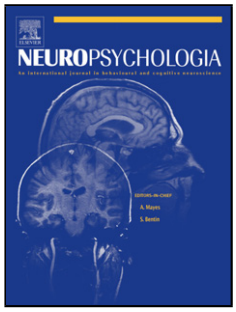

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Running head: PRIMING EXPRESSIONS IN AGNOSIA

The Right Place at the Right Time: Priming Facial Expressions with Emotional Face Components in Developmental Visual Agnosia

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Abstract

The current study examined the nature of deficits in emotion recognition from facial expressions in case LG, an individual with a rare form of developmental visual agnosia (DVA). LG presents with profoundly impaired recognition of facial expressions, yet the underlying nature of his deficit remains unknown. During typical face processing, normal sighted individuals extract information about expressed emotions from face regions with activity diagnostic for specific emotion categories. Given LG's impairment, we sought to shed light on his emotion perception by examining if priming facial expressions with diagnostic emotional face components would facilitate his recognition of the emotion expressed by the face. LG and control participants matched isolated face components with components appearing in a subsequently presented full-face and then categorized the face's emotion. Critically, the matched components were from regions which were diagnostic or non-diagnostic of the emotion portrayed by the full face. In experiment 1, when the full faces were briefly presented (150 ms), LG's performance was strongly influenced by the diagnosticity of the components: His emotion recognition was boosted within normal limits when diagnostic components were used and was obliterated when non-diagnostic components were used. By contrast, in experiment 2, when the face-exposure duration was extended (2000 ms), the beneficial effect of the diagnostic matching was diminished as was the detrimental effect of the non-diagnostic matching. These data highlight the impact of diagnostic facial features in normal expression recognition and suggest that impaired emotion recognition in DVA results from deficient visual integration across diagnostic face components.

Keywords: Developmental visual agnosia, facial expressions, diagnostic components

1. Introduction

Developmental visual agnosia (DVA) is characterized by lifelong difficulties with visual recognition in the absence of evident brain lesions, cognitive impairments or low level impaired eyesight (Farah, 1990; Gilaie-Dotan, Perry, Bonneh, Malach, & Bentin, 2009). Individuals with DVA may present with profound deficits in object recognition, impaired visual integration and deficits in processing face identity and face expression (Ariel & Sadeh, 1996; Aviezer, Hassin, & Bentin, in press; Gilaie-Dotan, et al., 2009). While previous work has demonstrated profound deficits in facial expression recognition in DVA the underlying cause remains unknown. The current study examined the impaired recognition of face-expressed emotions by testing how diagnostic face parts are perceived and integrated in case LG, an individual with a rare form of DVA with a profound visual integration deficiency (Gilaie-Dotan, et al., 2009).

Although severely impaired face identification is characteristic to DVA, this rare syndrome differs from classic developmental prosopagnosia (DP) in three important ways. First, from a clinical perspective, individuals with DVA typically present with profound and pervasive visual deficits, which typically include form agnosia, deficient perceptual integration of parts to a meaningful whole, and impaired generalized processing of faces, including gender, emotion, and identity information (Ariel & Sadeh, 1996; Duchaine, Nieminen-von Wendt, New, & Kulomaki, 2003). By contrast accumulating evidence suggests that most individuals with DP do not typically suffer from such pervasive visual deficits. Rather, they often have fairly intact recognition of social and emotional information from faces alongside specific deficits in identity processing (e.g., Dobel, Bolte, Aicher, & Schweinberger,

2007; Duchaine, Jenkins, Germine, & Calder, 2009; Duchaine, Murray, Turner, White, & Garrido, 2009; Duchaine & Nakayama, 2006; Duchaine, Parker, & Nakayama, 2003; Garrido et al., 2009; Humphreys, Avidan, & Behrmann, 2007; Palermo, Willis, Rivolta, Wilson, & Calder, 2010; Palermo et al., 2011; Todorov & Duchaine, 2008). While some DPs may have deficits with both face and object processing (Behrmann & Avidan, 2005) most exhibit face-specific deficits with no evidence of impairment in matched tests of object recognition or other types of visual recognition (Bentin, DeGutis, D'Esposito, & Robertson, 2007; Bentin, Deouell, & Soroker, 1999; Duchaine & Nakayama, 2005; Duchaine, Yovel, & Nakayama, 2007). Furthermore, LG, the individual with DVA tested here, displayed profound integration deficits which are uncharacteristic of the typical DP case. We further elaborate on the unique aspects of DVA as apposed to DP when we describe LG's case history.

The second important difference between DVA and DP stems from functional neuroanatomy. A previous study of LG revealed a highly atypical pattern of brain activity to visual stimuli which has not been described in DP. Specifically, Gilaie-Dotan and colleagues (2009) have shown that in LG, V1 was robustly activated by visual stimuli, and activity in down stream visual areas showed selectivity for houses and places (but not for faces and objects). Yet intriguingly, intermediate visual areas (V2-V4) showed strong deactivation in response to any visual stimulation. Studies in developmental prosopagnosia have yielded inconsistent results with regard to activation in the fusiform gyrus, with some studies showing normal activity (Avidan, Hasson, Malach, & Behrmann, 2005; Hasson, Avidan, Deouell, Bentin, & Malach, 2003) while others did not (Bentin, et al., 2007; Van den Stock, van de Riet, Righart, & de Gelder, 2008). Yet, studies with DP have not showed such atypical deactivation

of intermediate visual areas as in case LG, further establishing the difference between DP and, at least, the current case of DVA[1].

Finally, from an epidemiological perspective there is an additional distinction between DP and DVA: with an estimated prevalence of 2% in the general population (Kennerknecht et al., 2006), DP is surprisingly common, while DVA appears to be far rarer and is seldom described in the literature. Consequently, because of the scarcity of DVA cases, little is known about the perceptual mechanisms underlying their deficient face processing in general and their recognition of emotional expressions in particular. To this end, the present study makes an important contribution to a broader understanding of face processing impairments in DVA.

In their original report, Ariel and Sadeh (1996) described LG as poor at recognizing facial expressions; however the procedure and testing stimuli they used were informal. Recent follow up testing with prototypical and standardized facial expressions indicated that LG is still densely impaired at the recognition of facial expressions, e.g., his recognition of anger and disgust hovered around chance level (Aviezer, et al., in press). Yet, while the existence of LG's current impairment is well established, its underlying cause remains unclear.

One possible explanation for LG's deficit may be that he fails to correctly extract and process information from the emotional face components. Individuals with normal vision recognize basic facial expressions by extracting information from specific signals (e.g., nose wrinkling, eye widening, etc) which are diagnostic of particular emotions (Brosch, Pourtois, & Sander, 2010; Buck, 1994; Ekman, 1993; Schyns, Petro, & Smith, 2007; Smith & Scott, 1997; Smith, Cottrell, Gosselin, & Schyns, 2005; Whalen et al., 2004). Although research has demonstrated holistic characteristics in facial expression perception (Calder, Young, Keane, & Dean, 2000) the components themselves are often sufficient to drive full emotional recognition

(Ellison & Massaro, 1997). In this line, Smith and colleagues (2005) revealed distinct diagnostic fingerprint-regions for each expression category: while the diagnostic region for anger faces entailed the detection of activity in the eyes, the diagnostic region for disgust expressions entailed the detection of activity in the lower, oral-nasal regions. LG, however, has lifelong visual agnosia, and he may have never learned how to successfully process emotional faces. Specifically, he may be impaired at focusing his visual processing on the face regions which entail diagnostic face components and extracting from them the affective information necessary for categorization.

In order to examine the role of diagnostic-component processing in LG's deficit we devised a *component-matching task* which directs participants to process specific facial components which may facilitate or interfere with the subsequent categorization of a facial expression. As seen in Figure 1, the task starts with a *matching procedure*: the participant is exposed to an isolated facial component (e.g., a mouth) followed by a briefly presented full face and is asked whether the respective components (i.e., the two mouths) are identical or not. This is followed by a *facial-expression judgment procedure* in which the participant is asked to report the emotion of the full face.

Critically, the matched component may or may not be diagnostic of the actual emotion expressed by the full face. For example, consider a trial in which an image of a mouth (obtained from an angry face) precedes an image of a full angry face (Figure 1). The matched feature in this case is non-diagnostic because, as previously described, anger is not recognized from the information in the mouth but rather from information in the eyes. While the mouth region of angry faces may be uninformative for the recognition of anger, it may actually hold information erroneously suggesting other emotions. Hence, forcing participants to match a

non-diagnostic component (i.e., a facial component that provides no reliable information about the intentionally posed facial expression) may reduce the subsequent recognition of the facial expression.

Note that the component matching procedure could influence the facially-expressed emotion recognition in two, non-mutually exclusive ways, which were effectively intertwined in our design. First, by enhancing the recognition of emotional information self-contained in the prime and second, by facilitating the processing of emotional information in the location dictated by the matching procedure. In experiment 1 we presented the full faces for a brief duration and predicted that matching diagnostic features would enhance LG's recognition, while matching non-diagnostic features would impede his recognition. Experiment 2 further examined these two potential sources of influence by keeping the component information constant, while significantly increasing the duration of the full face thereby allowing the participants to extract information from additional face locations aside from the region initially imposed by the component matching procedure.

2. Case History – LG

Detailed descriptions of LG's case have been reported in the earlier studies of Ariel and Sadeh (1996) and more recently in the neuropsychological and neuroimaging investigations of Gilaie-Dotan and colleagues (2009). For the sake of the current report we briefly review a selective synopsis of LG's visual agnosia, focusing on his impaired visual integration (see Gilaie-Dotan and colleagues (2009) earlier report for a more detailed description).

