial discrimination. Each trial was repeated 4 times for a total of 288 trials. Each subject completed 8 practice trials, using stimuli not present in the experiment proper, prior to beginning the experiment.

Results

The results from Experiment 2 are shown in Figure 12 and were analyzed in the same manner as the results from Experiment 1. Analysis of the accuracy rate of the age-matched control on the between-object spatial discrimination task compared to the accuracy rate of the controls on the between-object spatial discrimination task did not reveal a significant difference ($t(14)=0.018$, $p>0.05$, $se=1.08$). A power analysis determined the smallest detectable difference to be 3.77%. Similarly, analysis of the accuracy rate of LB on the between-object spatial discrimination task compared to the accuracy rate of controls on the between-object spatial

discrimination task did not reveal a significant difference ($t(14)=0.018$, $p>0.05$, $se=1.08$).

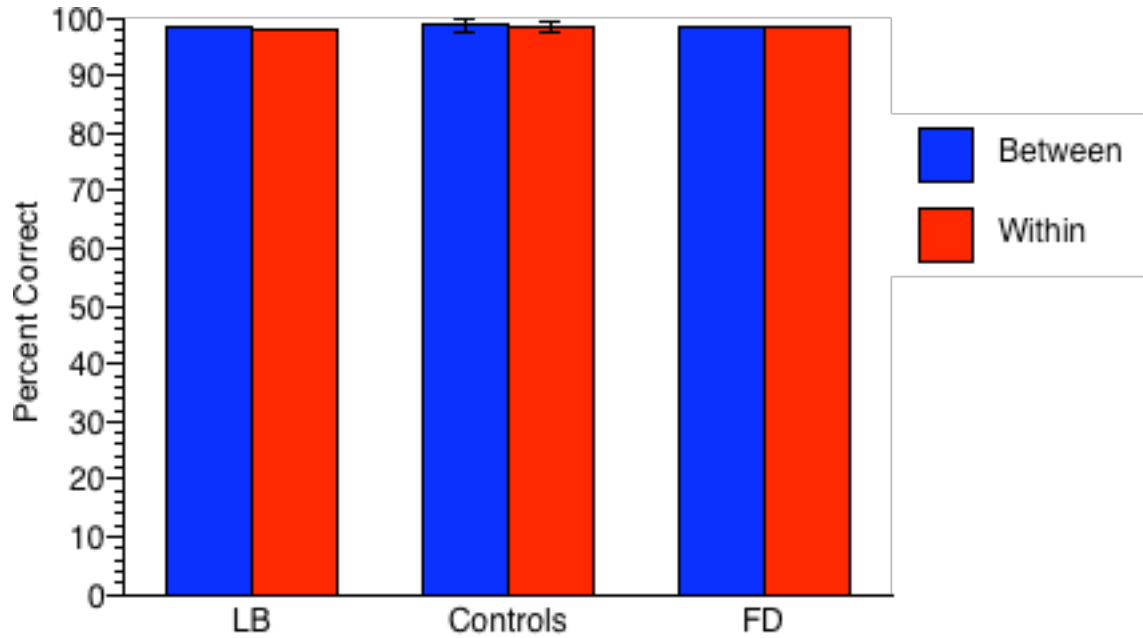


Figure 12. Accuracy rates from Experiment 2 (standard error bars are displayed for controls).

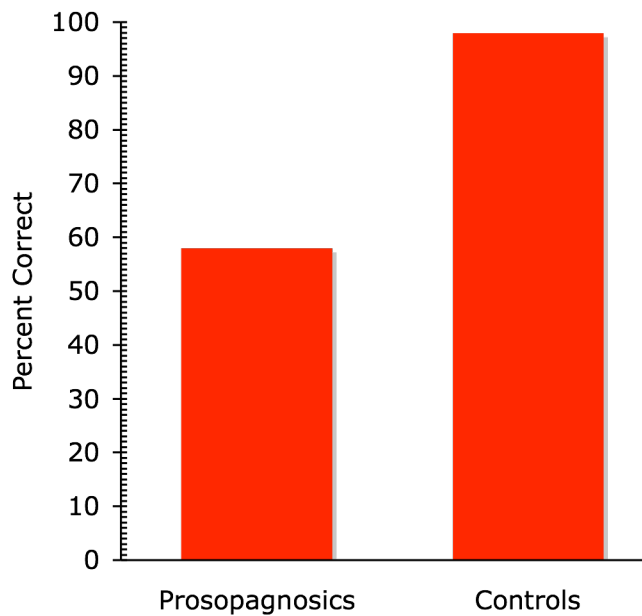


Figure 13. Accuracy rates from Barton and Cherkasova (2005).

Analysis of the accuracy rate of FD on the within-object spatial discrimination task compared with the controls' accuracy rate on the within-object spatial discrimination task did not reveal a significant difference ($t(14)=0.014$, $p>0.05$, $se=0.89$). Similarly, analysis of the accuracy rate of LB on the within-object spatial discrimination task compared with the controls' accuracy rate on the within-object spatial discrimination task did not reveal a significant difference ($t(14)=0.18$, $p>0.05$, $se=0.89$). LB's difference in performance on the between-object spatial discrimination task and the within-object spatial discrimination task, relative to controls, was calculated by a difference score and revealed no significant interaction ($t(14)=0.14$, $p>0.05$, $se=1.97$).

Further analysis of the age-matched control's accuracy in performing the between-object spatial discrimination task compared to the control group's accuracy was broken down by minutes of visual angle to reveal a significant difference at 63' ($t(14)=3.52$, $p<0.05$, $se=0.28$) but no significant difference at 42' ($t(14)=0.41$, $p>0.05$, $se=2.04$), 84' ($t(14)=0.34$, $p>0.05$, $se=0.28$), 105' ($t(14)=0.27$, $p>0.05$, $se=0.28$), 126' ($t(14)=0.56$, $p>0.05$, $se=0.28$) or 147' ($t(14)=0.27$, $p>0.05$, $se=0.28$). LB's accuracy in performing the between-object spatial discrimination task compared to the control group's accuracy broken down by minutes of visual angle revealed no significant difference at 42' ($t(14)=0.10$, $p>0.05$, $se=2.04$), 63' ($t(14)=0.25$, $p>0.05$, $se=0.28$), 84' ($t(14)=0.25$, $p>0.05$, $se=0.28$), 105' ($t(14)=0.25$, $p>0.05$, $se=0.28$), 126' ($t(14)=0.25$, $p>0.05$, $se=0.28$) or 147' ($t(14)=0.25$, $p>0.05$, $se=0.28$).

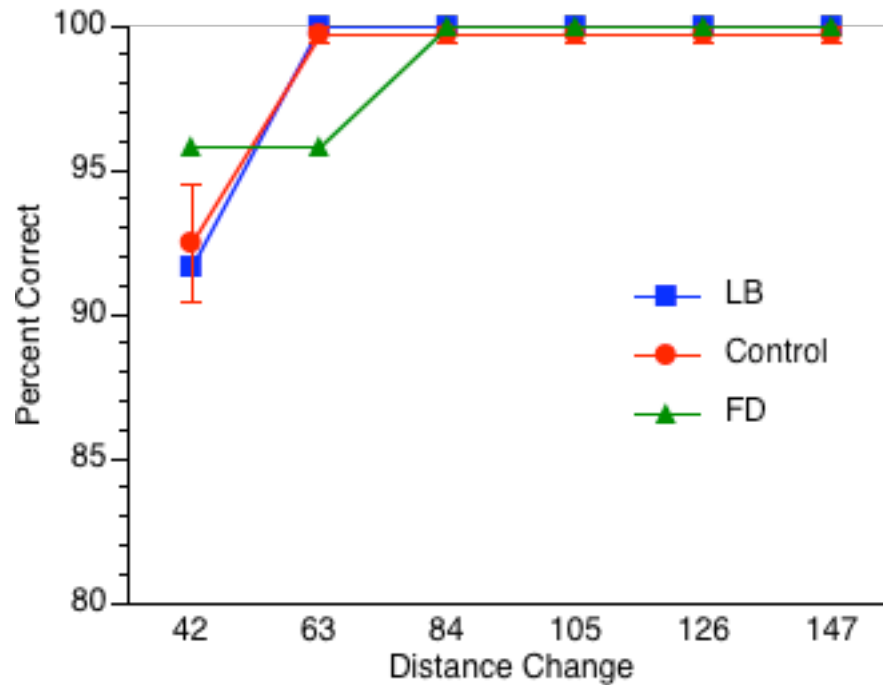


Figure 14. Accuracy data from the between-object spatial discrimination task in Experiment 2 displayed by minutes of visual angle.

