Face Processing Patterns of Persons with Asperger Syndrome

an Eye Tracking Study

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Abstract

One of the main diagnostic criteria for Asperger Syndrome is a severe social impairment (American Psychiatric Association [DSM-IV-TR] 2000), something that has often been connected to a more specific impairment in facial recognition. However, the main diagnostic tool (the DSM-IV-TR) has received much criticism during later years and is soon to be revised (Woodbury-Smith & Volkmar 2009). Among other things, many researchers claim that the diagnosis should be complemented with a sliding scale of severity (Ring, Woodbury-Smith, Watson, Wheelright & Baron-Cohen 2008). The use of facial information is central in the social interaction of humans, evident in the special patterns of visual scanning that people employ for facial stimuli (Yarbus 1967). Because of that, this symptom of Asperger Syndrome has become a high research priority. The impairment in facial recognition has been connected to a bias towards detail based processing (McPartland, Webb, Keehn & Dawson 2010). A recent study also connects this to an unusually high visual acuity, which could result in a disposition to focus on small facial features. In the present study. facial stimuli were prepared to provoke memory conjunction errors. This type of memory error means that a person erroneously claims to recognize a face assembled by pieces of previously shown stimuli. If a person is more prone to do so, that would imply that he or she is more focused on details than on configural information (Danielsson 2006). Two groups were tested, one consisting of non-diagnosed adults and one of adults diagnosed with Asperger Syndrome. A test for visual acuity was administered, which was followed by a series of facial recognition tasks. Responses in the latter part were given with a computer mouse, and eye fixations were recorded using a head mounted eye-tracking device. Three hypotheses were formulated. First, persons with AS were expected to perform more poorly in all facial recognition tasks. Second, persons with AS were expected to make more conjunction errors than test group subjects. Finally, persons with AS were expected to display a mean visual acuity significantly higher than that of the test group. However, no significant differences emerged between the groups in relation to either of the hypotheses, and results could not be referred to flaws in the experimental setup. Therefore, these results are taken to display the heterogeneity of the Asperger Syndrome population, and possibly the importance of early training measures to compensate for social impairments.

Preface

We would like to thank Henrik Danielsson, Torbjörn Falkmer, Marita Falkmer, Anna Sjörs and Joakim Dahlman for all their support and infinite patience. We would also like to thank Prof. Dr. Claus-Christian Carbon at the University of Bamberg for kindly letting us use his face image database, and Nerrolyn Ramstrand of Jönköping University for her eye-tracking assistance.

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Introduction

Few communicative skills are as universal and versatile as our facial expressions. Not only is the human face deeply connected to personal identity. The slightest variations tell of our intents or interests, and a smile or frown can travel the world without misunderstanding. Because of the range of information that our faces convey, individuals with impairments in facial recognition are severely held back in their social functioning. One group associated with both general social impairments and facial recognition impairments specifically are persons with Asperger Syndrome (hereafter also referred to as AS). Numerous studies have explored both causes and features of this symptom. In later sections, the most salient findings of such research are described and related to the subject at hand.

More than 60 years have passed since Hans Asperger's first attempt at defining the syndrome that would later carry his name, but the subject still stirs an intense nosological debate. During an Asperger Syndrome diagnosis the patient is evaluated according to a range of behavioural descriptions, seemingly inviting variations between individual clinicians. The present diagnostic tool is the DSM-IV-TR (Diagnostic and Statistical Manual of Mental Disorders) (American Psychiatric Association [DSM-IV-TR], 2000). As the theoretical chapter will show, much of its contents are currently being scrutinized. If the syndrome could instead be reliably connected to neurological factors, there ought to be a good chance of improving diagnostic precision. Studying the characteristics of facial recognition of persons with AS explores one facet of such research. Furthermore, exploring the facial information processing of persons with Asperger Syndrome may contribute to the improvement of compensatory measures. Because of diagnostic uncertainty however, studies on facial recognition involving AS persons have in many cases produced inconclusive results.

In this study, patterns of facial recognition of persons with Asperger Syndrome were investigated using an eye tracker, a device for recording eye fixations. Previous research referenced in the theory section has suggested that AS facial recognition impairment is connected to a bias towards detail based facial processing. In order to provoke such effects during trials, tests employed rigged facial stimuli. Some test images were assembled of parts from previously shown images. According to theory, a person focusing more on details in face perception would be more prone to false identifications of such stimuli. Furthermore, subjects were also tested for visual acuity. This was done in an attempt to replicate the results of Ashwin, Ashwin, Rhydderch, Howells & Baron-Cohen (2009), who have suggested that a bias towards detail based facial recognition of AS persons may be explained by an abnormally high visual acuity.