LG was diagnosed with DVA and prosopagnosia at the age of 8 (Ariel & Sadeh, 1996). He has no psychiatric or other neurological disease and MRI scanning found no discernible structural cortical abnormality (Gilaie-Dotan, et al., 2009). To date, at the age of 24, LG

functions as an independent adult although he has profound everyday difficulties with visual recognition. Objective clinical ophthalmologic examination did not indicate abnormal visual acuity (no refractive errors or optical correction were found necessary or effective) and, although some abnormalities were found in low level vision, these were not sufficient to explain his overall clinical presentation (for a detailed description of his low-level vision impairments see Gilaie-Dotan, et al., 2009).

2.1 High-level Perceptual Integration

LG, reads well, finished high school successfully and is about to obtain a university degree in bio-technology. However, in natural complex viewing conditions, serious difficulties arise. Informally, the way LG describes his problems is that

''Looking at objects further than about 4 m, I can see the parts but I cannot see them integrated as coherent objects, which I could recognize; however, closer objects I can identify if they are not obstructed; sometimes I can see coherent integrated objects without being able to figure out what these objects are.''

LG's visual integration was also examined formally with neuropsychological tests focused on this ability. In both the Hooper Visual Organization Test (HVOT), and the Overlapping Figure Test (Birmingham Object Recognition Battery (BORB-6; Riddoch & Humphreys, 1993) he scored in the impaired range. It is noteworthy that LG's performance stands in contrast to that of individuals with the more common DP who may present with intact performance on the HVOT (Bentin, et al., 2007) and the Overlapping Figure Test (Duchaine, 2000). Gilaie-Dotan and colleagues (2008) further demonstrated LG's integration deficit by presenting him with line drawing with or without occluding bars. Control participants easily integrated the visual information between the occluding bars and performed at nearly identical

levels regardless of the occlusion. By contrast, LG's performance dropped significantly with occluded images, indicating his difficulty at combining fragments into meaningful gestalts.

Recently, it has been shown that LG cannot integrate visual affective information from different sources (Aviezer, et al., in press). Specifically, when presented with emotional faces combined with congruent and incongruent emotion-expressing bodies he did not show the typical body influence on facial expression recognition (Aviezer et al., 2008), despite his successful recognition of the bodies alone. Although LG could correctly recognize the isolated emotional body context (93.75% correct, vs. 98.2% controls), unlike controls, his recognition of the facial expressions placed in congruent body contexts did not improve. Together, these findings highlight LG's specific impairments with visual integration.

2.2 Face Processing

Like other individuals with integrative visual agnosia (e.g., Aviezer et al., 2007; Riddoch & Humphreys, 1987) LG is extremely impaired in face processing. In the Benton Facial Recognition Test (Benton, Sivan, Hamsher, Varney, & Spreen, 1983), he scored in the severely impaired range, matching only 33 out of the 54 faces. Similarly, his performance in the Cambridge Face Memory Test (Duchaine & Nakayama, 2006) was 34/72, which is 6 points less than the average norm of individuals with DP and significantly below the normal mean performance of (58/72). When tested with specially designed tests of famous face identification, he was able to identify only 5 out of 53 faces (compared with an average of 40/53 in an age matched control group). LG was unable to identify his parents, his sister or himself, in photographs in which the contour and the hairline have been eliminated.

In a recent study we found several measures of LG's facial expression recognition deficient (Aviezer, et al., in press). First, his recognition of several basic face expressions was

near chance. Specifically relevant for the following experiments was his comparably poor recognition of prototypical anger faces and disgust faces. Second, LG made irregular confusions between facial expressions, such as frequently mis-categorizing negative facial expressions as "Happy". LG categorized 16/90 of negative expressions as happy, as opposed to a mere 0.7/90 in the control group.

3. Experiment 1

3.1 Method

3.1.1 Participants. LG and 42 Hebrew University students (26 female), mean age 20.3 (SD=2.1) participated in the study for course credit or payment.

3.1.2 Stimuli and design. Images of 6 individuals (3 female), each posing prototypical face expressions of disgust and anger were obtained from a standardized set (Ekman & Friesen, 1976). From each of the 12 faces used in this experiment two component images were cropped: one containing the eyes and one containing the mouth. Each of the disgust and anger faces was preceded, in separate trials, by eye and mouth components. Thus, a given facial expression (say, disgust) could be preceded by a component which could be diagnostic (an isolated mouth) or non diagnostic (isolated eyes) of the emotion posed by the face. Full face stimuli occupied a visual angle of approximately 13°× 6° when viewed at a distance of 60 cm from the screen. The isolated components were equal in size to the components in the full face (Figure 1).

We focused our present study on facial expressions of anger and disgust for three main reasons. First, the diagnostic recognition regions for anger and disgust are well documented and conveniently differentiated (Calder, et al., 2000; Smith, et al., 2005). While anger is best recognized from muscle activity in the upper half of the face, the opposite is true for disgust, which is best recognized from the lower half of the face (Aviezer, et al., 2008; Bassili, 1979;

Calder & Young, 2005; Calder, et al., 2000; Smith, et al., 2005). Calder et al. (2000) compared the recognition of facial expressions from upper face halves, lower face halves, and whole faces. Their results showed that for anger, whole and top half faces were equally recognizable, while bottom half faces were less recognizable. Conversely, for disgust, whole faces and bottom half faces were equally recognizable, while top half faces were less recognizable.

Second, the facial expressions of anger and disgust are ideal candidates for shifting across category boundaries because the two expressions are often confusable (Aviezer, Hassin, Bentin, & Trope, 2008; Ekman & Friesen, 1976). For example, the categorization and characteristic eye-scanning of disgust and anger faces can be shifted by emotional body context (Aviezer, et al., 2008). However, confusability occurs with isolated faces of anger and disgust as well (Susskind, Littlewort, Bartlett, Movellan, & Anderson, 2007). Hence, we expected that our manipulation would be most effective in altering the recognition between anger and disgust faces.

Third, as previously described in LG's case description, his recognition was severely and comparably impaired for both anger (LG *M*=20%, age group norm *M* = 82.1%, cut off = 50, chance level 16.6%) and disgust faces (LG *M* = 10%, age group norm *M*= 83.8%, cut off =60; chance level 16.6%, (Young, Perrett, Calder, Sprengelmeyer, & Ekman, 2002). Hence, we could assume that any success in emotion recognition following our manipulation did not result from differences in his baseline recognition.

Of the critical experimental trials, 24 were diagnostic (that is, participants were asked to match features that are diagnostic to the emotion; 12 anger and 12 disgust) and 24 were non-diagnostic (12 anger and 12 disgust). In order to veil the nature of the experimental manipulation, and to reduce the likelihood of participants linking specific features with a

particular face, the critical trials were diluted within a wide array of non-related categorization filler trials (72 emotional fillers and 48 social fillers). Note that these filler trials followed the exact same structure of the critical trials, i.e., a cuing feature (either mouth or eyes) was first presented and matched with the respective feature in a subsequent full face. The full faces were mostly morphed emotional combinations from a private set used in our lab (e.g. happy-disgust). The matching was then followed by participants scoring the expressive faces on a variety of social and emotional ratings (e.g., dominance, intelligence, expression etc).

The experimental design included 2 levels of component Diagnosticity (diagnostic, non-diagnostic) × 2 levels of the face Emotion (anger, disgust). One group of 21 participants was tested with diagnostic primes and another group of 21 participants was tested with non-diagnostic primes. Hence the analysis of the control group performance was based on a mixed-model ANOVA with Diagnosticity as the between-subjects factor and Emotion as the within-subject factor. In the diagnostic condition, isolated eyes (taken from angry faces) were matched with the eyes in full anger faces and isolated mouths (taken from disgust faces) were matched with the mouths in full disgust faces. In the non-diagnostic condition, we used the opposite association, eye matching for disgust faces and mouth matching for anger faces.

LG was tested in all 4 Diagnosticity × Emotion conditions. However, the influence of priming on his ability to categorize facial expressions was compared separately for the diagnostic and the non-diagnostic conditions with the respective control group. A mixed-model ANOVA procedure for assessing differences between an individual case and a control group in multi-factorial experiments (Corballis, 2009) was used, with Group (control, LG) as the between-subjects factor and Emotion as the within-subject factor [2]. We used the recognition accuracy of the emotional facial expressions as a dependent measure assessing the influence of

the matching diagnosticity. Note that by "accuracy" we refer to responses that correspond to the intended posed emotion (Ekman & Friesen, 1976).

3.1.3 Task and Procedure. At the start of each trial, an isolated facial component (e.g., a cropped image of a mouth) was presented for 1500 ms followed by a 500 ms fixation and the presentation of a full face expression for 150 ms (see Figure 1). Participants were then instructed to determine (A) if the isolated component was identical or non identical to the equivalent component appearing in the subsequently presented full face and (B) what was the emotion/social trait of the full face. In the component matching task, the identical conditions included trials in which the preceding isolated component was cropped from the subsequent face (e.g., a mouth cropped from John's anger face – matched with John's full anger face). In the non-identical conditions, the isolated component was cropped from a different identity face (e.g., a mouth cropped from Jack's anger face – matched with John's full anger face). The isolated components always appeared in the same spatial location in which the full face component would later appear. Identical and non-identical trials were equally frequent and presented in random order. It should be emphasized that the matching of the components *per se* was of no interest in our design, and it merely served to ensure that participants are allocating attention to and processing diagnostic or non-diagnostic information.