Further analysis of the age-matched control's accuracy in performing the within-object spatial discrimination task compared to the control group's accuracy was broken down by minutes of visual angle to revealed no significant difference at 42' ($t(14)=0.37$, $p>0.05$, $se=1.51$), 63' ($t(14)=0.44$, $p>0.05$, $se=0.64$), 84' ($t(14)=0.25$, $p>0.05$, $se=0.28$), 105' ($t(14)=0.37$, $p>0.05$, $se=0.38$), 126' ($t(14)=0.25$, $p>0.05$, $se=0.28$) or 147' ($t(14)=0.25$, $p>0.05$, $se=0.28$). Similarly, LB's accuracy in performing the within-object spatial discrimination task compared to the control group's accuracy broken down by minutes of visual angle revealed no significant difference at 42' ($t(14)=1.06$, $p>0.05$, $se=1.51$), 63' ($t(14)=0.44$, $p>0.05$, $se=0.64$), 84' ($t(14)=0.25$, $p>0.05$, $se=0.28$), 105' ($t(14)=0.37$, $p>0.05$, $se=0.38$), 126' ($t(14)=0.25$, $p>0.05$, $se=0.28$) or 147' ($t(14)=0.25$, $p>0.05$, $se=0.28$).

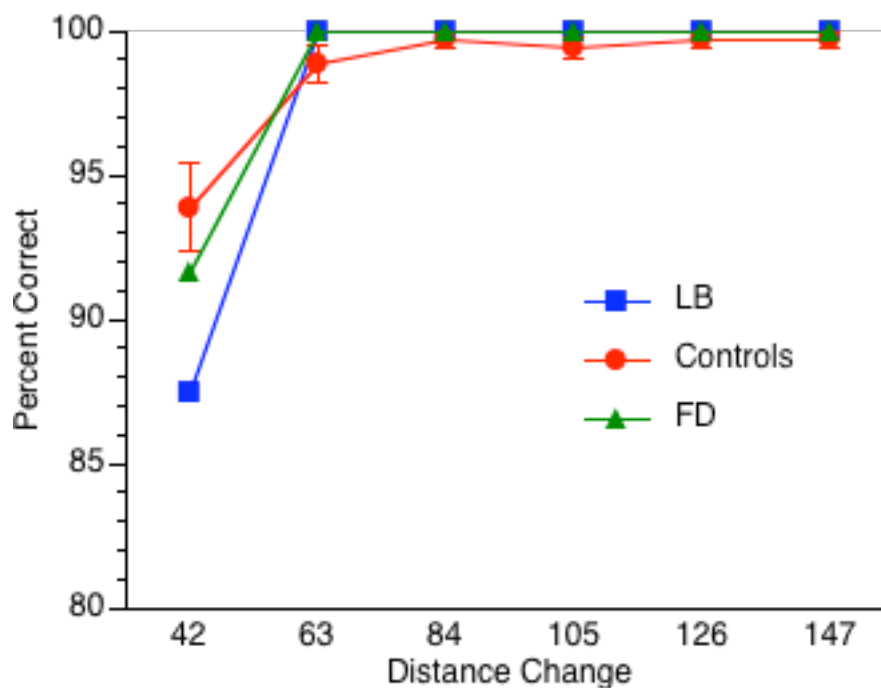


Figure 15. Accuracy data from the within-object spatial discrimination task in Experiment 2 displayed by minutes of visual angle.

A within subjects ANOVA on the combined within and between subject data for the control subjects revealed a significant effect of distance change ($F(5, 70)=25.32, p<0.001$) showing that the experiment was powerful enough to detect effects in the data.

Discussion

The results from Experiment 2 do not indicate a difference in performance on between-object and within-object discriminations in prosopagnosia. LB did not differ significantly from controls on her performance on either the between-object spatial discrimination task or the within-object spatial discrimination task. The only statistically significant differences found in Experiment 2 were between FD and controls on the 63' of visual angle between-object spatial discrimination task

($t(14)=3.52$, $p<0.05$). However, given the large number of statistical tests being run, this finding may well be a type I error. LB, the control group and FD had high accuracy rates of 98.61%, 98.69% and 98.61%, respectively, on the between-object spatial discrimination task and 97.92%, 98.56% and 98.61%, respectively, on the within-object spatial discrimination task. As with Experiment 1, there appears to be a ceiling effect due to the low difficulty level of Experiment 2.

Figures 14 and 15 provide the accuracy data from Experiment 2 broken down by minutes of visual angle changes on the between-object and within-object tasks. These data show that the 63' to 147' of visual angle changes had performance at ceiling while performance at 42' of visual angle began to decline. At 42' of visual angle, LB, the control group, and FD were 91.67%, 92.5% and 95.83% accurate on the between-object spatial discrimination task, respectively, and 87.5%, 93.89% and 91.67% accurate on the within-object spatial discrimination task, respectively. Further, the ANOVA results indicated a significant effect of distance change on performance. These results support the finding from Experiment 1 that there is a drop off in performance at smaller minutes of visual angle changes such as those used in Barton and Cherkasova's (2005) within-face spatial discrimination task, so it is possible that their findings are due to prosopagnosics having difficulties discriminating small distances.

The purpose of Experiment 2 was to determine whether difficulties in performing spatial discrimination tasks in prosopagnosia extend to objects other than faces, and the results from the current study indicate that there is no difference in performance on either object discrimination tasks or face discrimination tasks. There

is a debate in the prosopagnosia literature concerning whether or not the deficits in prosopagnosics extend to other objects with the coordinate relation hypothesis suggesting that the impairments should extend to objects other than faces. The coordinate relations hypothesis would predict that LB should perform worse than controls on the within-object and between-object tasks, which is in agreement with the results found by Barton and Cherkasova (2005); however, Barton and Cherkasova (2005) did not test between-object spatial discrimination judgments.

The findings of Barton and Cherkasova (2005) are contrary to results proposed by some researchers who claim that impairments in prosopagnosia are selective to faces (Farah, Levinson, & Klein, 1995). Farah, Levinson and Klein (1995) would have predicted that Experiment 2 should have found that LB performs similarly to controls on the within-object and between-object spatial discrimination tasks. In this view, prosopagnosics have selective impairments in faces, so they should not show impairments on object spatial discrimination tasks. However, due to the low difficulty level, which resulted in a ceiling effect for Experiment 2, it is difficult to determine whether prosopagnosics are impaired on within-object or between-object spatial discrimination tasks relative to controls.

Experiment 3

In Experiment 1, the procedural confounds from Barton and Cherkasova (2005) were corrected so that the distances on the between-face and within-face spatial discrimination tasks were the same. The distances from the between-face spatial discrimination task of Barton and Cherkasova (2005) were used in Experiment 1, but these distances resulted in a ceiling effect in the results. LB did

not differ significantly from controls on the between-face and within-face spatial discrimination tasks but it is difficult to determine whether or not this can be replicated in other prosopagnosics due the low difficulty level of the experiment. The purpose of Experiment 3 was to use the distances from the within-face spatial discrimination task of Barton and Cherkasova (2005) to determine if prosopagnosia is a deficit in between-face or within-face spatial discrimination. If Barton and Cherkasova's (2005) finding that prosopagnosia is the result of within but not between face spatial impairments was due to the discrimination of different distances on the two tasks, LB should be significantly worse than controls on the within-face and between-face spatial discrimination tasks in Experiment 3. The experimental procedure was modified so that reaction times could be collected to ensure that a speed-accuracy trade off was not present.

Method

Subjects

The subjects used were the same subjects from Experiment 1.

Apparatus

The apparatus used was the same apparatus from Experiment 1.

Stimuli

Stimuli for Experiment 3 were grayscale photos of three identical faces. Each face occupied an area of $8.8^\circ \times 8.8^\circ$ of visual angle and the three faces were located in a triangular configuration. There were three blemishes present either within one face or one blemish present on each face. The blemishes were also in a triangular configuration 8.8° apart from each other with one of the two bottom blemishes being

displaced from the other two blemishes by 4.2', 8.4', 12.6', 16.8', 21', 25.2', 29.4' or 33.6' of visual angle. The triangular configuration of the blemishes had the possibility of occurring in six different locations (three locations on the between-face task and three locations on the within-face task). There were a total of 96 images. Examples of the stimuli are located in Figure 16.