The theoretical background describes the AS diagnosis in general, some controversies, and the subject of facial recognition in connection to the domain. Following this, the present study will be described in detail. After this, the following chapter presents analysed eye tracker, response and visual acuity data. This is followed by a discussion of results. Finally, possible future areas of research in connection to this subject are suggested.

Theoretical background

This chapter will begin with a brief overview of the Asperger Syndrome diagnosis and some of its controversies. Following this, a deeper review of facial recognition research aimed at persons within the Autism spectrum is provided (Autism Spectrum Disorders is hereafter sometimes referred to as ASD). Recent findings are brought up and some possible causes are described. Lastly, a few sections describe eye tracking as a method in psychological research, and the concept of memory conjunction errors employed in the present study is reviewed.

Development of the diagnosis

In 1944, Hans Asperger made his first descriptions of patients, young boys, who displayed severe difficulties with social interaction (Asperger H; annot. Frith U [1944] 1991). It would however take until 1981 for the condition to be given its present name, when English psychiatrist Lorna Wing used the denomination Asperger Syndrome in developing Hans Asperger's findings (Wing L. 1981). Since then, a great effort has gone into differentiating it from other disorders within the Autism spectrum. The disorder was initially defined as a mild form of autism, but studies referenced later on have revealed features that do not mirror the characteristics of other associated conditions. Even today, 17 years after the syndrome's inclusion in the DSM IV, some researchers are arguing for it to be removed altogether. This chapter will reference such researchers and an attempt will be made to describe our current understanding of the diagnosis, different causal explanations, some controversies, and particularly the question of facial recognition in persons with Asperger Syndrome.

DSM-IV

The Diagnostic and Statistical Manual of Mental Disorders is published by the American Psychiatric Association (American Psychiatric Association [DSM-IV-TR], 2000). In 1994, the manual reached its fourth revision (DSM IV) and was subsequently revised in 2000 (DSM IV-TR). The contents of the manual connected to Asperger Syndrome are not uncontroversial. In 2013, the next version of the manual is set to be published. Some sources referenced further on indicate that its sections about AS will likely be extensively revised.

The DSM IV defines Asperger Syndrome using a set of criteria. First mentioned is a severe impairment in social interaction. Moreover, it is stated that persons with AS are likely to develop restricted, repetitive patterns of behaviour, interests and activities. This is typically manifested by the collection of large amounts of information about a specific subject. In more recent studies, it is emphasized that AS persons normally do not display the stereotypical repetitive motor movements of persons with autism (Woodbury-Smith & Volkmar 2009). Also, persons with Asperger Syndrome show no significant delays in language acquisition or cognitive development. Children with AS display age-appropriate learning skills and adaptive behaviours. Parents often describe children with Asperger Syndrome as "talking before walking". Typically children display strengths in verbal ability and weaknesses in visual-motor and spatial skills. Despite this, symptoms of over-activity and inattention are said to be frequent, something that often leads to a diagnosis of ADHD. There is also evidence that Asperger Syndrome is associated with depression, something that may have to do with anxiety due to failing social relations (Ghaziuddin, Weidmer-Mikhail & Ghaziuddin 1998). Finally, DSM IV mentions that the disorder is diagnosed some five times more often in males than females, a statement which is contested by Woodbury-Smith et al. stating a 9:1 male-female ratio.

Difficulties in discerning from other ASD

Currently the standard for making an AS diagnosis is to employ a combination of methods. The Autism Diagnostic Interview Revised (ADI-R) consists of a guide for discerning AS symptoms in a semi-structured interview, while the Autism Observation Scale (ADOS) describes diagnosis during structured play (Woodbury-Smith & Volkmar 2009). Many researchers note the difficulties in separating Asperger Syndrome from the range of other autism spectrum disorders. For example, Kamp-Becker, Smidt, Ghahreman, Heinzel-Gutenbrunner, Becker and Remschmidt (2010) tested both children and adolescents trying to make out discrete phenotypes for the different disorders. Their results point toward the conclusion that the difference between AS and High Functioning Autism (HFA) is mainly a matter of symptom severity. Woodsbury-Smith & Volkmar mentions the possibility that the different disorders within the autism spectrum have been developed independently mostly because they derive from different stems of research. In fact, interdisciplinary research could reveal that they have very much in common. One study performed by Klin, Pauls, Schultz and Volkmar (2005) criticizes the DSM-IV definition of AS, particularly the way autism is given precedence over other disorders. For example, the developmental onset of words and phrases is said to be too vague a criterion for diagnosis. Basing assessments on criterion like that might produce a bias towards making autism diagnoses. Normal variations in development may be inflated in the diagnostic process. Instead, Klin et al. wish to emphasize the importance of impairments in social communication. Features like pedantic language with odd prosody set the AS group apart from the delayed, repetitive language of persons with autism.