After the component-matching task, participants immediately categorized the full face on one of various characteristics (e.g., attractiveness, emotion, age, etc). All face judgments (emotional and social) were carried out by choosing one of 6 options appearing on screen. When emotions were determined, the 6 options included the basic emotions of anger, sadness, fear, disgust, surprise, and happiness. Permitting six basic emotional response options allowed us to examine if LG displays atypical emotional categorizations as a function of the component

diagnosticity. The critical trials of interest were those in which isolated components (both identical and non-identical) were matched with the components embedded in the facial expressions of anger and disgust, followed by emotion judgments.

3.2 Results

The accuracy rate in the component matching task was 93.3% for the controls and 90.7% for LG. A mixed ANOVA showed that the overall component matching performance of LG was comparable to that of the controls, and there were no differences between diagnostic and non diagnostic trials for both LG and controls (all *Fs* < 1). Subsequent analyses were run on the correct trials.

3.2.1. Diagnosticity effects on control participants. We first characterized the responses of the control group alone. Then we followed protocols for assessing individual cases in multi-factorial experiments with an ANOVA in which the between subject Group factor (single case vs. controls) was tested for a main effect and interaction (Corballis, 2009)

The Emotion (anger, disgust) × Diagnosticity (diagnostic, non-diagnostic) ANOVA within the control group showed that facial expression recognition was systematically influenced by the diagnosticity of the cuing component. When the matched component was diagnostic for the emotion expressed by the full face, the overall recognition of the facial expression was more accurate than when the matched component was non-diagnostic, $F(1,40) = 11.7$, $p < .001$, $\eta_p^2 = .227$ (Figure 2; for a full breakdown by emotion category see Table 1). While participants were overall more accurate at recognizing anger (*M*=66.1%, *SD*=18.2) than disgust (*M*=46.8%, *SD*=23.1) $F(1,40)=19.8$, $p < .0001$, $\eta_p^2 = .331$, the Diagnosticity × Emotion interaction was not significant, $F < 1$.

3.2.2. Diagnosticity effects: LG vs. controls. We next examined if LG and controls were differently influenced by the diagnosticity of the priming component. When the matching task involved non-diagnostic face components, LG's emotion recognition was significantly worse than controls $F(1,20)=7.4$, $p < .013$, $\eta_p^2 = .272$. There was no significant effect of the face Emotion and no interaction (both *p*s > .2). By contrast, with diagnostic face components LG's emotion recognition improved dramatically (compared to his recognition of isolated face expressions) and, in fact, he did not differ significantly from controls, $F(1,20)=2.6$, $p < .121$, $\eta_p^2 = .116$, Figure 2. Similarly, the effect of the face Emotion and interaction were not significant, both *F*s < 1.

Since eyes are diagnostic for anger whereas the mouth is diagnostic for disgust, the correct response (in the diagnostic condition) at the emotion recognition stage following eye-matching was anger and following mouth-matching was disgust. Although the diagnostic and non-diagnostic conditions in our design were equally probable, it could still be possible that the participants developed strategies by which they were biased to respond "anger" when primed by eyes and respond "disgust" when primed by mouth. Moreover, this bias could have developed differently in the control groups in which a between-participant design was used and for LG, in which the effect of diagnosticity was, by necessity, tested within-participant. We addressed this concern in two ways: First we adapted a signal detection approach in which we defined "anger" responses to disgust faces presented in the non-diagnostic condition (i.e., following priming with eyes) and "disgust" responses to anger faces presented in the non-diagnostic condition (i.e., following priming with a mouth) as false alarms. The percentage of false alarms in LG (29.1%) was nearly identical to controls (29.6%) suggesting that LG did not develop prime-linked strategies differently than controls, $t(20) = .05$, $p = .96$.

Second, to examine if strategies were developed during the task, we compared the expression recognition accuracy for the first half of the stimuli and the second half of the stimuli in LG and 20 control participants (10 diagnostic, 10 non-diagnostic). This analysis revealed similar patterns of performance for the first vs. second half within control participants ($t(9) = .9$, $p = .38$). Furthermore, an analysis within LG's individual responses confirmed that effect of diagnosticity ($p < .01$) was maintained in the first half and second half, but the two halves did not differ ($p > .1$) and did not interact with the diagnosticity ($p > .1$) which speaks against the possibility that LG and the control subjects developed different strategies along the experiment.

3.2.3. Diagnosticity effects in LG: a supplementary examination with features. To what degree was LG's performance based on the information self contained in the isolated face components? We re-ran the component matching task on LG using face stimuli in which all the inner components except for those to-be matched, were digitally erased. For example, if the initially presented component was a mouth, the following full face had all the internal face information erased but the mouth, which remained intact in its original location (Figure 3). Consequently, the recognition of the emotion expressed by the full face could only be based on the information recognized from the component recognition, as no other expression-relevant information was available. Under the erased-face condition, LG's average performance with non diagnostic components (8.3%) was virtually identical to his performance with full faces (8.3%), and his performance with diagnostic components was significantly improved (29.15%), though to a lesser degree than his performance with full faces (49.9%). This suggests that the information in the isolated components played an important, though not exclusive role in determining LG's emotion recognition.

3.3 Discussion

The results of Experiment 1 indicate that when LG focused on a particular face component, his recognition of facial expressions was considerably influenced by the component's emotion diagnosticity. Indeed, when the matched component was diagnostic for the facial expression LG's recognition was not significantly different from that of participants in the control condition. By contrast, when the matched component was non-diagnostic, LG lost his (already reduced) ability to recognize the emotion from the face. Interestingly, the follow up test in which the face stimuli were presented only with the matched components (i.e., the other face components erased out), showed a very similar pattern of results: LG had reduced accuracy with non diagnostic components and increased accuracy with diagnostic components.

The fact that LG was as accurate as control participants in the diagnostic condition and around chance in the non-diagnostic condition suggests that (a) despite his visual agnosia he is able to extract emotional information expressed by an isolated component and (b) his categorization in this task heavily relied on that information. This raises the question: why was LG's average recognition of isolated anger and disgust (presented for an unlimited duration) so poor (LG=15%, chance=16.6)?

Perhaps when unprimed, LG does not know where to look and given the opportunity to screen various locations in the face he takes into account erroneous information which should be ignored. In Experiment 2 we examined this possibility by using the same procedure as in experiment 1 with the exception that the exposure duration of the full face was significantly extended.

4. Experiment 2

Experiment 1 demonstrated that matching emotion-diagnostic face components augmented LG's recognition of facial expressions, indeed, to the control level. On the other hand, when non-diagnostic components were matched his emotion categorization performance was significantly reduced. LG's inability to identify facial expressions in the non-diagnostic condition is particularly conspicuous since control participants were able to do so well above chance, perhaps by shifting from the non-diagnostic cue to the rest of the face. If so, perhaps presenting the face for a longer duration should allow a less biased and more thorough processing of all face components which, for controls, may improve recognition overall (see also Clark, Winkielman, & McIntosh, 2008), as well as reduce the difference between the diagnostic and non-diagnostic conditions.

However, given LG's impaired visual integration we suspected that additional processing time might actually pose for him more of a challenge than an advantage, because he would "go astray" with his impaired visual processing. In fact, it is possible that when given the opportunity to screen the whole face, LG should lose the advantage of being cued to diagnostic facial expression information. To test this, we replicated the design of Experiment 1, with the exception that the exposure of the full face was extended from 150 ms to 2000 ms.

4.1 Method

4.1.1Participants. 80 Hebrew University students (48 female), mean age 23.4 participated in the study for course credit or payment [3].

4.1.2 Stimuli, procedure and design. Experiment 2 was identical to experiment 1 with the exception that the full faces appeared for 2000 ms instead of 150 ms. As in experiment 1, the analysis of the control group performance was based on a mixed-model ANOVA with

Diagnosticity as the between-subjects factor and Emotion as the within-subject factor. By contrast, LG was tested in all 4 Diagnosticity × Emotion conditions. Thus for his analysis, the influence of priming on his ability to categorize facial expressions was compared separately for the diagnostic and the non-diagnostic conditions with the respective control group. A mixed-model ANOVA procedure for assessing differences between an individual case and a control group in multi-factorial experiments (Corballis, 2009) was used, with Group (control, LG) as the between-subjects factor and Emotion as the within-subject factor.

4.2. Results

4.2.1. LG versus controls - extended duration. The accuracy rate in the component matching task was 96.2% for the controls and 86.5% for LG. A mixed ANOVA showed that the overall component matching performance of LG was comparable to that of controls, and there were no differences between diagnostic and non diagnostic trials for both LG and controls (all *F's* < 1). Subsequent analyses were run on the correct matching trials.

As in Experiment 1, we first characterized the responses of the control group alone and then followed protocols for assessing individual cases in multi-factorial experiments with an ANOVA in which the between subject Group factor (single case vs. controls) was tested for a main effect and interaction (Corbalis, 2009).

The mixed-model ANOVA with Diagnosticity as the between-subjects factor and Emotion as the within-subjects factor showed that control participants in the diagnostic matching group were more accurate at recognizing the facial expressions than participants in the non-diagnostic group, $F(1,78) = 4.79$, $p < .032$, $\eta_p^2 = .06$. As in Experiment 1, and in line with Ekman's norms (Matsumoto & Ekman, 1988) participants were more accurate at recognizing anger (*M*=77.7%, *SD*=19.8) than disgust (*M*=51.4%, *SD*=25.5), $F(1,78)=65.3$, $p <$

.0001, η_p^2 = .45. However, the Emotion × Diagnosticity interaction was not significant ($F(1,78) < 1$), indicating that the effect of Diagnosticity was similar across disgust and anger facial expressions (Figure 4). A full breakdown by emotion category is supplied in the lower panel of Table 1.