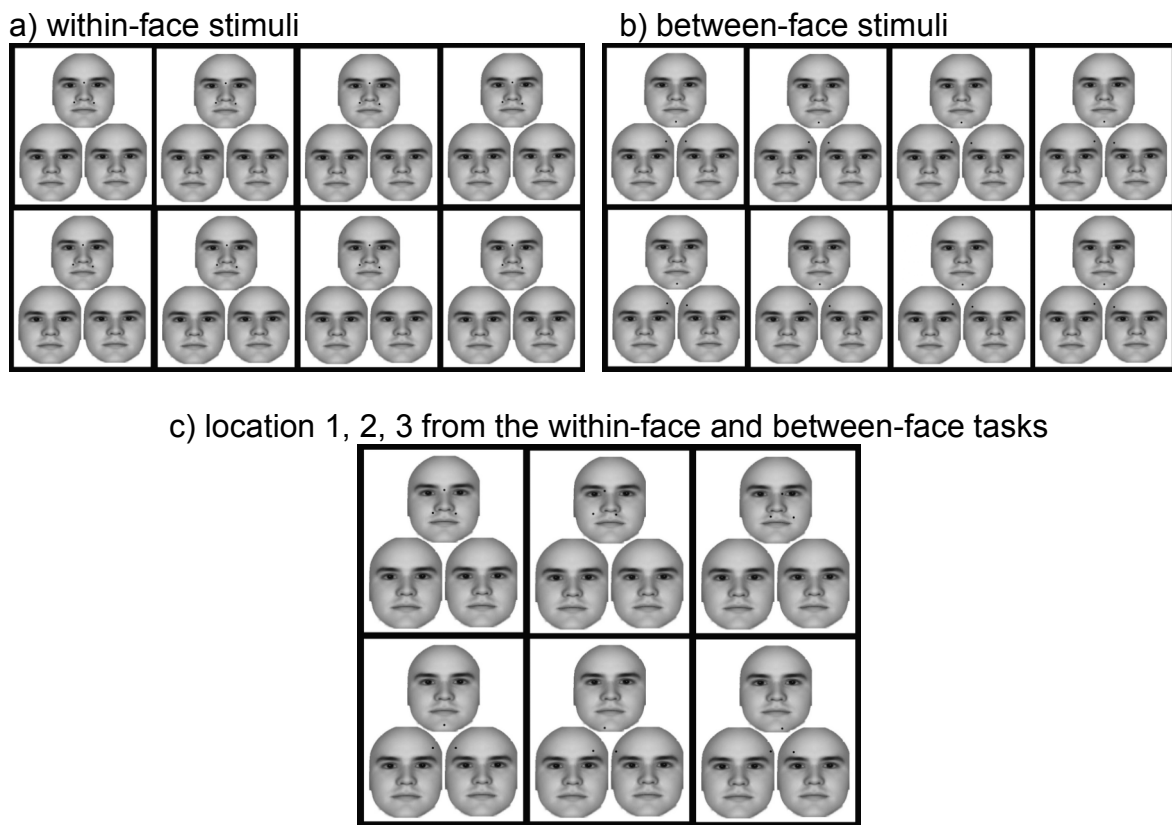


Figure 16. Examples of the possible stimuli presented in the within-face and between-face tasks in Experiment 3. (a) within-face stimuli, (b) between-face stimuli, (c) examples of locations 1, 2 and 3 for the within-face and between-face tasks. The subject's task was to determine which blemish, the lower left or the lower right, is more distant to the other two blemishes.

Procedure

The participant initiated each trial with a key press on the computer keyboard. After a key press, a cue was presented for 500 ms, followed by one of the stimuli for which remained on the screen until the subject responded. The subject's task was to determine which blemish (the lower left or the lower right) was farther from the other two blemishes. The subjects were instructed to press the "z" key if the lower left blemish was farther from the other two blemishes and press the "/" key if the lower right blemish was farther from the other two blemishes.

The experiment consisted of 384 trials that were presented in a randomized order. There were 96 stimulus displays in the experiment: 48 within-face and 48 between-face. The triangular arrangement of blemishes occurred in three locations on the within-face trials and three locations on the between-face trials. Of the 48 images within-face trials and between-face trials; 16 (8 with lower right blemish changed and 8 with lower left blemish changed) were distance changes in location one, 16 in location two, and 16 in location three (see Figure 16). Half of the trials were tests of within-face spatial discrimination and the other half of the trials were tests of between-face spatial discrimination. Each trial was repeated 4 times for a total of 384 trials. Each subject completed 8 practice trials, using stimuli not present in the experiment proper, prior to beginning the experiment.

Results

Accuracy Data

The accuracy rate results from Experiment 3 are shown in Figure 17 and were analyzed in the same manner as the results from Experiment 1. Analysis of the

accuracy rate of the age-matched control on the between-face spatial discrimination task compared to the accuracy rate of the controls on the between-face spatial discrimination task did not reveal a significant difference ($t(14)=0.11$, $p>0.05$, $se=2.58$). A power analysis determined the smallest detectable difference to be 9.00%. Similarly, analysis of the accuracy rate of LB on the between-face spatial discrimination task compared to the accuracy rate of controls on the between-face spatial discrimination task did not reveal a significant difference ($t(14)=0.55$, $p>0.05$, $se=2.58$).

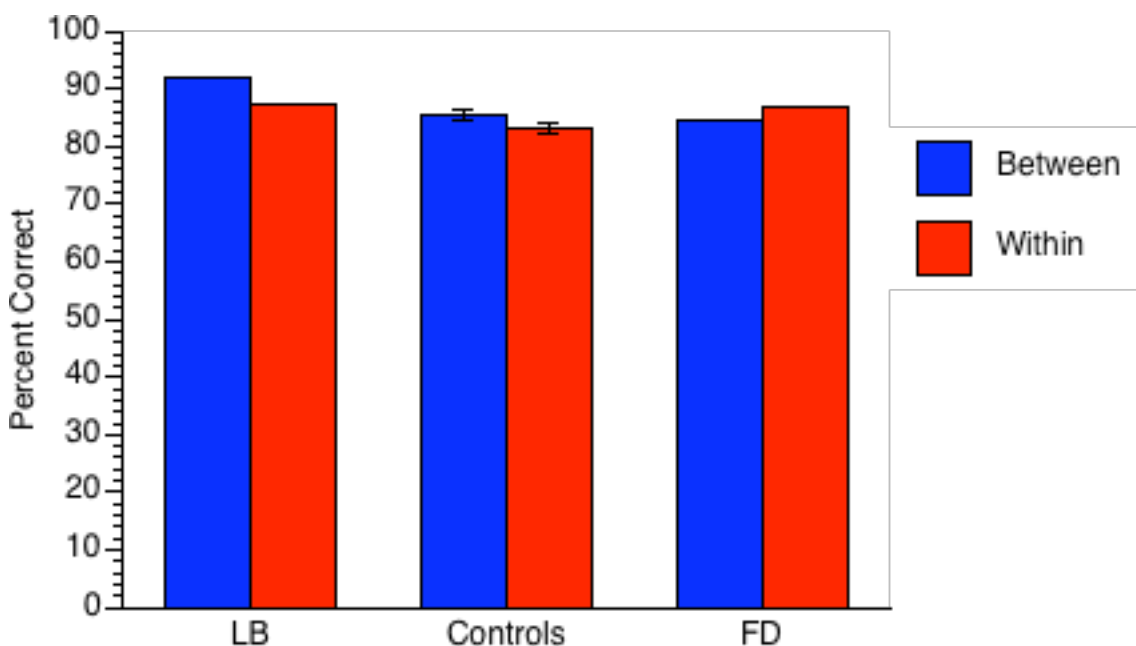


Figure 17. Accuracy rates from Experiment 3 (standard error bars are displayed for controls).

Analysis of the accuracy rate of FD on the within-face spatial discrimination task compared with the controls' accuracy rate on the within-face spatial discrimination task did not reveal a significant difference ($t(14)=0.31$, $p>0.05$,

se=2.84). Similarly, analysis of the accuracy rate of LB on the within-face spatial discrimination task compared with the controls' accuracy rate on the within-face spatial discrimination task did not reveal a significant difference ($t(14)=0.36$, $p>0.05$, se=2.84). LB's difference in performance on the between-face spatial discrimination task and the within-face spatial discrimination task, relative to controls, was calculated as a difference score and revealed no significant interaction ($t(14)=0.18$, $p>0.05$, se=5.42).

Further analysis of the age-matched control's accuracy in performing the between-face spatial discrimination task compared to the control group's accuracy was broken down by distance change to reveal that FD was significant worse than controls at 4.2' ($t(14)=2.91$, $p<0.05$, se=2.28) but there was no significant difference at 8.4' ($t(14)=1.28$, $p>0.05$, se=2.31), 12.6' ($t(14)=0.81$, $p>0.05$, se=2.49), 16.8' ($t(14)=0.21$, $p>0.05$, se=2.22), 21' ($t(14)=0.84$, $p>0.05$, se=1.84), 25.2' ($t(14)=1.21$, $p>0.05$, se=1.44), 29.4' ($t(14)=0.17$, $p>0.05$, se=2.03), or 33.6' ($t(14)=0.46$, $p>0.05$, se=1.46). LB's accuracy in performing the between-face spatial discrimination task compared to the control group's accuracy broken down by distance change revealed no significant difference at 4.2' ($t(14)=0.18$, $p>0.05$, se=2.28), 8.4' ($t(14)=0.41$, $p>0.05$, se=2.31), 12.6' ($t(14)=0.81$, $p>0.05$, se=2.49), 16.8' ($t(14)=1.12$, $p>0.05$, se=2.22), 21' ($t(14)=1.39$, $p>0.05$, se=1.84), 25.2' ($t(14)=1.91$, $p>0.05$, se=1.44), 29.4' ($t(14)=0.33$, $p>0.05$, se=2.03), or 33.6' ($t(14)=1.15$, $p>0.05$, se=1.46).