The problem of definition persists however, since many researchers have noted great variability within the AS group concerning among other things communication features and ritualistic behaviours. For example, Ghaziuddin (2010) found many behavioural features that separate persons with AS from those with autism. The former are active but odd in their social interactions compared to the latter, an assessment consisting of several behavioural and clinical observations – high intelligence, impulsivity and hyperactivity in combination with a tendency to ask inappropriate questions, fixation on topics of interest and a pedantic manner of speaking. Furthermore, the studied group was largely heterogeneous in behaviour. Ghaziuddin's results may imply that these conditions do not only differ in severity, but also in quality. Some of researchers argue that autism spectrum disorders should be placed on a sliding scale of severity. Ring, Woodbury-Smith, Watson, Wheelright and Baron-Cohen (2008) administered questionnaires to 333 persons within the autism spectrum. Their results seem to imply that behavioural discrepancies are connected to a grade of severity of symptoms rather than discrete sub-types within the range. Others still hold that the different disorders should be described as subtypes (Ghaziuddin, 2008; Ring, Woodbury-Smith, Watson, Wheelwright & Baron-Cohen, 2008).

Neurological findings and genetical base

Several brain regions have been established to be connected to the disorder. These include the frontal and temporal lobes (Schultz, Gauthier, Klin, Fulbright, Anderson, Volkmar, Skudlarski, Lacadie & Cohen & Gore, 2000; Schultz, Grelotti, Klin, Kleinman, Van der Gaag, Marois & Skudlarski, 2003; Happe, Ehlers, Fletcher, Frith, Johansson, Gillberg, Dolan, Frackowiak & Frith, 1996) and the amygdala (Kwon, Ow, Pedatella, Lotspeich & Reiss, 2004; Welchew, Ashwin, Berkouk, Salvador, Suckling, Baron-Cohen & Bullmore, 2005).

Even though many studies on this topic have dealt with the autism spectrum in general there is enough evidence in the research referenced above to state that the different disorders seem to have a resembling neurological expression. Some of these results are interesting when dealing with the domain of face recognition. This will be commented on in later episodes.

Psychiatric researchers are still engaged with the question whether AS has a genetic explanation, or if it is caused by circumstances during the pregnancy and/or later development. There is some evidence of an increased frequency of Asperger Syndrome among family members of AS individuals. Woodsbury-Smith & Volkmar (2009) refer to one study where 99 families containing members with AS have been studied. Here a strong family history of Asperger Syndrome could be shown among first-degree relatives. These results are supported by similar results by Ghaziuddin, Weidmer-Mikhail and Ghaziuddin (1998).

Although the idea that ASD is inherited seems to have strong support, the severity of the disorder appears to be very much affected by environmental factors and/or general development. Research has been presented showing that as many as 20% of persons diagnosed with AS do not display its features in adulthood. In many other cases the severity of symptoms are at least greatly diminished (Woodbury-Smith & Volkmar 2009).

Future nosological development

In relation to future research, Woodbury-Smith and Volkmar (2009) mention the importance of exploring the relationship between autism and AS further. More importantly however, the current basis for diagnosis should be thoroughly revised, i.e. the DSM-IV. According to the authors, researchers must free themselves from the assumption that AS can be readily described as a subtype to autism. Doing that may lead to a better basis for external validity of the syndrome. Some such attempts have been made, for example by Klin, Pauls, Schultz and Volkmar (2005).

Asperger Syndrome and face recognition

The ability to recognize faces is a skill central to the social functioning of humans, a fact demonstrated by our constant monitoring of other persons' facial expressions. From these we may draw conclusions about emotional states, level of engagement, focus of attention and probable future actions (Leopold & Rhodes 2010). The recognition of faces seems to draw on specific mental functions and displays unique behavioural patterns in comparison to perception of other types of stimuli. All faces share the same basic structure, and very subtle features must be exploited in the process of recognition.

Many studies have noted the specific characteristics of human face processing. For example, early research (Yin 1970) revealed what has later been named the *face-inversion effect*. The recall of inverted faces is highly inferior to upright stimuli, something that is not manifested when regular objects (houses in Yin’s study) are used. The conclusion drawn from this was that configural information is used for processing upright faces, information which is lost when they are inverted. This use of a face’s configuration has been denominated holistic processing, as opposed to the feature oriented process of recognizing object stimuli. As Jemel, Mottron and Dawson (2006) note, impaired face processing is one of the most commonly cited aspects of the social cognition deficits observed among persons with autism spectrum disorder. Because of its prominent function in social settings, exploring both the impairment’s origin, specific features and possible compensatory strategies is highly prioritized in research on ASD.