Our primary interest was to contrast LG with the control group. The mixed-model ANOVAs showed that with diagnostic components, LG was significantly worse than controls in recognizing the full face emotions, $F(1,39)=7.9$, $p < .007$, η_p^2 = .17. There was no significant effect of emotion, $F(1,39)=0.8$, $p = .7$, or Group × Emotion interaction, $F(1,39)=2.37$, $p < .132$, η_p^2 = .057. In the non-diagnostic condition, although LG was considerably less accurate than controls, ANOVA showed that this difference was not significant, $F(1,39)=2.356$, $p = .133$. As in the diagnostic condition, there were no significant effects of Emotion $F(1,39)=1.3$, $p = .258$ or interaction $F(1,39)=.36$, $p = .55$.

As in experiment 1 we used a false alarm analysis to control for the possibility of different response strategies governing LG's performance and that of the controls. The analysis showed that the false alarm rate for LG (33%) did not differ significantly from that of controls (22.9%), $t(39) = .9$, $p = .37$, suggesting that as in experiment 1, LG and controls did not employ different strategies.

4.2.1. Brief (150 ms) vs. extended (2000 ms) duration. In order to examine if the face duration influenced facial expression recognition, we compared performance across experiment 1 (duration = 150 ms) and experiment 2 (duration = 2000 ms). We first examined, within the control groups, if exposure duration influenced emotion recognition with a Duration (150 ms, 2000 ms) × Diagnosticity (diagnostic, non-diagnostic) ANOVA. As seen in Figure 5, emotion recognition was overall higher in the 2000 ms duration than in the 150 ms condition, $F(1,120)$

= 5.56, $p < .02$. Additionally, control participants were more accurate in the diagnostic than in the non-diagnostic conditions, $F(1,120) = 14.3$, $p < .0001$. The Duration × Diagnosticity interaction was not significant, $F < 1$.

We next examined LG's performance in the 150 ms vs. 2000 ms using his individual trials as a random factor. A significant Diagnosticity × Duration ANOVA emerged $F(1,22) = 6.68$, $p < 0.017$ indicating that LG was more accurate with diagnostic vs. non diagnostic cues when the duration was 150 ms ($p < .05$), however, when the duration was 2000 ms, no significant difference emerged between the different diagnosticity levels, ($p > .7$).

4.3 Discussion

Compared to Experiment 1, increasing the face exposure duration reduced LG's performance when the matched components were diagnostic and improved his performance when the components were non-diagnostic. By contrast, control participants took advantage of the additional time during which they could scan the face and improved their performance irrespective of diagnosticity. One possible interpretation of the current data is that that while in short full-face exposure condition LG initially utilized the emotional information available in the matched component (or its location), when given enough time, he attempts to screen the whole face and bases his emotion categorization on impaired integration of various facial components. When LG is initially cued by diagnostic components any shift can only reduce his accuracy. Conversely, when he is first cued by non-diagnostic components, any shift can only improve his performance.

5. General Discussion

The aim of the current experiments was to characterize the nature of the facial expression recognition deficits in LG, a young man with DVA. We utilized a component matching task which imposed the processing of specific components and specific face regions which were either diagnostic or non-diagnostic of the actual face emotion. In experiment 1, in which the full facial expression appeared for a brief period of time, LG's emotion recognition improved with diagnostic component matching and declined with non diagnostic matching. Control participants were also more accurate with diagnostic than non diagnostic matching, yet their performance was not so extremely determined by the diagnosticity of the matched components. In experiment 2, when the full facial expression appeared for an extended duration, the overall effect of the component matching on LG's performance was diminished: he lost the advantage of the diagnostic matching and he was released from the negative influence of the non-diagnostic matching. In fact, at the extended duration, diagnosticity no longer had a significant effect for LG. By contrast, the diagnosticity of the matched component was still consequential for control participants even at 2000 ms.

As noted, our task induced two factors that cannot be readily teased apart: the influence of the prime component itself and the influence of the prime directing initial processing to a specific location in the full face. Our data suggest that LG is strongly influenced by the information contained in the component itself. In the 150 ms duration, LG had no choice but to process the information in the component prime and in the imposed full face location. Once the matching was over the face was gone. This resulted in LG's recognition being strongly determined, for better or worse, by the diagnosticity of the information determined by the matching procedure. LG was metaphorically "taken by the hand" and forced to decipher the

face under specific informational constraints. However priming *per se* cannot tell the whole story. This is clear because LG's performance retained a similar but notably weaker pattern of influence from the matching diagnosticity when tested with primes followed by erased full faces.

In the 2000 ms duration, LG was exposed to the same prime components, however, the additional exposure time gave him an opportunity to scan the full face and adjust his initial perceptual impression. In contrast to control participants who took advantage of this additional time and generally improved during the initial processing of the face expression, LG actually lost the benefit of processing the diagnostic component first. It is possible that having the opportunity to scan the full face, his reliance on the first processed component dissipates and he attempts to recognize the emotion by integrating the information delivered by the initially processed component with the rest of the face. However, given his impaired visual integration skills, this attempt fails, leading him to randomly rely on diagnostic and non diagnostic face components. Conversely, when the cue is non-diagnostic, LG can only gain from the extra time given because it increases the likelihood of him leaving the erroneous region and stumbling upon a diagnostic cue.

5.1 Relevance to models of emotion perception

Current models of emotion perception differ in their emphasis on part-based vs. holistic-based processes in facial expression recognition. On one end of the continuum are componential models which stress the importance of diagnostic features for specific emotions. For example, Ellison and Massaro (1997) proposed a part based model in which emotion recognition of a full face expression can be predicted just as well from its isolated parts alone (e.g., mouth shape, eyebrow shape). More recent work using "bubbles", a technique in which

faces are perceived through various small patches of Gaussian filters, has shown that different emotional face categories are characterized by distinct diagnostic filter functions (Smith, et al., 2005). Although these filters focus on diagnostic face regions as apposed to diagnostic face parts, they share the notion that emotion perception proceeds through fragments of isolated diagnostic information, and they have little to say about the perception of the full face.

On the other end of the continuum, are holistic models of emotion perception. For example, Calder and colleagues (2000) have argued that holistic processing, the fusion of facial features to a unitary Gestalt, is just as characteristic of emotion perception, as it is in identity perception. Specifically, by combining top and bottom face halves conveying different emotions, it has been shown that viewers do not merely focus on task relevant features, rather, the features are fused to a holistic perceptual image which includes all the available face information (Calder, et al., 2000).

Whereas the models are not mutually exclusive, little is known about how part based and holistic based processing interact in expression recognition. LG's results in the current set of experiments (along with the control data) are the first to demonstrate the prevailing influence that part based feature processing can have on full face holistic perception. Specifically, it is seems that biasing the processing of the face to specific diagnostic or non-diagnostic regions can strongly change the subsequent holistic processing of the face. Although it might not be surprising that feature priming has an influence on face perception when the face is briefly presented (Exp, 1), it is striking that control participants were still influenced by feature diagnosticity even when the face duration was prolonged and enabled full screening (Exp 2). Thus, despite ample time, viewers could not easily correct the initial impression caused by the priming cue.

It is however important to note that despite this aforementioned priming influence, individuals with normal vision still maintain an overall accurate recognition of the face. This suggests that their holistic impression of the face "kicks in" and corrects, to a certain extent, the non-diagnostic information. LG, on the other hand, lacks such functional holistic processing of the face, and therefore his performance is much more strongly determined by the prime.

These findings may have important implications for real life social interactions. Specifically, they indicate that preceding contextual information may bias the processing of particular face regions as well as simultaneously available context. Recent work has shown that emotional body context may bias the scanning of emotional facial expressions (Aviezer, et al., 2008) as well as the categorization of facial expressions. Furthermore, the influence of affective body context (whether congruent or incongruent) cannot be disregarded, even when participants are motivated to focus on the face and even when they believe the body is irrelevant for the task (Aviezer, Bentin, Dudarev, & Hassin, 2011). While the influence of being primed with incongruent non-diagnostic regions is modest compared to the influence of incongruent body context, both may shared a similar mechanism.

5.2 Lack of Integration or Impaired Integration?

Previous work has demonstrated that in contrast to controls, individuals with acquired integrative agnosia and acquired prosopagnosia may display better performance when processing isolated face parts, (Boutsen & Humphreys, 2002; Riddoch & Humphreys, 1987; Stephan, Breen, & Caine, 2006) or inverted faces (de Gelder & Rouw, 2000; Farah, Wilson, Maxwell Drain, & Tanaka, 1995) than when processing faces in their natural, upright form. One interpretation of these paradoxical effects is that impaired integration of the face

components during holistic processing disrupt an otherwise relatively intact ability to make local perceptual matches on face parts (Boutsen & Humphreys, 2002; Stephan, et al., 2006). In other words, it is not that the integration skills are absent, but rather that they are abnormal, in a disruptive manner.

This pattern may seem in line with the fact that LG does worse at utilizing diagnostic cues when additional processing time is available, however, some notable differences should be outlined. First, while LG was capable of extracting information from the components, his accuracy was actually higher with full faces (49.9%) than with erased faces in which only the diagnostic components were available (29.1%). Second, in contrast to LG, the agnosia in all the aforementioned cases was acquired (following stroke or traumatic brain injury). Indeed individuals with developmental agnosia do not typically show the inverted inversion effect (de Gelder & Rouw, 2000). Hence, although LG performs more poorly when the diagnostic matching coincides with an extended duration to process the face, it is yet unclear if at the core of his deficit is lack of integration or rather, residual yet impaired integration.