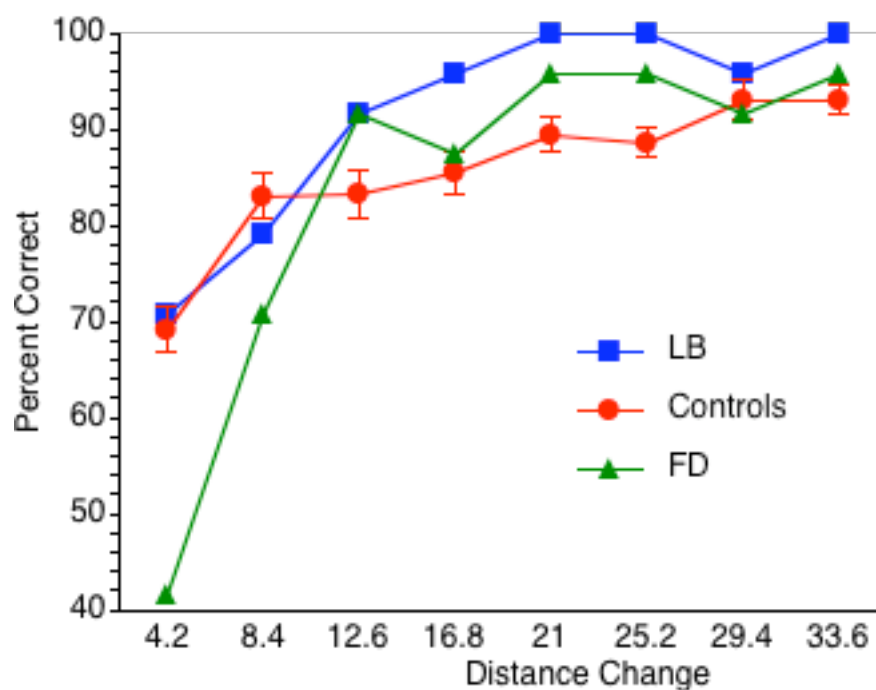


Figure 18. Accuracy data from the between-face spatial discrimination task in Experiment 3 displayed by distance change.

Further analysis of the age-matched control's accuracy in performing the within-face spatial discrimination task compared to the control group's accuracy was broken down by distance change and revealed no significant difference at 4.2' ($t(14)=1.26$, $p>0.05$, $se=2.34$), 8.4' ($t(14)=0.23$, $p>0.05$, $se=2.29$), 12.6' ($t(14)=1.71$, $p>0.05$, $se=2.31$), 16.8' ($t(14)=0.23$, $p>0.05$, $se=2.36$), 21' ($t(14)=0.51$, $p>0.05$, $se=2.10$), 25.2' ($t(14)=1.11$, $p>0.05$, $se=1.63$), 29.4' ($t(14)=1.34$, $p>0.05$, $se=2.26$), or 33.6' ($t(14)=0.43$, $p>0.05$, $se=1.56$). Similarly, LB's accuracy in performing the within-face spatial discrimination task compared to the control group's accuracy broken down by minutes of visual angle revealed no significant difference at 4.2' ($t(14)=0.83$, $p>0.05$, $se=2.34$), 8.4' ($t(14)=0.68$, $p>0.05$, $se=2.29$), 12.6' ($t(14)=0.84$, $p>0.05$, $se=2.31$), 16.8' ($t(14)=0.63$, $p>0.05$, $se=2.36$), 21' ($t(14)=0.99$, $p>0.05$,

se=2.10), 25.2' ($t(14)=1.11$, $p>0.05$, se=1.63), 29.4' ($t(14)=0.89$, $p>0.05$, se=2.26), or 33.6' ($t(14)=1.08$, $p>0.05$, se=1.56).

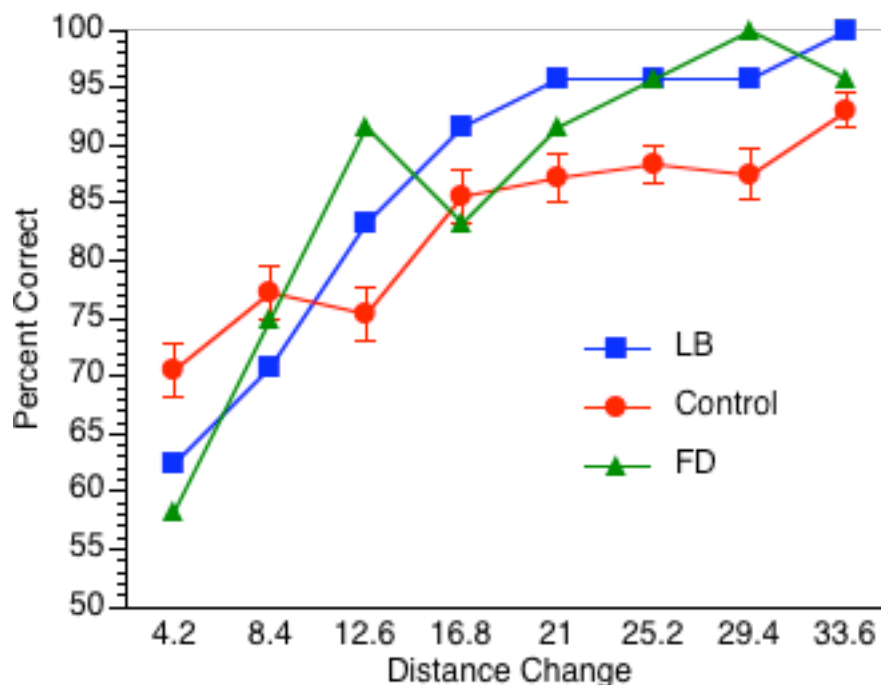


Figure 19. Accuracy data from the within-face spatial discrimination task in Experiment 3 displayed by distance change.

A within subjects ANOVA on the control subjects data combined on between and within object trials revealed a significant effect of distance change ($F(7, 94)=29.71$, $p<0.001$) demonstrating that the experiment was sufficiently powerful to find effects.

Reaction Time Data

The mean reaction time on the between-face trials for LB, the control group and FD were 1813 ms, 1261 ms ($s=604$), and 1085 ms, respectively. LB's reaction times for the between-face trials broken down by distance change were 2089 ms

(4.2'), 2186 ms (8.4'), 2214 ms (12.6'), 2222 ms (16.8'), 1529 ms (21'), 1562 ms (25.2'), 1494 ms (29.4') and 1209 ms (33.6'). The control group's reaction times for the between-face trials broken down by distance change were 1700 ms (s=1002, 4.2'), 1436 ms (s=602, 8.4'), 1424 ms (s=745, 12.6'), 1242 ms (s=499, 16.8'), 1212 ms (s=442, 21'), 1074 ms (s=339, 25.2'), 1066 ms (s=343, 29.4'), and 935 ms (s=211, 33.6'). The age-matched control's reaction times for the between-face trials broken down by distance change were 1434 ms (4.2'), 1170 ms (8.4'), 1266 ms (12.6'), 1043 ms (16.8'), 1009 ms (21'), 940 ms (25.2'), 953 ms (29.4') and 868 ms (33.6').

The mean reaction time on the within-face trials for LB, the control group and FD were 1910 ms, 1304 ms (s=610), and 1021ms, respectively, LB's reaction times for the within-face trials broken down by distance change were 2351 ms (4.2'), 2233 ms (8.4'), 2227 ms (12.6'), 1953 ms (16.8'), 1887 ms (21'), 1695 ms (25.2'), 1572 ms (29.4') and 1368 ms (33.6'). The control group's reaction times for the within-face trials broken down by distance change were 1511 ms (s=860, 4.2'), 1450 ms (s=734, 8.4'), 1395 ms (s=632, 12.6'), 1399 ms (s=665, 16.8'), 1256 ms (s=523, 21'), 1227 ms (s=511, 25.2'), 1130 ms (s=373, 29.4'), and 1065 ms (s=421, 33.6'). The age-matched control's reaction times for the within-face trials broken down by distance change were 1278 ms (4.2'), 1131 ms (8.4'), 1046 ms (12.6'), 918 ms (16.8'), 1095 ms (21'), 943 ms (25.2'), 925 ms (29.4') and 834 ms (33.6'). Thus, the reaction time data for the within-face and between-face trials did not indicate a speed-accuracy trade off.

Discussion

The purpose of Experiment 3 was to replicate Barton and Cherkasova's (2005) finding that prosopagnosia is a disorder of within but not between face spatial discrimination using the within-face distances from their original study. In Barton and Cherkasova (2005), the distances in the between-face spatial discrimination tasks were 42', 63', 84', 105', 126', and 147' of visual angle while the distances in the within-face spatial discrimination task distances were 4.2', 8.4', 12.6', 16.8', 21, 25.2', 29.4' and 33.6' of visual angle. The accuracy rates obtained in the Barton and Cherkasova (2005) study are illustrated in Figure 8 and show that the controls performed similarly on the between-face and within-face spatial discrimination tasks while the prosopagnosics performed worse on the within-face spatial discrimination task than the between-face spatial discrimination task. Because different distances were used on the within-face and between-face spatial discrimination task, it is difficult to interpret the findings of Barton and Cherkasova (2005).

In Experiment 1, the confound of different distances on the within and between face spatial discrimination task was corrected, and the results did not indicate that prosopagnosia is the result of impairments in within-face spatial discrimination. Experiment 3 was designed to test the within-face distances used in Barton and Cherkasova (2005) to determine if their results could be replicated using these distances. The results obtained in Experiment 3 do not indicate a difference in performance on the between-face and within-face spatial discrimination tasks in prosopagnosia. LB did not differ significantly from controls on her performance on

the between-face spatial discrimination task or on the within-face spatial discrimination task.