The specific features of face recognition have been explored deeply. In the past, the triangle composed by the two eyes and the mouth has been described as the typical fixation pattern in face processing (Yarbus 1967). This triangle of configural information seems to be very robust. Young, Hellawell and Hay (1987) showed that subjects were able to use very limited facial features for recognition. Either half of a person’s face could be used effectively. However, when halves of different faces where combined, performance was greatly diminished. It seemed that when a full face was available a holistic method of recognition took priority over feature based functions, even though it lead to inferior results. Hole, George, Eaves and Razek (2002) tested subjects’ recognition of famous faces under various amounts of compression, and found that faces could be compressed as much as 25% without any degradation of recognition ability.

Despite the strong support for claiming superiority of holistic recognition and the face information triangle, later research has implied that some facial features are more important than others. For example, Sadr, Jarudi and Sinha (2003) showed that recognition of famous faces depended heavily on eyebrows, rather than on eyes or mouth. These results were attributed to the use of eyebrows to convey emotion and the fact that eyebrows typically constitute high contrast parts of human faces. Interestingly, the ability to make use of the configural information of faces is also preserved despite severe degradations in resolution. Yip and Sinha (2002) demonstrated that face recognition was largely unimpaired despite lowering the resolution of stimuli to 7x10 pixels. Furthermore, the role of colour in face recognition has also been studied. Yip and Sinha (2002) demonstrated that when shape cues in images of faces are compromised humans rely on colour cues to determine identity.

Dynamic properties of faces can also have substantial effects on recognition. When incorporating dynamic cues such as expressive or talking movements in recognition tests, recognition has been facilitated (Lander & Chuang 2005). It seems fair to infer that face recognition comprises a battery of functions, which engage hierarchically depending on the quality of stimuli. Determining which variation of stimuli to choose for a specific experiment will depend both on the specific phenomenon of interest and a trade-off between ecological validity and experimental control.

Problems with face recognition have often been indicated to have a high influence on social impairments of persons with ASD, and because of that a great deal of effort has gone into explaining this phenomenon. Studies on the broad ASD population has revealed reduced face inversion and face decomposition effects, which has been interpreted as a dominance of feature oriented processing strategies (McPartland, Webb, Keehn & Dawson 2010). Trepagnier, Sebrechts and Peterson (2002) made some interesting suggestions to possible causes of face recognition impairment in the ASD group. The *Gaze-Disruption*-hypothesis states that interferences in social attention during the child's first months, caused by neuropsychiatric problems, may bring about autistic symptoms. An early propensity for anxiety or depression may impair the child's social development. This idea has some support in the fact that children who are born blind but who have their vision restored as early as at two months age, still show lasting impairments in face processing.

In particular interest to this study, Nakahachi, Yamashita, Iwase, Ishigami, Tanaka, Toyonaga, Maeda, Hirotsune, Tei, Yokoi, Okajima, Shimizu and Takeda (2008) performed studies showing that persons with AS tend to interpret visual stimuli in parts rather than as a whole, a phenomenon denominated *poor central-coherence*. The authors also discuss possible causes suggesting impairments in the fusiform gyrus, because of its alleged function in combining parts into wholes. In another study by Bookhemier, Wang, Scott, Sigman and Dapretto (2008) persons with ASD showed a lower activation in frontal areas and the amygdala during face recognition tasks. These are areas connected to social cognition, which could be interpreted to mean that persons with ASD treat faces similar to other objects in their processing. Rondan and Deruelle (2007) performed tests that add detail to the question of holistic versus detail based recognition. Here, persons within the ASD spectrum got to look at objects and faces constructed by other smaller objects. The ASD group chose to interpret the global form to the same extent as the control group, implying that global processing of the ASD group was intact. However, they did display greater problems with handling spatial relations between different parts of faces and objects. When that was demanded, test persons were believed to rely more on local processing.

In the past it was believed that persons with ASD have impaired face recognition because they avoid looking at the face area. Falkmer, Larsson, Bjällmark and Falkmer (2010), refuted this, performing experiments to study visual search strategies for face identification among adult persons with AS. An eye-tracker was used to register fixations. The eye area was of specific interest, because prior research has implied that persons with Asperger Syndrome avoid eye-contact. The test group had greater difficulties with identifying faces than the control group, but surprisingly persons with AS depended heavily on the eye area for identification. However, the results also showed that persons with Asperger Syndrome depended less on the “face information triangle”, and displayed more fixations in other parts of the face.

Other results have also complicated the issue of ASD face recognition impairments. An eye-tracking study was performed by McPartland, Webb, Keehn and Dawson (2010). The test group consisted of adolescents with ASD, which scored below the control group on face recognition and socio-emotional function, but displayed the same patterns of attention. The authors relate this to previous findings, which show that when persons with ASD are given enough time and stimuli is of high resolution they display more typical patterns of face processing. This was also observed by Hadjikhani, Joseph, Snyder, Chabris, Clark and Steele (2004). In the study of McPartland et al., stimuli display times of eight seconds were used. The fact that the persons with Asperger Syndrome in the study displayed normal patterns of attention is attributed to variations within the ASD group. According to the authors, both nosological difficulties and differing early interventions (social therapies) may explain varying results between similar studies.