Interestingly, although individuals with CP display normal emotion recognition from faces, recent work shows their holistic perception of facial expressions is weaker than controls (Palermo, et al., 2011). This implies that unlike controls, CPs rely more on part based recognition than on full face Gestalt perception. Our data suggest that LG too can efficiently rely on part based emotion recognition. However, unlike individuals with CP, who seem to retain the ability to spontaneously utilize diagnostic features in full faces, LG is severely impaired in standard tests of emotional face recognition. Interestingly, his ability to associate diagnostic features with specific prototypical emotions is relatively preserved but is only released under artificial guiding of visual processing to relevant regions.

5.3 Disentangling Diagnostic Content from Diagnostic Location

In the current experiments we chose to manipulate the processing of the face and its components by means of a feature matching task. Whereas this method is useful for directing participants to particular face regions, the results cannot completely tease apart the influence of the content of the initially presented feature prime from the influence of where it directs participants when processing the full face. Following studies may remedy this caveat by directing participants to a specific face region while avoiding any feature primes. One method reported in the literature has been to direct processing to particular face regions via explicit command (Adolphs et al., 2005). Although this method might be useful in some cases, it may induce demand characteristics and, therefore, might lead to the development of naïve theories in which emotions are most expressed by particular face regions. A less explicit method of guided scan-paths has been used in which participants are instructed to fixate on a small dynamic cross which is superimposed upon a scene (Morris, Green, Marion, & McCarthy, 2008). While this method can guide the exact scan-path of participants, it has the disadvantage of interfering with the processing of the target image because participants are focused on an extraneous superimposed object. One possibility to address these caveats in future research is to manipulate attentional sets prior to the presentation of the face using non affective stimuli. This method has been recently demonstrated in a study in which global or local processing of the face has been primed by manipulating the level of processing Navon letters that preceded each face (Gao, Flevaris, Robertson, & Bentin, 2011). Adapting such a procedure it should be easy to keep participants fixated at the location of the matched targets without interfering with the processing of the face and without confounding the primed location with the prime information.

5.4 Summary

We used a matching task to examine the influence of processing diagnostic and non-diagnostic components on emotional face recognition in LG, a case of DVA with impaired recognition of facial expressions. Our findings show that the duration of the face processing is a critical factor in determining LG's influence from diagnostic and non-diagnostic component cues. With briefly presented faces, LG was strongly influenced by the emotional diagnosticity of the component matching task: his emotion recognition was within normal limits when the components were diagnostic and it was obliterated when the components were non-diagnostic. By contrast, when the face appeared for an extended duration, the diagnostic component matching did not help and his recognition dropped, while performance when matching non-diagnostic components actually improved. Overall, these results highlight the residual capabilities as well as the deficient processes involved in facial expression recognition in DVA. Further, they shed additional light on visual integrative processes that are typically involved in perceiving emotions expressed by faces.

Authors' Notes

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References

Adolphs, R., Gosselin, F., Buchanan, T. W., Tranel, D., Schyns, P., & Damasio, A. R. (2005). A mechanism for impaired fear recognition after amygdala damage. *Nature, 433*(7021), 68-72.

Ariel, R., & Sadeh, M. (1996). Congenital visual agnosia and prosopagnosia in a child: a case report. *Cortex, 32*(2), 221-240.

Avidan, G., Hasson, U., Malach, R., & Behrmann, M. (2005). Detailed exploration of face-related processing in congenital prosopagnosia: 2. Functional neuroimaging findings. *Journal of Cognitive Neuroscience, 17*(7), 1150-1167.

Aviezer, H., Bentin, S., Dudarev, V., & Hassin, R. R. (2011). The automaticity of emotional face-context integration. *Emotion.*

Aviezer, H., Hassin, R., & Bentin, S. (in press). Impaired Integration of Emotional Faces and Affective Body Context in a Rare Case of Developmental Visual Agnosia. *Cortex.*

Aviezer, H., Hassin, R., Bentin, S., & Trope, Y. (2008). Putting facial expressions into context. In N. Ambady & J. Skowronski (Eds.), *First Impressions*. New York: Guilford Press.

Aviezer, H., Hassin, R. R., Ryan, J., Grady, C., Susskind, J., Anderson, A., . . . Bentin, S. (2008). Angry, disgusted, or afraid? Studies on the malleability of emotion perception. *Psychological Science, 19*(7), 724-732.

Aviezer, H., Landau, A. N., Robertson, L. C., Peterson, M. A., Soroker, N., Sacher, Y., . . . Bentin, S. (2007). Implicit integration in a case of integrative visual agnosia.

Neuropsychologia, 45(9), 2066-2077. doi: DOI 10.1016/j.neuropsychologia.2007.01.024

Bassili, J. N. (1979). Emotion recognition: The role of facial movement and the realtive inportance of upper and lower areas of the face. *Journal of Personality and Social Psychology, 37*(11), 2049-2058.

Behrmann, M., & Avidan, G. (2005). Congenital prosopagnosia: face-blind from birth. *Trends in Cognitive Sciences, 9*(4), 180-187.

Bentin, S., DeGutis, J. M., D'Esposito, M., & Robertson, L. C. (2007). Too many trees to see the forest: Performance, event-related potential, and functional magnetic resonance imaging manifestations of integrative congenital prosopagnosia. *Journal of Cognitive Neuroscience, 19*(1), 132-146.

Bentin, S., Deouell, L. Y., & Soroker, N. (1999). Selective visual streaming in face recognition: Evidence from developmental prosopagnosia. *NeuroReport, 10*(4), 823.

Benton, A. L., Sivan, A. B., Hamsher, K. d., Varney, N. R., & Spreen, O. (1983). *Contribution to neuropsychological assessment*. New York: Oxford University Press.

Boutsen, L., & Humphreys, G. W. (2002). Face context interferes with local part processing in a prosopagnosic patient. *Neuropsychologia, 40*(13), 2305-2313.

Brosch, T., Pourtois, G., & Sander, D. (2010). The perception and categorisation of emotional stimuli: A review. *Cognition & Emotion, 24*(3), 377-400.

Buck, R. (1994). Social and emotional functions in facial expression and comunication: The readout hypothesis. *Biological Psychology, 38*(2-3), 95-115.

Calder, A. J., & Young, A. W. (2005). Understanding the recognition of facial identity and facial expression. *Nature Reviews Neuroscience, 6*(8), 641-651. doi: 10.1038/nrn1724

Calder, A. J., Young, A. W., Keane, J., & Dean, M. (2000). Configural information in facial expression perception. *Journal of Experimental Psychology-Human Perception and Performance, 26*(2), 527-551.

Clark, T. F., Winkielman, P., & McIntosh, D. N. (2008). Autism and the Extraction of Emotion From Briefly Presented Facial Expressions: Stumbling at the First Step of Empathy. *Emotion, 8*(6), 803-809. doi: 10.1037/a0014124

Corballis, M. C. (2009). Comparing a single case with a control sample: Correction and further comment. *Neuropsychologia, 47*(13), 2696-2697.

Corballis, M. C. (2009). Comparing a single case with a control sample: Refinements and extensions. *Neuropsychologia, 47*(13), 2687-2689.

Crawford, J. R., Garthwaite, P. H., & Howell, D. C. (2009). On comparing a single case with a control sample: An alternative perspective. *Neuropsychologia, 47*(13), 2690-2695.

de Gelder, B., & Rouw, R. (2000). Configural face processes in acquired and developmental prosopagnosia: evidence for two separate face systems? *NeuroReport, 11*(14), 3145.

de Gelder, B., & Rouw, R. (2000). Paradoxical configuration effects for faces and objects in prosopagnosia. *Neuropsychologia, 38*(9), 1271-1279.

Dobel, C., Bolte, J., Aicher, M., & Schweinberger, S. R. (2007). Prosopagnosia without apparent cause: overview and diagnosis of six cases. *Cortex, 43*(6), 718-733.

Duchaine, B. (2000). Developmental prosopagnosia with normal configural processing. *NeuroReport, 11*(1), 79.

Duchaine, B., Jenkins, R., Germine, L., & Calder, A. J. (2009). Normal gaze discrimination and adaptation in seven prosopagnosics. *Neuropsychologia, 47*(10), 2029-2036. doi: 10.1016/j.neuropsychologia.2009.03.011

Duchaine, B., Murray, H., Turner, M., White, S., & Garrido, L. (2009). Normal social cognition in developmental prosopagnosia. *Cognitive neuropsychology, 26*(7), 620-634.

Duchaine, B., & Nakayama, K. (2005). Dissociations of face and object recognition in developmental prosopagnosia. *Journal of Cognitive Neuroscience, 17*(2), 249-261.

Duchaine, B., & Nakayama, K. (2006). The Cambridge Face Memory Test: Results for neurologically intact individuals and an investigation of its validity using inverted face stimuli and prosopagnosic participants. *Neuropsychologia, 44*(4), 576-585.

Duchaine, B., Nieminen-von Wendt, T., New, J., & Kulomaki, T. (2003). Dissociations of visual recognition in a developmental agnosic: Evidence for separate developmental processes. *Neurocase, 9*(5), 380-389.

Duchaine, B., Parker, H., & Nakayama, K. (2003). Normal recognition of emotion in a prosopagnosic. *Perception, 32*(7), 827-838. doi: 10.1068/p5067

Duchaine, B., Yovel, G., & Nakayama, K. (2007). No global processing deficit in the Navon task in 14 developmental prosopagnosics. *Social cognitive and affective neuroscience*.

Ekman, P. (1993). Facial expression and emotion. *American Psychologist, 48*(4), 384-392.

Ekman, P., & Friesen, W. V. (1976) *Picture of facial affect*. Palo Alto, CA: Consulting Psychologists Press.