Figures 18 and 19 show the accuracy results from the between-face and within-face spatial discrimination tasks broken down by minutes of visual angle changes on the between-face and within-face spatial discrimination tasks. When the results were broken down by distance change, the only significant result obtained was between FD and controls at 4.2' of visual angle ($t(14)=2.91$, $p<0.05$, $se=2.28$). In addition, these data show a drop off in performance at smaller distance changes. At the largest distance changes used in Experiment 3, 33.6', LB, the control group and FD were 100%, 93.06% and 95.83% accurate on the between-face spatial discrimination task, respectively, and 100%, 93.06% and 95.83% accurate on the within-face spatial discrimination task, respectively. However, at the smallest minute of visual angle change used in Experiment 3, 4.2', LB, the control group and FD were 70.83%, 69.17% and 41.67% accurate on the between-face spatial discrimination task, respectively, and 62.5%, 70.56% and 58.33% accurate on the within-face spatial discrimination task, respectively. The ANOVA results indicated that there was a significant effect of distance change on performance.

The results from Experiment 3 indicate that the results from Barton and Cherkasova (2005) may be explained by prosopagnosics having poor visual acuity, which made it difficult for them to discriminate the small distances used on the within-face spatial discrimination task. This discrepancy in performance did not appear in the between-face spatial discrimination task because the prosopagnosics were able to make spatial discriminations for the large distances Barton and

Cherkasova (2005) used in these tasks. One problem with this interpretation is that LB's performance did not differ significantly from controls in Experiment 3, so she was able to perform the spatial discrimination tasks at small distances that the prosopagnosics from Barton and Cherkasova (2005) were unable to perform. Upon completion of Experiment 3, LB was interviewed and asked if she used any strategies to help her complete the experiments. She indicated that she had not used any heuristics to complete Experiment 3.

Experiment 4

In Experiment 2, between-object and within-object spatial discrimination tasks were used to determine whether impairments in prosopagnosia extend to objects other than faces. The distances from the between-face spatial discrimination task of Barton and Cherkasova (2005) were used in Experiment 2, but these distances resulted in a ceiling effect in the results. The purpose of Experiment 4 is to make the task more difficult so that the performance would be lifted off the floor using the distances from the within-face and within-object spatial discrimination tasks of Barton and Cherkasova (2005) to determine if spatial impairment deficits in prosopagnosia extend to objects other than faces.

Method

Subjects

The subjects used were the same subjects from Experiment 1.

Apparatus

The apparatus used was the same apparatus from Experiment 1.

Stimuli

Stimuli for Experiment 4 were grayscale photos of three identical balls. Each ball occupied an area of $8.8^\circ \times 8.8^\circ$ of visual angle and the three balls were located in a triangular configuration. There were three dots presented in a triangular configuration either within one ball (within-object spatial discrimination task) or there was one dot on each of the three balls (between-object spatial discrimination task). The balls were in a triangular configuration 8.8° apart from each other with either the lower right or the lower left dot being displaced from the other two dots by $4.2'$, $8.4'$, $12.6'$, $16.8'$, $21'$, $25.2'$, $29.4'$ or $33.6'$ of visual angle. The triangular configuration of the dots had a possibility of occurring in six different locations (three locations on the between-object task and three locations on the within-object task). There were a total of 96 images. Examples of the stimuli are located in Figure 20.

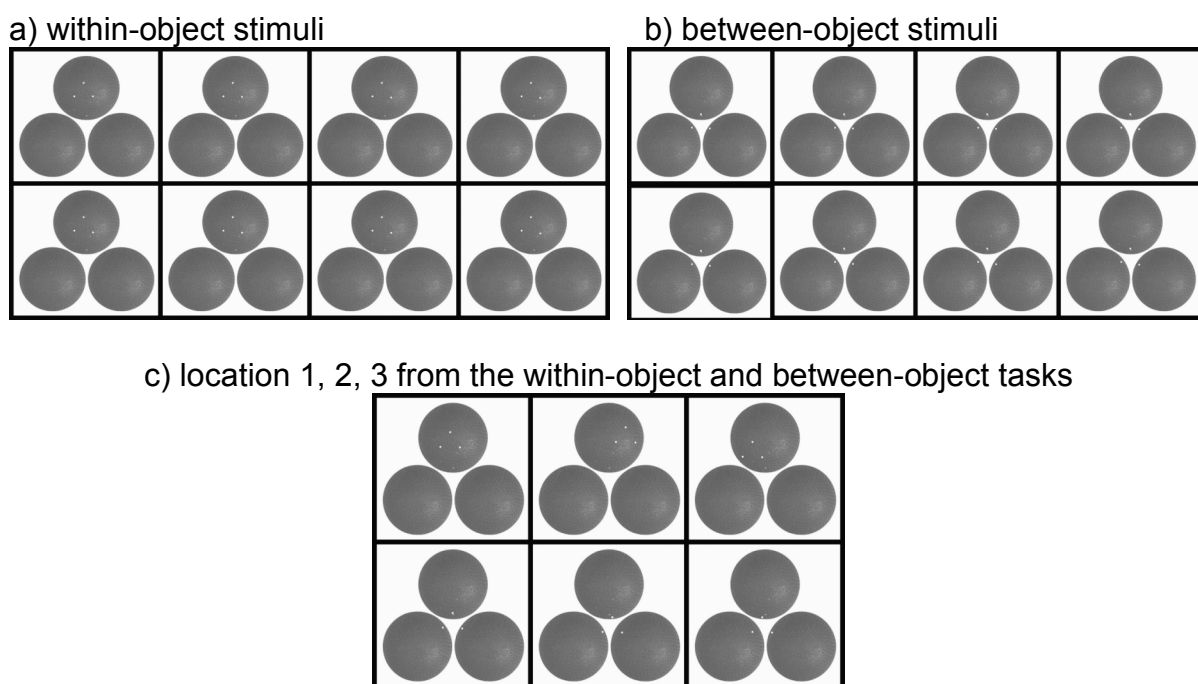


Figure 20. Examples of the possible stimuli presented in the within-object and between-object tasks in Experiment 4. (a) within-object stimuli, (b) between-object stimuli, (c) examples of locations 1, 2 and 3 for the within-object and between-object tasks. The subject's task was to determine which dot, the lower left or the lower right, was more distant from the other two dots.

Procedure

The participant initiated each trial with a key press on the computer keyboard. After a key press, a cue was presented for 500 ms, followed by one of the stimuli, which remained on the screen until the subject responded. The subject's task was to determine which dot (the lower left or the lower right) was farther from the other two dots. The subjects were instructed to press the "z" key if the lower left dot was farther from the other two dots and press the "r" key if the lower right dot was farther from the other two dots.

The experiment consisted of 384 trials that were presented in a randomized order. There were 96 stimulus displays in the experiment: 48 within-object and 48

between-object. The triangular arrangement of dots occurred in three locations on the within-object trials and three locations on the between-object trials. Of the 48 images within-object trials and between-object trials; 16 (8 with lower right dot changed and 8 with lower left dot changed) were distance changes in location one, 16 in location two, and 16 in location three (see Figure 20). Half of the trials were tests of within-object spatial discrimination and the other half of the trials were tests of between-object spatial discrimination. Each trial was repeated 4 times for a total of 384 trials. Each subject completed 8 practice trials, using stimuli not present in the experiment proper, prior to beginning the experiment.

Results

The results from Experiment 4 are shown in Figure 21 and were analyzed in the same manner as the results from Experiment 1. Analysis of the accuracy rate of the age-matched control on the between-object spatial discrimination task compared to the accuracy rate of the controls on the between-object spatial discrimination task did not reveal a significant difference ($t(14)=0.14$, $p>0.05$, $se=3.95$). A power analysis indicated the smallest detectable difference to be 13.50%. Similarly, analysis of the accuracy rate of LB on the between-object spatial discrimination task compared to the accuracy rate of controls on the between-object spatial discrimination task did not reveal a significant difference ($t(14)=0.06$, $p>0.05$, $se=3.95$).