A study which may bring some light to other conflicting results around this matter was presented by Barton, Cherkasova, Hefter, Cox, O’Connor and Manoach (2004). Here face recognition studies were performed on a group of persons all falling somewhere inside the ASD spectrum. Results showed that eight persons from the test group performed equally to the control group, while the 16 other test persons performed considerably worse. As a whole, the group performed somewhere between the control group and patients with prosopagnosia. This could not be connected to specific diagnoses of the eight persons, which could either imply that these persons had been diagnosed on differing criteria or that they displayed behavioural treats typical for ASD, but did not share the underlying causes for these.

Face recognition and memory conjunction errors

Making a memory conjunction error means falsely recognizing stimuli consisting of parts from previously memorized stimuli. This behaviour has been recognized in several studies and was employed by Henrik Danielsson (2006) when studying face recognition of persons with learning disability. Here the tendency to make conjunction errors was associated with a bias towards processing facial features rather than facial configurations (poor central coherence). In contrast, images of the type *feature* are constructed from both previously displayed and new facial features, which should not be equally deceiving. As mentioned earlier, this bias has also been recognized among persons with Asperger Syndrome. Because of that. an experimental setup using stimuli to provoke memory conjunction errors seemed to be fitting for the present study.

Asperger Syndrome and visual acuity

An interesting hypothesis about the cause for face recognition impairment among persons with ASD has been presented by Ashwin, Ashwin, Rhydderch, Howells & Baron-Cohen (2009). 20:10 is generally held to be the upper limit of human visual acuity. In tests employing FrACT and Landholts C, the authors tested the visual acuity of 15 grown men. Eight of these were diagnosed with high-functioning autism (HFA) and seven with Asperger Syndrome. Surprisingly, the test group displayed a mean visual acuity 2.79 times higher (20:7) than normal. This level of acuity is reported to be at the same level of birds of prey. There was no difference in performance between persons with HFA and AS. The authors suggest that this could be explained by higher densities of foveal cone cells in the eyes of persons with ASD. It is possible that an extreme visual acuity and potential to register details overshadows the ability to integrate details globally, which in turn could explain impairments in face processing.

Eye-tracking

In his 1967 book, Yarbus described eye movement experiments from the 1950s where a tight-fitting contact lens was connected to the participant's eye. A famous example consisted of measuring eye-movements of subjects looking at a reproduction of Ilya Repin's painting *The Unexpected Visitor*. Here it was clear that all participants, when uninstructed, directed most of their attention to the faces of the people in the picture. This behaviour also appeared to be cyclical. When subjects were observed during a longer period, the same pattern of visual attention seemed to repeat itself. Here the pattern called the *face information triangle* emerged, revealing a strong preference for the eyes compared to other facial features.

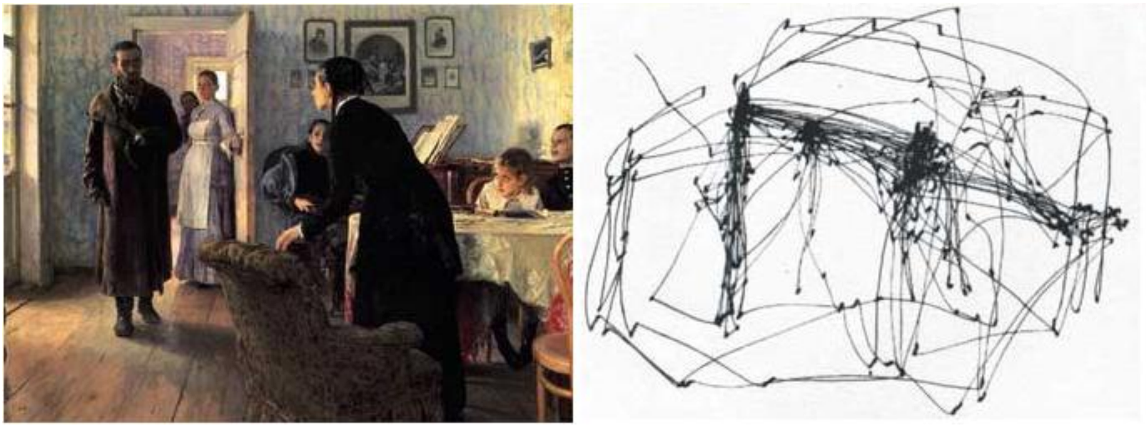

Figure 1: Left: Repin's painting The Unexpected Visitor. Right: Saccades and fixations of a person trying to identify the ages of the persons in the painting.