Ekman, P., & Friesen, W. V. (1976). *Pictures of facial affect*. Palo Alto, CA: Consulting Psychologists Press.

Ellison, J. W., & Massaro, D. W. (1997). Featural Evaluation, Integration, and Judgment of Facial Affect. *Journal of Experimental Psychology: Human Perception and Performance, 23*(1), 213-226.

Farah, M. J. (1990). *Visual agnosia: Disorders of object recognition and what they tell us about normal vision*. Cambridge, MA, US: The MIT Press.

Farah, M. J., Wilson, K. D., Maxwell Drain, H., & Tanaka, J. R. (1995). The inverted face inversion effect in prosopagnosia: Evidence for mandatory, face-specific perceptual mechanisms. *Vision research, 35*(14), 2089-2093.

Gao, Z., Flevaris, A. V., Robertson, L. C., & Bentin, S. (2011). Priming global and local processing of composite faces: revisiting the processing-bias effect on face perception. *Attention, Perception, & Psychophysics*, 1-10.

Garrido, L., Furl, N., Draganski, B., Weiskopf, N., Stevens, J., Tan, G. C. Y., . . . Duchaine, B. (2009). Voxel-based morphometry reveals reduced grey matter volume in the temporal

cortex of developmental prosopagnosics. *Brain, 132*, 3443-3455. doi: 10.1093/brain/awp271

Gilaie-Dotan, S., Perry, A., Bonneh, Y., Malach, R., & Bentin, S. (2009). Seeing with Profoundly Deactivated Mid-level Visual Areas: Non-hierarchical Functioning in the Human Visual Cortex. *Cerebral Cortex, 19*(7), 1687-1703.

Hasson, U., Avidan, G., Deouell, L. Y., Bentin, S., & Malach, R. (2003). Face-selective activation in a congenital prosopagnosic subject. *Journal of Cognitive Neuroscience, 15*(3), 419-431.

Humphreys, K., Avidan, G., & Behrmann, M. (2007). A detailed investigation of facial expression processing in congenital prosopagnosia as compared to acquired prosopagnosia. *Experimental Brain Research, 176*(2), 356-373. doi: 10.1007/s00221-006-0621-5

Kennerknecht, I., Grueter, T., Welling, B., Wentzek, S., Horst, J., Edwards, S., & Grueter, M. (2006). First report of prevalence of non-syndromic hereditary prosopagnosia (HPA). *American Journal of Medical Genetics Part A, 140A*(15), 1617-1622. doi: 10.1002/ajmg.a.31343

Matsumoto, D., & Ekman, P. (1988). Japanese and Caucasian facial expressions of emotion (IACFEE). San Francisco, CA: Intercultural and Emotion Research Laboratory, Department of Psychology, San Francisco State University.

Morris, J. P., Green, S. R., Marion, B., & McCarthy, G. (2008). Guided saccades modulate face-and body-sensitive activation in the occipitotemporal cortex during social perception. *Brain and Cognition, 67*(3), 254-263.

Palermo, R., Willis, M., Rivolta, D., Wilson, C. E., & Calder, A. (2010). Holistic perception of facial expression in congenital prosopagnosia. *Journal of Vision, 10*(7), 591. doi: 10.1167/10.7.591

Palermo, R., Willis, M. L., Rivolta, D., McKone, E., Wilson, C. E., & Calder, A. J. (2011). Impaired holistic coding of facial expression and facial identity in congenital prosopagnosia. *Neuropsychologia*.

Riddoch, M. J., & Humphreys, G. W. (1987). A case of integrative agnosia. *Brain, 110*, 1431-1462.

Riddoch, M. J., & Humphreys, G. W. (1993). *BORB: Birmingham Object Recognition Battery*. Hove (OK): Lawrence Erlbaum Associates.

Schyns, P. G., Petro, L. S., & Smith, M. L. (2007). Dynamics of visual information integration in the brain for categorizing facial expressions. *Current Biology*, *17*, 1580-1585. doi: 10.1016/j.cub.2007.08.048

Smith, C. A., & Scott, H. S. (1997). A componential approach to the meaning of facial expressions. In J. A. Russell & J. M. Fernandez-Dols (Eds.), *The psychology of facial expression* (pp. 229-254). New York: Cambridge University Press.

Smith, M. L., Cottrell, G. W., Gosselin, F., & Schyns, P. G. (2005). Transmitting and decoding facial expressions. *Psychological Science, 16*(3), 184-189.

Stephan, B. C., Breen, N., & Caine, D. (2006). The recognition of emotional expression in prosopagnosia: Decoding whole and part faces. *Journal of the International Neuropsychological Society, 12*(06), 884-895.

Susskind, J. M., Littlewort, G., Bartlett, M. S., Movellan, J., & Anderson, A. K. (2007). Human and computer recognition of facial expressions of emotion. *Neuropsychologia, 45*(1), 152-162. doi: DOI: 10.1016/j.neuropsychologia.2006.05.001

Todorov, A., & Duchaine, B. (2008). Reading trustworthiness in faces without recognizing faces. *Cognitive Neuropsychology, 25*(3), 395-410. doi: 10.1080/02643290802044996

Van den Stock, J., van de Riet, W., Righart, R., & de Gelder, B. (2008). Neural correlates of perceiving emotional faces and bodies in developmental prosopagnosia: an event-related fMRI-study. *PLoS One, 3*(9), e3195.

Whalen, P. J., Kagan, J., Cook, R. G., Davis, F. C., Kim, H., Polis, S., . . . Johnstone, T. (2004). Human Amygdala Responsivity to Masked Fearful Eye Whites. *Science, 306*(5704), 2061. doi: 10.1126/science.1103617

Young, A., Perrett, D., Calder, A., Sprengelmeyer, R., & Ekman, P. (2002). Facial expressions of emotion: Stimuli and tests (FEEST): San Antonio, TX: Harcourt Assessment.

Footnotes

[1] Since DVA is an extremely rare syndrome and there is no imaging data from other cases, we do not know whether this strange pattern of activations in the visual system is typical to DVA or peculiar to LG.

[2] Although some concerns with the Corbalis protocol have been raised (Crawford, Garthwaite, & Howell, 2009) we found using it justifiable as 1) we did not use it to examine dissociations in performance across different cognitive domains, and 2) we were content with conservative interpretations concerning the relations of the single case to the population from which the control group was drawn (Corballis, 2009; Corballis, 2009).

[3] Since we expected control performance to improve with the extended duration in experiment 2, we enlarged our *N* in order to capture a wide representation of normal variance to which LG could be compared.

Table 1.

Mean recognition (SD) of facial expressions as a function of expressions category, prime diagnosticity, group, and duration. Note that the 150 ms data are from experiment 1 while the 2000 ms data are from experiment 2.

		Anger		Disgust	
Duration	Group	Diagnostic	Non-diagnostic	Diagnostic	Non-diagnostic
150 ms	Control	71.5 (15.5)	60.7 (19.4)	55.9 (22.5)	37.7 (20.5)
	LG	58.3	16.6	41.6	0
2000 ms	Control	75.6 (18.6)	71.9 (19.3)	53.3 (27.3)	44.3 (26.6)
	LG	16.6	33.3	33.3	25.0

Figure captions

Figure 1. Outline of an experimental trial. At the first stage a component (mouth or eyes) was shown and was later matched (as same/different) to the corresponding component in the full face. Subsequently, the emotion of the full face was determined. The figure portrays a "same" trial because the isolated mouth is identical to the full face mouth. The trial is also "non-diagnostic" because the mouth is not diagnostic of facial anger.

Figure 2. Recognition of the emotional face expressions presented for 150 ms, in the diagnostic vs. non diagnostic matching conditions, for LG and controls (Experiment 1). Note that the two diagnosticity levels were presented to controls between subjects, while LG was presented with both diagnosticity levels. As the Diagnosticity × Emotion interaction was not significant, we simplified our graphs by grouping the emotions.