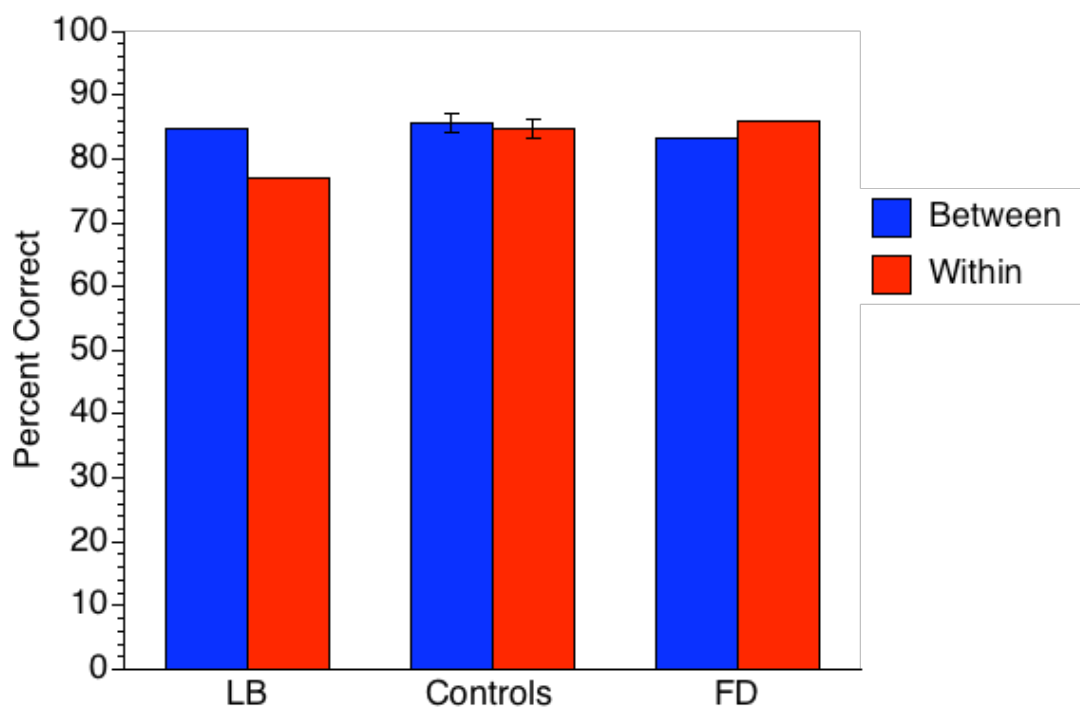


Figure 21. Accuracy rates from Experiment 4 (standard error bars are displayed for controls).

Analysis of the accuracy rate of FD on the within-object spatial discrimination task compared with the controls' accuracy rate on the within-object spatial discrimination task did not reveal a significant difference ($t(14)=0.08$, $p>0.05$, $se=3.87$). Similarly, analysis of the accuracy rate of LB on the within-object spatial discrimination task compared with the controls' accuracy rate on the within-object spatial discrimination task did not reveal a significant difference ($t(14)=0.48$, $p>0.05$, $se=3.87$). LB's difference in performance on the between-object spatial discrimination task and the within-object spatial discrimination task, relative to controls, was calculated using a difference score and revealed no significant interaction ($t(14)=0.40$, $p>0.05$, $se=7.82$).

Further analysis of the age-matched control's accuracy in performing the between-object spatial discrimination task compared to the control group's accuracy was broken down by distance change to reveal a significant difference at 25.2' ($t(14)=2.32$, $p<0.05$, $se=1.31$) but no significant difference at 4.2' ($t(14)=1.40$, $p>0.05$, $se=2.45$), 8.4' ($t(14)=0.73$, $p>0.05$, $se=2.65$), 12.6' ($t(14)=0.65$, $p>0.05$, $se=1.86$), 16.8' ($t(14)=1.09$, $p>0.05$, $se=1.85$), 21' ($t(14)=1.59$, $p>0.05$, $se=2.15$), , 29.4' ($t(14)=1.00$, $p>0.05$, $se=1.08$), or 33.6' ($t(14)=0.23$, $p>0.05$, $se=1.15$). LB's accuracy in performing the between-object spatial discrimination task compared to the control group's accuracy broken down by distance change revealed no significant difference at 4.2' ($t(14)=0.16$, $p>0.05$, $se=2.45$), 8.4' ($t(14)=0.40$, $p>0.05$, $se=2.65$), 12.6' ($t(14)=1.20$, $p>0.05$, $se=1.86$), 16.8' ($t(14)=1.09$, $p>0.05$, $se=1.85$), 21' ($t(14)=0.19$, $p>0.05$, $se=2.15$), 25.2' ($t(14)=0.77$, $p>0.05$, $se=1.31$), 29.4' ($t(14)=1.00$, $p>0.05$, $se=1.08$), or 33.6' ($t(14)=0.65$, $p>0.05$, $se=1.15$).

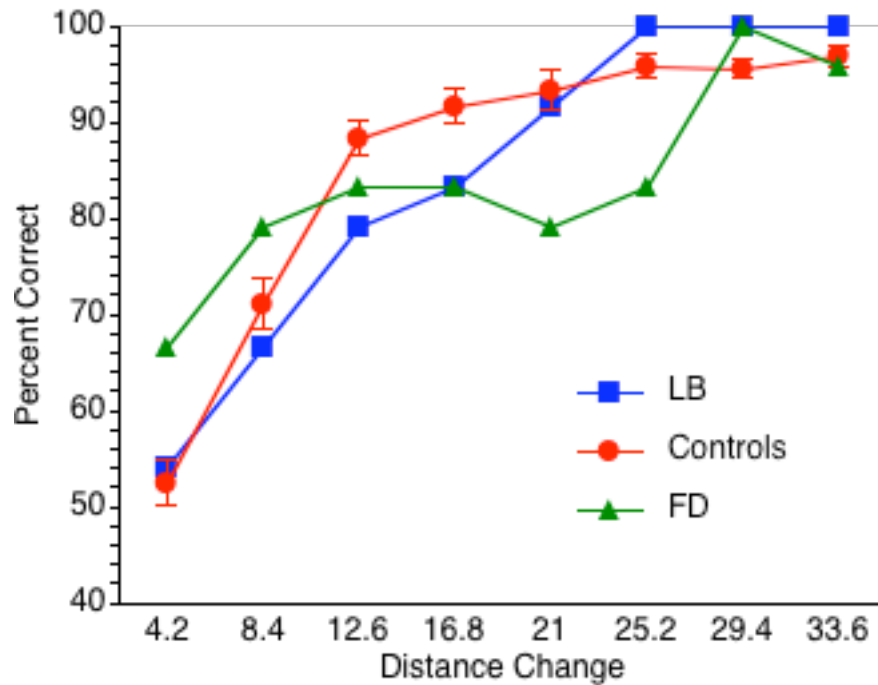


Figure 22. Accuracy data from the between-object spatial discrimination task in Experiment 4 displayed by distance change.

Further analysis of the age-matched control's accuracy in performing the within-object spatial discrimination task compared to the control group's accuracy was broken down by distance change to reveal a significant difference at 4.2' ($t(14)=4.60$, $p>0.05$, $se=1.61$) but no significant difference at 8.4' ($t(14)=0.75$, $p>0.05$, $se=3.06$), 12.6' ($t(14)=1.46$, $p>0.05$, $se=2.03$), 16.8' ($t(14)=0.64$, $p>0.05$, $se=2.11$), 21' ($t(14)=1.33$, $p>0.05$, $se=1.62$), 25.2' ($t(14)=2.11$, $p>0.05$, $se=1.75$), 29.4' ($t(14)=1.32$, $p>0.05$, $se=0.87$), or 33.6' ($t(14)=1.61$, $p>0.05$, $se=1.17$). LB's accuracy in performing the within-object spatial discrimination task compared to the control group's accuracy broken down by distance change to reveal no significant difference at 4.2' ($t(14)=0.42$, $p>0.05$, $se=1.61$), 8.4' ($t(14)=1.89$, $p>0.05$, $se=3.06$), 12.6' ($t(14)=1.03$, $p>0.05$, $se=2.03$), 16.8' ($t(14)=1.12$, $p>0.05$, $se=2.11$), 21'

($t(14)=0.08$, $p>0.05$, $se=1.62$), 25.2' ($t(14)=1.54$, $p>0.05$, $se=1.75$), 29.4' ($t(14)=1.32$, $p>0.05$, $se=0.87$), or 33.6' ($t(14)=0.75$, $p>0.05$, $se=1.17$).

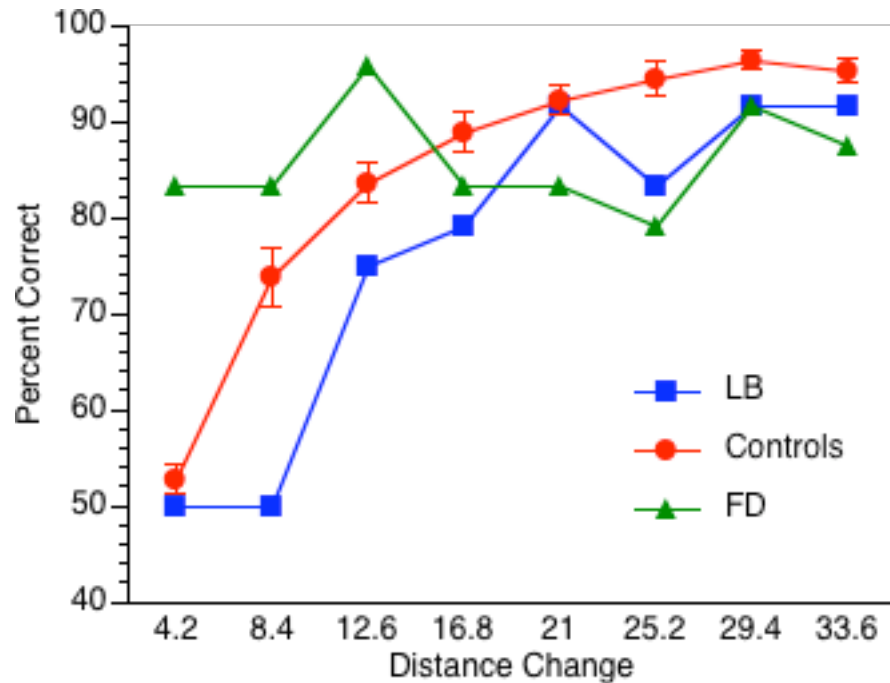


Figure 23. Accuracy data from the within-object spatial discrimination task in Experiment 4 displayed by distance change.