Another interesting result from this work was that participants displayed vastly differing patterns of visual attention depending on what instructions were given. According to the interpretation of Yarbus this demonstrated that studying eye movements revealed to some extent the thought processes of the subject, a theory later named the *Strong eye-mind-hypothesis*.

Since Yarbus's experiments eye-tracking has become a common tool in psychological research, although his theories on the tie between eye movements and thought has later been questioned. Posner (1980) carried out experiments showing that attention does not have to be exclusively tied to the position of the fovea. Rather, he stated, attention should be thought of as a wider beam where direct focus only constitutes part of a person's attention. If the work of Yarbus proposed a strong eye-mind hypothesis, Underwood and Everatt (1992) challenged this conception researching the domain of eye movements during reading, and forming what might be called a weak eye-mind hypothesis. What the eye lingers on does not necessarily have to be connected to what the mind is doing. For example, a reader's eyes may linger at the stop of a sentence while the meaning of the sentence is being processed. This fact does not give any special weight to the particular point in the text where focus is resting. While the eyes move cognitive processes may be directed at either past, present or future events (Underwood & Everatt 1992).

There have been several studies using eye tracking to explore face recognition of persons with AS, although none using the memory conjunction error phenomenon to study face recognition strategies. Other examples are Trepagnier, Sebrechts and Peterson (2002) studying face recognition versus object recognition and more recently Falkmer, Bjällmark, Larsson and Falkmer (2011) investigating visual search strategies of persons with Asperger Syndrome.

Hypotheses

As the theoretical background demonstrated, the conception that persons with AS have inferior facial recognition has been dominating for a long time. Because of that, the present study was expected to repeat that general pattern. In particular, persons with AS were expected to perform poorly when presented with conjunction stimuli, because the Asperger group has been associated with more detail based facial processing.

The concept of a bias towards detail based facial recognition in AS persons has been connected to eyesight by authors Ashwin, Ashwin, Rhydderch, Howells and Baron-Cohen (2009). Their results are remarkable and deserved to be investigated further. The chance to do so appeared in this study. If these results could indeed be replicated, it could perhaps deepen our understanding of the facial recognition of persons with AS.

More specifically, the following patterns were expected to emerge

Hypothesis 1: Persons with AS were expected to perform more poorly in all facial recognition tasks.

Hypothesis 2: Persons with AS were expected to make more conjunction errors than control group subjects.

Hypothesis 3: Persons with AS were expected to display a mean visual acuity significantly higher than that of the control group.

Method

In this section the experimental setup will be described, from the selection of test group participants to the physical and conceptual design of experimental rig and stimuli.

Participants

The selection was made using two main criteria, age and uncorrected eye-sight. A lower age limit of 17 was used, and in these cases a guardian's consent would be required. The unaided eye-sight criterion was stated as 'being able to see details in an image of approximately 50x70 cm at a distance of 1 meter'. If participants used glasses or contact lenses, they were encouraged to wear these. All participants gave their written consent, agreeing to take part in the study, and were informed that individual data would not be identifiable, but that the bulk of data could be used by researchers in future studies.

AS group

Participants in the test group were recruited from all over Sweden, using contacts and Internet forums for AS individuals. They were offered some monetary compensation as well as having all their travel expenses paid. A majority of test group participants were recruited from educational programs fitted for students with an AS diagnosis. For reasons of convenience the lab was moved to the boarding school where the tests were performed. 24 persons were recruited, of which 7 were female and 17 male. Ages ranged from 17 up to 59, the mean age being 25 with a standard deviation of 12.3. Of these subjects, 9 used either glasses or contact lenses.

Control group

Control persons were recruited using various advertisements both on and off the internet. No monetary compensation was offered to this group. 25 control subjects were recruited, 17 female and 8 male. Out of these, 10 used some sort of visual correction. Ages ranged from 19 to 47 with a mean age of 26 and a standard deviation of 7.64.

Equipment and materials

Stimuli

The raw material for stimuli images was obtained with the help from Claus-Christian Carbon at the University of Bamberg. These images were photographs of adult males and females, ages 20-40. Several steps were taken by the authors to avoid obvious cues for recall. Individuals with extreme characteristic features like dark beards, salient piercings and other deviating traits were removed from the stimuli material, and all remaining images were colour corrected. After this exclusion process all faces were positioned with their centres at the same spot in the images, and heights of faces were normalized. Stimuli were divided into males and females, each consisting of four categories. Stimuli of the type “Old” were images that had been presented during the encoding phase of the test, and therefore unmodified. Stimuli of the type “New” were unmodified images that were not presented during the encoding phase.