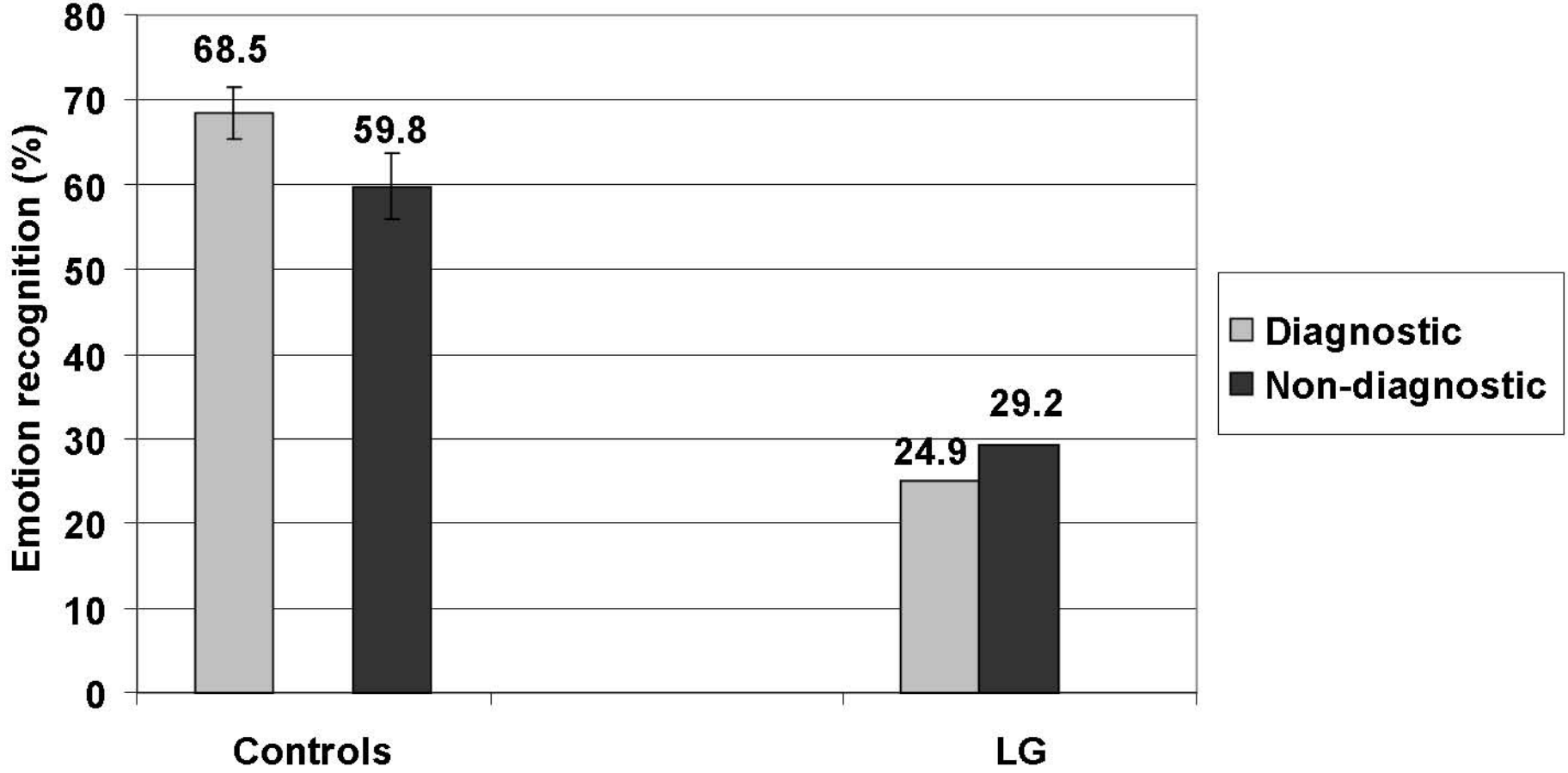
Figure 3. Outline of an experimental trial in the "component only" supplemental matching task in which LG was tested. The additional task was identical to the main task of experiment 1, however, all the inner features in the full faces (except for the to-be matched components) were digitally erased.

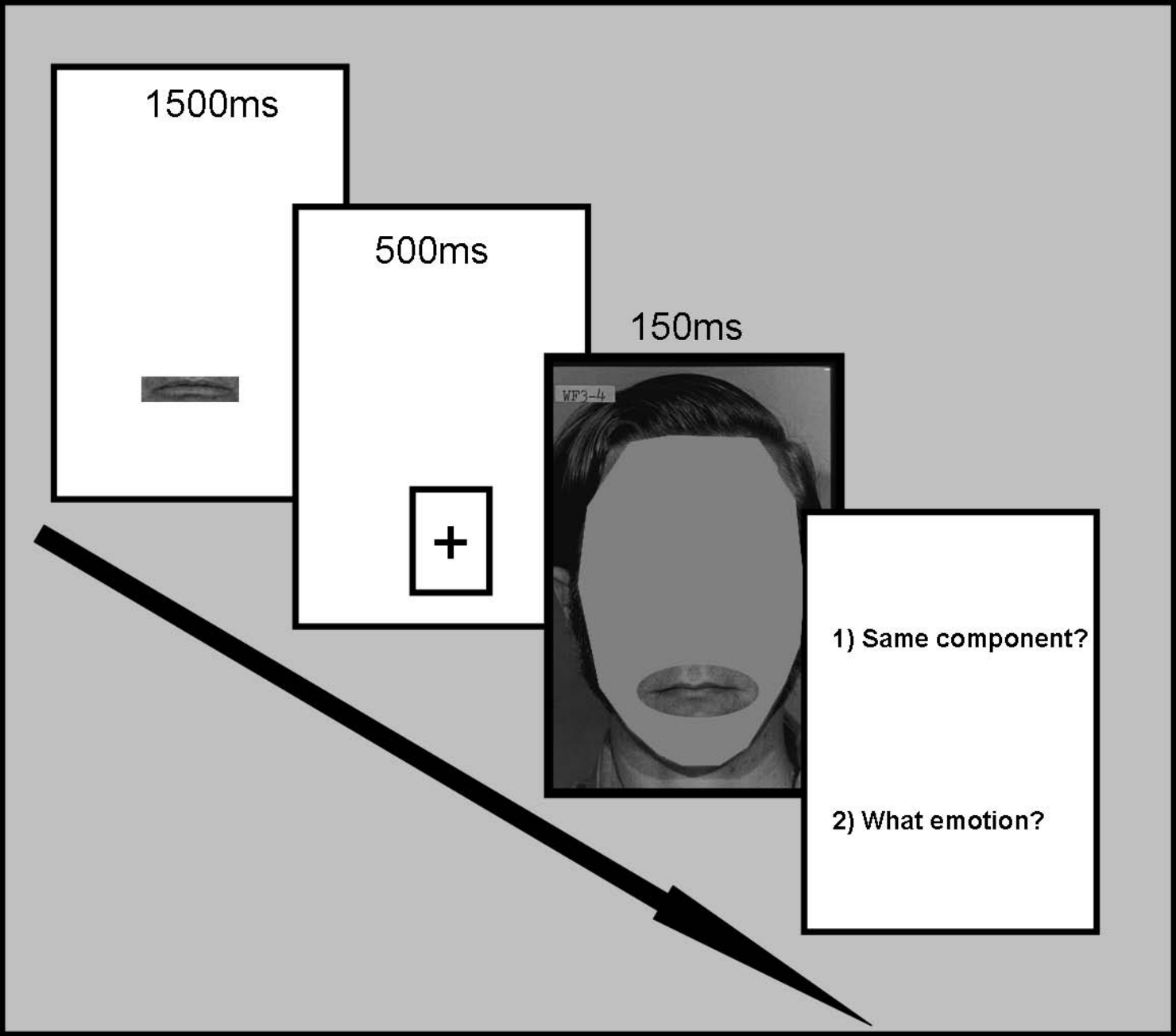
Figure 4. Recognition of the emotional face expressions presented for 2000 ms, in the diagnostic vs. non diagnostic matching conditions, for LG and controls (Experiment 2). Note that as in experiment 1, the two diagnosticity levels were presented to controls between subjects, while LG was presented with both diagnosticity levels. As in Experiment 1, the Diagnosticity × Emotion interaction was not significant, hence, we simplified our graphs by grouping the emotions.

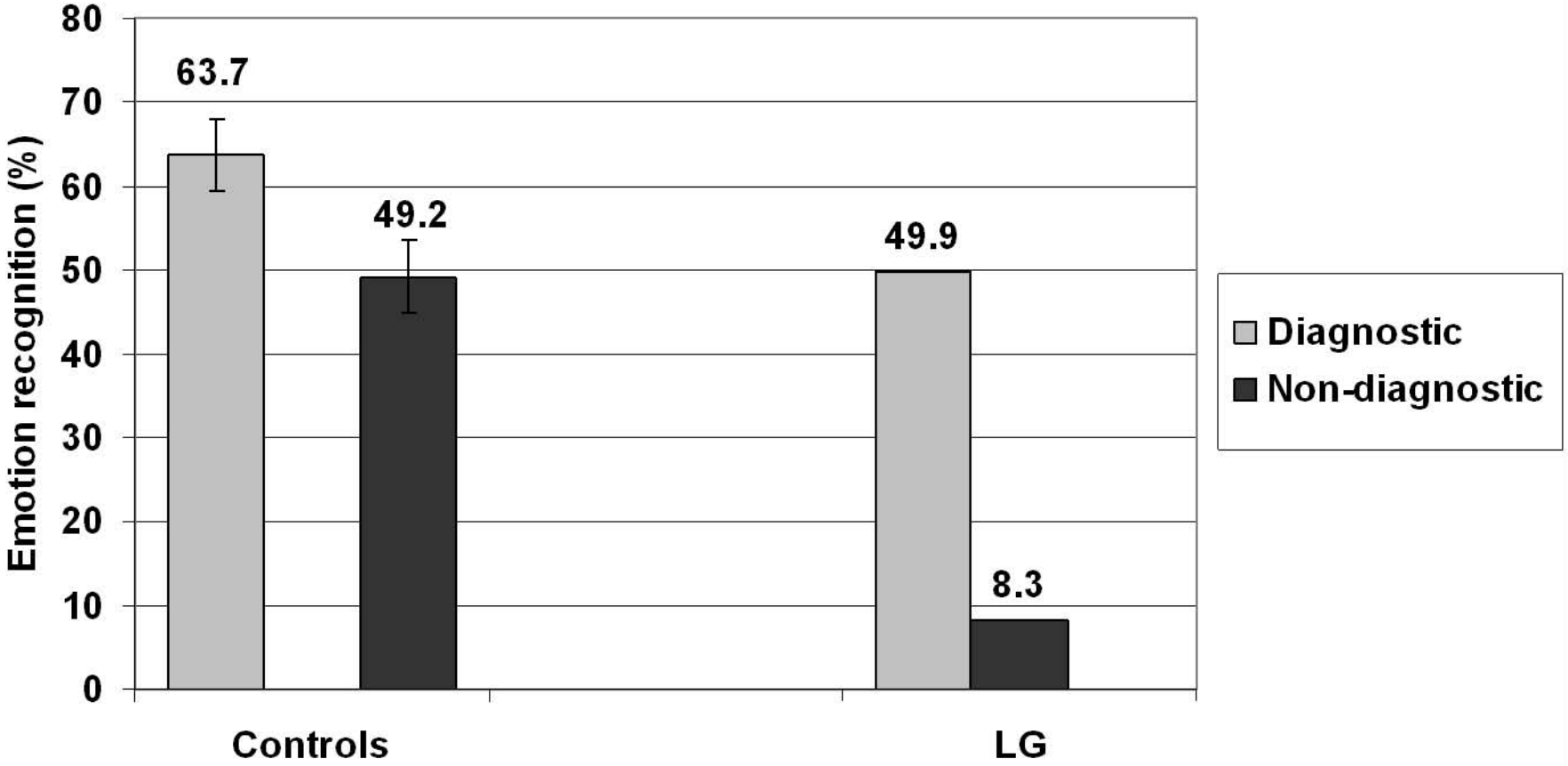
Figure 5. Summary of emotion recognition data from experiments 1 and 2 showing the interaction between component diagnosticity, face duration, and group.