A within subjects ANOVA on the control subjects data combined over between and within object trials showed a significant effect of distance change on performance ($F(7.94)=163.51$, $p<0.001$) showing that the experiment was sufficiently powerful to find effects in the data.

Reaction Time Data

The mean reaction time on the between-object trials for LB, the control group and FD were 1668 ms, 1299 ms ($s=795$), and 1247 ms, respectively. LB's reaction times for the between-object trials broken down by distance change were 2254 ms

(4.2'), 2281 ms (8.4'), 1869 ms (12.6'), 1661 ms (16.8'), 1529 ms (21'), 1331 ms (25.2'), 1169 ms (29.4') and 1251 ms (33.6'). The control group's reaction times for the between-object trials broken down by distance change were 1974 ms (s=1309, 4.2'), 1550 ms (s=893, 8.4'), 1383 ms (s=773, 12.6'), 1153 ms (s=449, 16.8'), 1153 ms (s=505, 21'), 1031 ms (s=376, 25.2'), 1018 ms (s=447, 29.4'), and 1131 ms (s=813, 33.6'). The age-matched control's reaction times for the between-object trials broken down by distance change were 1460 ms (4.2'), 1322 ms (8.4'), 1338 ms (12.6'), 1213 ms (16.8'), 1167 ms (21'), 1274 ms (25.2'), 1209 ms (29.4') and 996 ms (33.6').

The mean reaction time on the within-object trials for LB, the control group and FD were 1764 ms, 1248 ms (s=632), and 1084 ms, respectively. LB's reaction times for the within-object trials broken down by distance change were 2071 ms (4.2'), 1795 ms (8.4'), 1761 ms (12.6'), 1979 ms (16.8'), 1882 ms (21'), 1654 ms (25.2'), 1549 ms (29.4') and 1423 ms (33.6'). The control group's reaction times for the within-object trials broken down by distance change were 1705 ms (s=969, 4.2'), 1608 ms (s=826, 8.4'), 1301 ms (s=581, 12.6'), 1190 ms (s=491, 16.8'), 1183 ms (s=532, 21'), 1087 ms (s=382, 25.2'), 991 ms (s=304, 29.4'), and 919 ms (s=292, 33.6'). The age-matched control's reaction times for the within-object trials broken down by distance change were 1378 ms (4.2'), 1339 ms (8.4'), 1078 ms (12.6'), 1011 ms (16.8'), 1103 ms (21'), 1004 ms (25.2'), 908 ms (29.4') and 853 ms (33.6'). The reaction time data for the within-object and between-object trials did not indicate a speed-accuracy trade off.

Discussion

The purpose of Experiment 4 was to use the within-object spatial discrimination distances from Barton and Cherkasova (2005) to determine if the spatial impairments in prosopagnosia extend to objects other than faces.

The results from Experiment 4 do not indicate a difference in performance on between-object and within-object discriminations in prosopagnosia. LB did not differ significantly from controls on her performance on either the between-object spatial discrimination task or the within-object spatial discrimination task.

Figures 22 and 23 provide the accuracy data from Experiment 4 broken down by minutes of visual angle changes on the between-object and within-object tasks. When the results were broken down by minute of visual angle changes, the only statistically significant differences found were between FD and controls on the 25.2' of visual angle between-object spatial discrimination task ($t(14)=2.32$, $p<0.05$) and the 4.2' of visual angle within-object spatial discrimination task ($t(14)=4.60$, $p<0.05$). In addition, these data show a drop off in performance at smaller distance changes. At the largest distance change used in Experiment 4, 33.6', LB, the control group and FD were 100%, 96.94% and 95.83% accurate on the between-face spatial discrimination task, respectively, and 91.67%, 95.28% and 87.5% accurate on the within-face spatial discrimination task, respectively. However, at the smallest minute of visual angle change used in Experiment 4, 4.2', LB, the control group and FD were 54.17%, 52.50% and 66.67% accurate on the between-face spatial discrimination task, respectively, and 50.00%, 52.78% and 83.33% accurate on the

within-face spatial discrimination task, respectively. The ANOVA results indicated that there was a significant effect of distance change on performance.

Experiment 4 was designed to be a follow up study to Experiment 2, which used the between-face spatial distances from Barton and Cherkasova (2005). In Experiment 2, there was no significant difference between LB and controls on the within-object and between-object spatial discrimination tasks, which is evidence that the experimental design of Barton and Cherkasova (2005) was flawed. Experiment 4 was designed to use the within-face spatial distances from Barton and Cherkasova (2005) in an attempt to replicate their result that difficulties in performing spatial discrimination tasks in prosopagnosia extend to objects other than faces. The results from the Experiment 4 indicate that there is no difference in LB's performance on the within and between object discrimination tasks.

There is a debate in the prosopagnosia literature concerning whether or not the deficits in prosopagnosics extend to objects other than faces with the coordinate relation hypothesis suggesting that the impairments should extend to objects other than faces. The coordinate relations hypothesis would predict that LB should perform worse than controls on both the within-object and between-object tasks; however, the results from the Barton and Cherkasova (2005) within-object task were not replicated in Experiment 4 which is interesting as prosopagnosics have been shown to have difficulties discriminating small distances such as those used in Experiment 4. Upon completion of Experiment 4, she was interviewed about her performance and asked if she used any strategies to help her successfully complete the task. She denied using any heuristics to complete the task.

GENERAL DISCUSSION

In the current study, four experiments tested whether prosopagnosia was the result of impairments in within-object spatial discrimination as posited by Barton and Cherkasova (2005) or the result of inability to discriminate small distances. The purpose of Barton and Cherkasova (2005) was to determine whether prosopagnosia was the result of within-face or between-face spatial impairments and to determine if these impairments extended to non-face objects. Barton and Cherkasova (2005) had a major experimental confound in that different distances were used in the between-face and within-face spatial processing tasks. For the within-face spatial discrimination task, Barton and Cherkasova (2005) used distances changes of 4.2', 8.4', 12.6', 16.8', 21', 25.2', 29.4' and 33.6' of visual angle while the between-face spatial discrimination task used distances changes of 42', 63', 84', 105', 126' and 147'. Due to the use of different distances between the two tasks, it is difficult to interpret the findings of Barton and Cherkasova (2005).

In addition, Barton and Cherkasova (2005) concluded that these spatial impairments extend to non-face objects, but the experimental design with non-face objects only tested within-object processing and the stimuli used were dot patterns, not objects in any conventional sense. Therefore, it is unclear if prosopagnosics have impairments on between-object processing of distances. The current study was designed to correct the two confounds present in the experimental design of Barton and Cherkasova (2005) by using the same distances on the within-face and between-face tasks as well as testing both within-object and between-object processing of non-face objects.

The goal of Experiment 1 was to replicate Barton and Cherkasova's (2005) finding of impaired within-face spatial discrimination in prosopagnosia using the same distances on the within-face and between-face tasks. The large distance changes from Barton and Cherkasova's (2005) between-face spatial task, 42' to 147' of visual angle, were used and the results did not indicate an impairment on between-face or within-face spatial processing in prosopagnosia. LB's mean accuracy did not differ significantly from controls even when the results were broken down by minutes of visual angle. However, there is the possibility of a ceiling effect for the distances between 63' and 147' of visual angle as all experimental subjects performed at near 100% on those discriminations, but the results from Experiment 1 did indicate that the discrimination task is more difficult for the prosopagnosic at smaller distances. At the 42' of visual angle change, performance did begin to drop which indicated that the different distances used by Barton and Cherkasova (2005) may have contributed to their findings. If the distances used in their original between-face task resulted in low difficulty level as shown here, it is possible that the distances used in their within-face task resulted in high difficulty level.

Experiment 2 attempted to replicate the finding of Barton and Cherkasova (2005) that spatial impairments in prosopagnosia extend to non-face objects by using the between-face spatial distances to test within-object and between-object spatial processing in a prosopagnosic. In the original study, Barton and Cherkasova (2005) tested only within-object processing so it is uncertain whether or not prosopagnosics have impairments in between-object processing. The results from Experiment 2 did not indicate an impairment in within-object or between-object

spatial discrimination in prosopagnosia. LB's mean accuracy did not differ significantly from controls even when the results were broken down by minute of visual angle changes. Furthermore, Experiment 2 replicated the finding of Experiment 1 that the between-face distances used by Barton and Cherkasova (2005) resulted in low difficulty level of the experiment. LB and the controls performed at ceiling for the 63' to 147' and performance began to decline near the 42' distance. Experiment 2 provided further evidence that the confound of distance in Barton and Cherkasova (2005) contributed to their findings.