“Conjunction” stimuli were images where the inner and outer parts of faces from the encoding phase had been mixed (old + old). Finally, “Feature” stimuli were images where either the inner or the outer part of the face came from a previously shown image, but where the other part did not (old + new). Images selected for combination were matched as closely as possible to give a natural appearance. Through all considerations made about stimuli, ecological validity is obviously affected. The level of naturalness in stimuli for this study was determined from practical reasons. Images were of high quality, but still frontal images were selected in an attempt to limit the range of available cues.

Figure 2: Two original images and the resulting conjunction stimulus image

Physical equipment

The eye-tracker used was the “Mobile Eye” device from Applied Science Laboratories Eye Tracking, with head mounted optics and a colour scene camera. This device is mounted on a pair of protective glasses, with a portion of the right glass cut out to give room for the mirror. The eye camera was fixed at the right hand side (from user point of view).

To aid the test subject in the task of maintaining a good posture, a chin support was used. The participant’s chin rested in a cup, and a pillow was wedged between the top of the head and the chin support frame. Figure 4 shows a test participant placed in the chin support, with the stiff pillow wedged between him and the rig. The eye-tracker is positioned on the persons head, and the answering device (a wireless computer mouse) is placed in front of the test subject. The projector can be seen behind the participant on his left hand side (emitting a blue light).

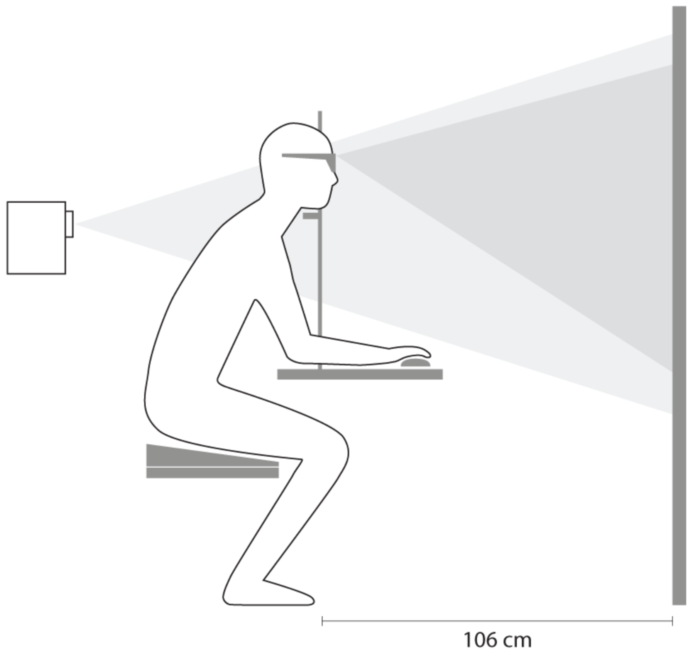

Figure 3: Sketch showing a seated test subject, projector beam and viewing angle of the scene camera.

To prevent slouching and improve the posture of participants, a wedge shaped cushion was placed on the chair. A pillow with a hard back was placed between the participant’s chest and the chin support frame.

Figure 4: A participant during the calibration process.

Visual acuity of participants was measured using a Precision Vision "2000" Series Revised ETDRS Translucent Chart "1", designed for a 2 meter range with a maximum measurable acuity of 2.0 (40:20). This chart was used at a 4 meter range, which raised the maximum measurable acuity to 4.0 (80:20). The chart was mounted in a back-lit cabinet, placed on a mobile support. ETDRS stands for **E**arly **T**reatment **D**iabetic **R**etinopath **S**tudy.

Figure 5: ETDRS chart used.

The digital projector used was made by Sony, specifications unknown.

Tasks

Three blocks comprised the experimental tasks, and are described in the following sections.

Training session

For the participant to learn the test procedure a training session was carried out, which was very similar to the real tests. The main difference between the training session and the real tests was that a different set of images was used, and that the training session could be repeated indefinitely (until the participant was comfortable with the procedure). A series of 5 encoding and 8 recall images were shown to the participant using the projector. The participant was instructed to memorize the first five. When the eight latter faces were presented, the participant was to give an answer to whether he/she had seen that face before. Answers were given using a computer mouse, where the left button corresponded to “Image recognized” and the right button to “Not recognized”. The response had to be given when a particular ‘answering screen’ was displayed. This screen was shown 2 seconds. The task was repeated until the participant was comfortable with the test procedure, and could respond in a satisfying way.

Short / long test

The whole of the test consisted of five parts; four short tests and one long test. Each short test consisted of 5 images for encoding and 8 images for recall. The long test consisted of 20 images for encoding and 32 images for recall. Time duration of each short test was 1 minute and 55 seconds, which adds up to a total of 7 minutes and 40 seconds for the block of short tests. The duration of the long test was 7 minutes and 9 seconds. Half of the participants started with the four short tests, and half started with the long test. Between each test the participant could take a short break, and the eye-tracker could be re-calibrated if needed. The answering procedure of this task was the same as in the training session.