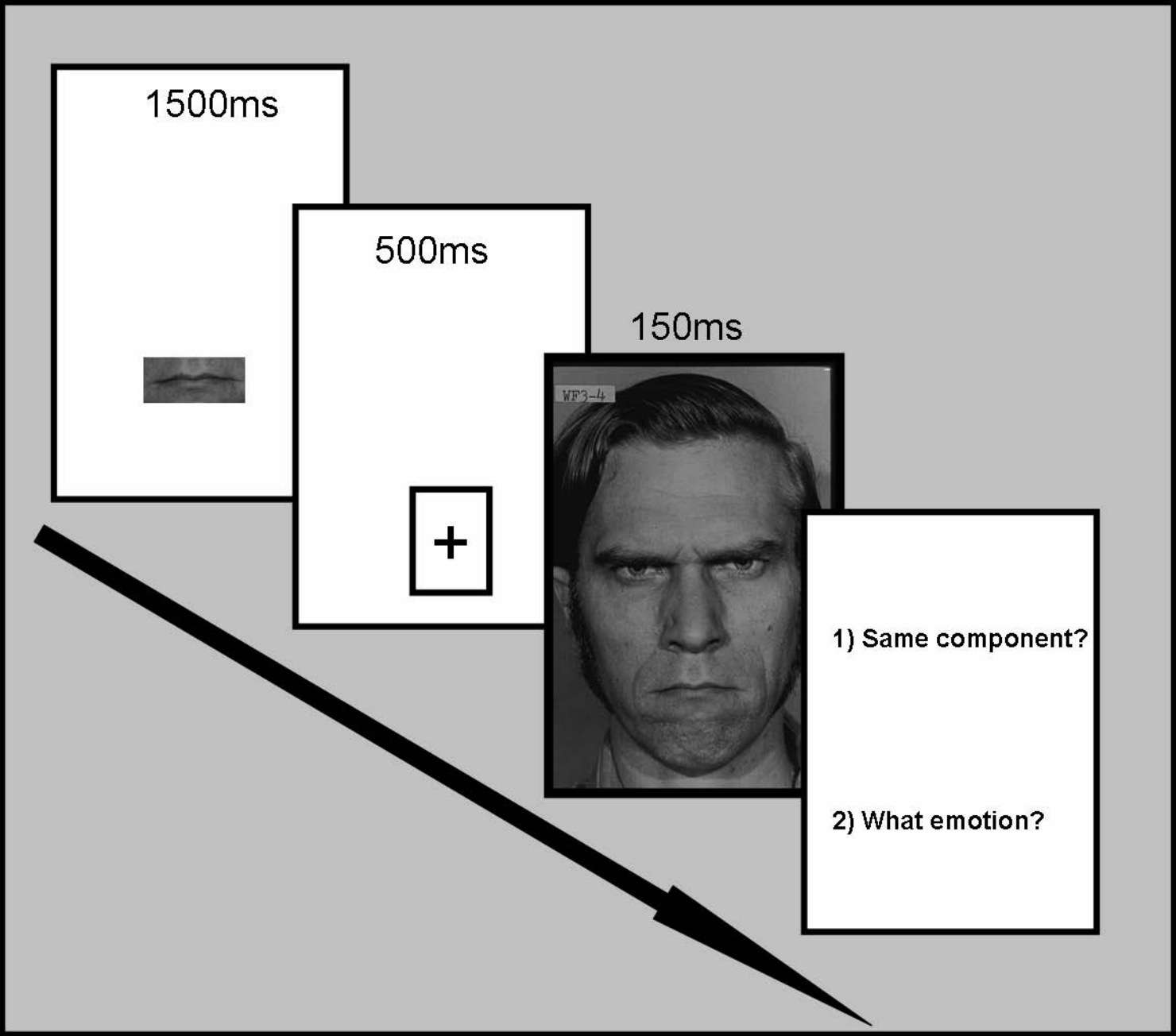
Highlights

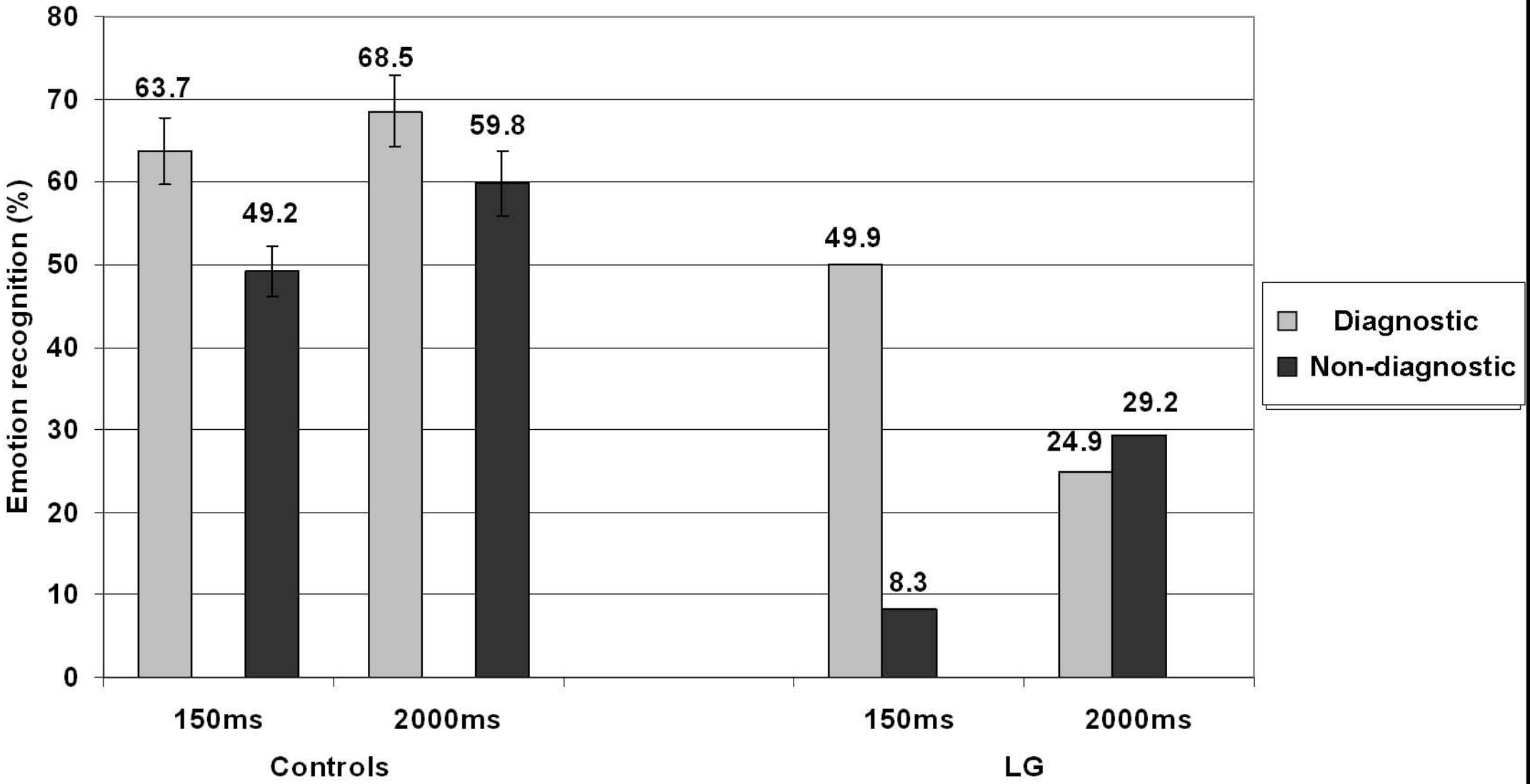
- We examine impaired emotion recognition in developmental visual agnosia.
- We manipulated the processing of diagnostic or non-diagnostic face components.
- In brief exposures, emotion recognition is boosted by diagnostic components.
- In long exposures, the advantage of diagnostic matching is diminished.


80
70
60
50
40
30
20
10
0
Emotion recognition (%)
68.5
59.8
24.9
29.2
Controls
LG
Diagnostic
Non-diagnostic


1500ms
500ms
150ms
WF3-4
1) Same component?
2) What emotion?


80
70
60
50
40
30
20
10
0
Emotion recognition (%)
63.7
49.2
49.9
8.3
Controls
LG
Diagnostic
Non-diagnostic


1500ms
500ms
150ms
WF3-4
1) Same component?
2) What emotion?


80
70
60
50
40
30
20
10
0
Emotion recognition (%)
63.7
49.2
68.5
59.8
49.9
8.3
24.9
29.2
150ms
2000ms
150ms
2000ms
Controls
LG
Diagnostic
Non-diagnostic