Experiments 1 and 2 provided evidence that the distance confound in Barton and Cherkasova (2005) contributed to the finding of impairments in within-object spatial processing, but Experiments 1 and 2 had low difficulty levels with possible ceiling effects. The ceiling effects found in Experiments 1 and 2 make it difficult to interpret the findings, so Experiments 3 and 4 were designed to pull performance off the ceiling by making the task more difficult. The purpose of Experiments 3 and 4 were to replicate Experiments 1 and 2, respectively, using the within-face distances from Barton and Cherkasova (2005). If the finding of impairment in within-object but not between-object spatial processing was due to the use of different distances between the two tasks, Experiments 3 and 4 should be more difficult as these experiments are using the smaller within-object distances from Barton and Cherkasova (2005).

Neither Experiments 3 nor 4 found a significant difference in performance in the prosopagnosic in within-object and between-object spatial processing. LB's mean accuracy did not differ significantly from controls in either experiment even

when the results were broken down by minutes of visual angle. The only significant results from the two experiments were between the age-matched control, FD, and the control group. However, the overall mean accuracy rates for Experiments 3 and 4 were much lower than Experiments 1 and 2. The mean accuracy rates for LB, the control group and FD were 98.27%, 98.57%, and 98.84%, respectively, in Experiment 1 and 89.5%, 84.78% and 85.54%, respectively, in Experiment 3. Similarly, the mean accuracy rates for LB, the control and FD were 98.27%, 98.63% and 98.61%, respectively, in Experiment 2 and 80.76%, 85.18% and 84.64% in Experiment 4. Furthermore, when the results from Experiments 3 and 4 were broken down by minutes of visual angle, LB and the controls had drastic declines in performance as the distances used in the task decreased (see Figures 18, 19, 22 and 23). These findings indicate that the within-face distances used by Barton and Cherkasova (2005) produced more difficult experimental trials than the between-face distances and likely contributed to their finding of spatial impairments on within-object but not between-object spatial discrimination.

There are some notable differences between Barton and Cherkasova (2005) and the current study. First, Barton and Cherkasova (2005) altered the within-object and between-object distances on all three objects present in the triangular configuration whereas the current study only altered distances on the lower right or lower left objects. These differences would make the current study an easier task than Barton and Cherkasova (2005) which may account for the ceiling effects from Experiment 1 and 2; however, there was not a ceiling effect in Experiments 3 and 4 so the findings of Barton and Cherkasova (2005) should have been replicated if they

were not the result of confounds with the original experimental design. The second notable difference between Barton and Cherkasova (2005) and the current study is that Barton and Cherkasova (2005) manipulated the facial features on the within-object task while the current study manipulated blemishes present on the faces. Prosopagnosics have difficulty recognizing the facial features so one possible criticism of the current study could be that the study was testing the ability of prosopagnosics to discriminating distances between dots which is not their impairment. However, Barton and Cherkasova (2005) found similar results on their within-face and within-object task and their within-object required the prosopagnosics to discriminate distances between pairs of dots. The current study should have been able to replicate their findings if they were not due to confounds in the experimental design because the current study used a similar experimental design as the within-object task where significant results were found.

One peculiar finding from this experiment was the ability of the prosopagnosic, LB, to perform the within-object and between-object spatial discrimination tasks as well as, and in some cases better than, the controls. LB has been shown previous, O'Brien, Cooper, Casner & Brooks (2006), impairments at discriminating small distances such as those used in the within-face and within-object spatial tasks in the current study. Previous tests, (O'Brien, Cooper, Casner & Brooks (2006), of her spatial discrimination ability have used a different task, recreating spatial distances, so perhaps the finding of no difficulty in discriminating small distances in the current study may be due to the use of a different task in this study. The Coordinate Relations Hypothesis holds that prosopagnosia is the result of

impairments to the coordinate relations system, which computes exact metric distances, so the Coordinate Relations Hypothesis would have predicted that LB should be impaired at discriminating the smaller metric changes in the within-object tasks. In addition, other studies have shown that prosopagnosics are impaired at discriminating small distances (Grusser, O. J., & Landis, T., 1991), so it is unclear why LB was able to perform similarly to controls on both tasks.

Diffuse Brain Damage and Spatial Discrimination Performance

The Barton and Cherkasova (2005) study concluded that prosopagnosics have impaired within-object but not between-object spatial discrimination. However, one of the prosopagnosics used in the study performed similarly to controls on both the within-face and within-object tasks. This individual was Subject 009 who is a 49-year-old male that suffered a right posterior cerebral artery stroke (Barton & Cherkasova, 2005). Barton and Cherkasova (2005) contributed this finding to the Subject 009's focal brain damage relative to the other prosopagnosics used in their study. Figure 24 shows Figure 1 from Barton and Cherkasova (2005), which displays template drawings of the MRI lesions of the acquired prosopagnosic individuals used in the study. Subject 009 has less diffuse brain damage than the other four prosopagnosics. Most notably, the damage to the middle occipito-temporal lobe is located in the posterior portion of the lobe in Subject 009 while it extends more anterior in the other four prosopagnosic patients as indicated by the red boxes in Figure 24.

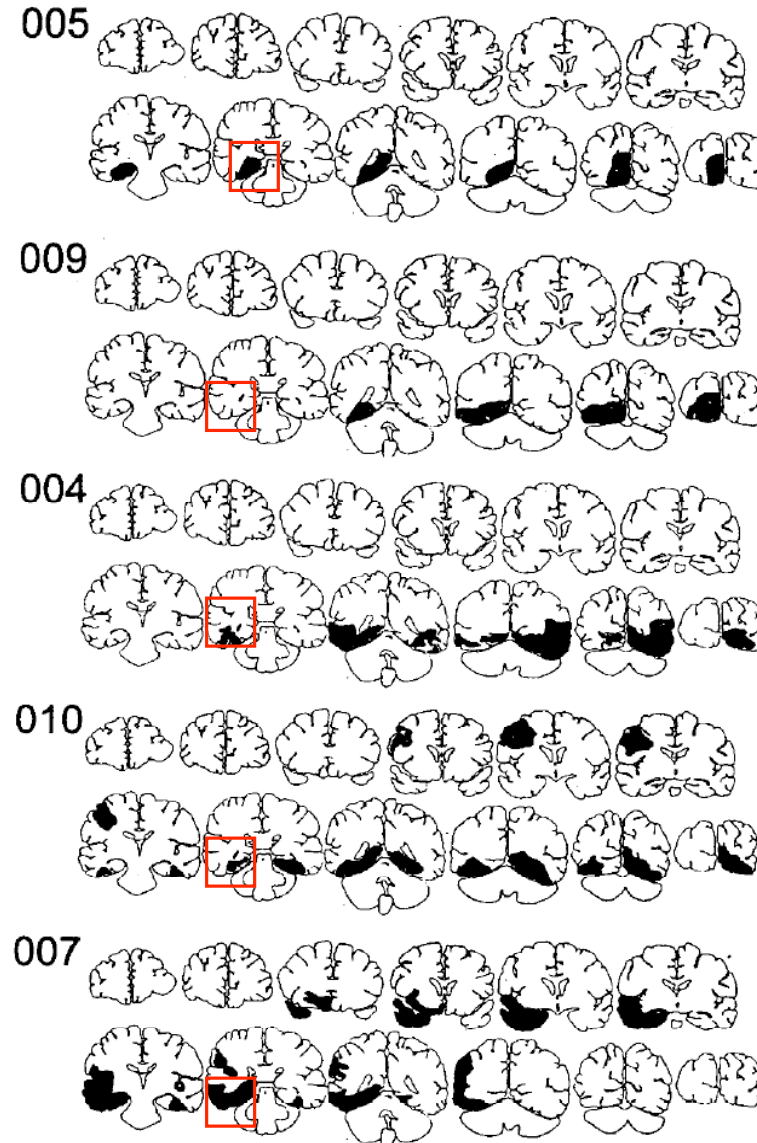


Figure 24. Figure 1 from Barton and Cherkasova (2005) represents template drawings of the lesions of the five acquired-prosopagnosics used in the study. The red boxes indicate the more anterior region of the middle occipito-temporal lobe that is intact in Subject 009 and LB but damaged in the other prosopagnosic individuals.

Because LB performed similarly to Subject 009 and both LB and Subject 009 performed better than the other prosopagnosics from Barton and Cherkasova (2005), the brain damage experienced by all prosopagnosics was closely examined

to determine if there were any similarities or differences. Interestingly, both LB and Subject 009 had a posterior cerebral artery stroke that resulted in brain damage mainly to the posterior middle occipito-temporal lobe while the other prosopagnosics had damage that extended more anterior in the middle occipito-temporal lobe. This finding suggests that the performance of LB and Subject 009 on the small spatial discrimination distances may be due to this anterior region of the middle occipito-temporal lobe remaining intact. Perhaps damage to this region affects the ability to discriminate small distances.

Future Directions

The current study did not find a within-object or between-object spatial impairment in prosopagnosia. The results from the experiments used in the study indicate that prosopagnosia is not the result of a specific spatial impairment, but they do not provide evidence in support of the Coordinate Relations Hypothesis viewpoint that prosopagnosia is a deficit in computing exact distances as LB was not significantly different from controls on her ability to perform the spatial discriminations in any of the tasks reported herein. Future studies should investigate LB's ability to discriminate small distances in an attempt to determine why she was able to perform the within-object tasks.

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