Visual acuity test

The participant was placed on a chair at a distance of 4 meters from the covered up ETDRS chart. When the test started the chart was uncovered and the participant started reading the characters out loud, from top to bottom, left to right. When no more characters could be made out, the test was stopped. Every erroneous identification was noted.

Test managers

Throughout the experiments, each task during sessions was appointed to the same test manager. All interaction with participants during experiments was also strictly scripted, in addition to being kept to an absolute minimum.

Data processing

Data was presented and processed using custom made software, which is described below.

HDPISV

In order to allow for a 1:1 mapping between eye-tracker and response data, a reliable and time keeping software to display stimuli had to be found. The only option that appeared in our efforts was SuperLab (http://www.superlab.com/). Thorough testing revealed that this software was unable to accurately keep time when using long sequences of images. In this software it is possible to specify the duration each image is shown (in milliseconds), as well as the pause between images. One would then assume that the sum of time snippets would be identical with the time it took the program to go through the image sequence from start to end. After some testing it was clear that this software wasn't designed for such precise measures, since each test could differentiate with more than ten per cent. That is to say, an image sequence with 10 images shown for 500 milliseconds, with a 100 millisecond pause after reach of these, should result in a six second long sequence (0.5 * 10 + 0.1 * 10). With the use of a stop watch sequences of different lengths were tested, and the difference between observed time and predicted time was noted. There was no regularity in the deviation between predicted time and observed time. This meant that a new program had to be devised from scratch, in hope of securing predictable image sequence viewing. The new software (Henrik Danielsson Paradigm Image Sequence Viewer) was developed in Java and had the following features:

- Accurate time keeping (no deviations larger than one second over several minutes long sequences)
- Automatic registration and correction of response data
- Its own file format to specify image sequences (.hdp)
- No limitations in test length, stimuli image sizes or resolutions

Data processing software

The amount of data to be processed and analysed per test subject consisted of:

- 5 plain text files containing responses from test group participants. Each file contains between 8 and 32 lines. The information contained in this file is ‘image number’, ‘image type’, ‘response’. The response is automatically transformed by the image sequence viewer software to be either ‘correct’ or ‘not correct’.
- 5 video files containing individual information about the eye-tracker calibration (and information to help doing a 1:1 mapping between eye-tracker data and the stimuli images)
- 5 files in the format CSV containing the eye-tracker data. Each file contains between 2500 and 12000 lines.

Above mentioned files were then to be combined with the image sequence files, describing what type of image was shown at what time interval. With all the information listed above it was possible to create a 2x2x4x5(+4) matrix, which was used for the final statistical analysis.

The matrix vectors were:

- Test length (2)
  - Short
  - Long
- Answer type (2)
  - Correct
  - Wrong
- Image type (4)
  - Old
  - New
  - Conjunction
  - Feature
- Measures (5)
  - Number of fixations
  - Average fixation length
  - Part eye
  - Part mouth
  - Part other

The vector was then expanded with 4 new variables:

- Participant ID
- Group ID (0 = control group, 1 = test group)
- Excluded or missing fixations for the long test
- Excluded or missing fixations for the short test

The final result is a table with 84 columns, and a row for each participant. To produce above mentioned vectors a number of programs had to be constructed, that combined, extracted or summarized in one way or the other. Detailed information about the functions of the programs will be left out of this essay.

Data sorting and extraction

Experiments yielded vast amounts of data, which had to be processed in several steps before interpretation.

Eye-tracker data and fixations

Eye-tracker fixation data was extracted from raw data and sorted into three predefined categories, namely eyes, mouth and other using a pixel mapping strategy. These regions were defined by using an overlay of a sample of images from the stimuli material, hence trying to cover as much of each region as possible, but at the same time exclude areas not defined by the region. Both the eye region and the mouth region partially overlapped with the nose, but for several reasons this was not addressed. One reason was of a technical nature. It would require too much effort to separate the nose fixations, and the other reason was that most fixations were either directly on the eyes, or on (or slightly around) the mouth. Nose fixations were rare, and were still partially covered by the region between mouth and eye. Almost all participants moved to a certain degree during tests, typically sagging as the test went along. This meant that the same pixel mapping could not be used throughout. Instead, regions were tailored for each participant with respect to a mean pixel mapping, calculated from start and finish scene camera data.

The traits covered by the different regions were (see also Figure 6):

- Eye - Both eyes, eye-brows, part of the upper nose ridge, side of the chin out to the ears
- Mouth - Both lips, and a small area above and below. Occasionally the mouth area included a part of the lower part of the nose. This area was limited to left and right by the same criteria as the eye region.
- Other - Hair, chin, neck, nose, forehead and areas not located on the face. This area is represented in the image as “outside the boxes”.

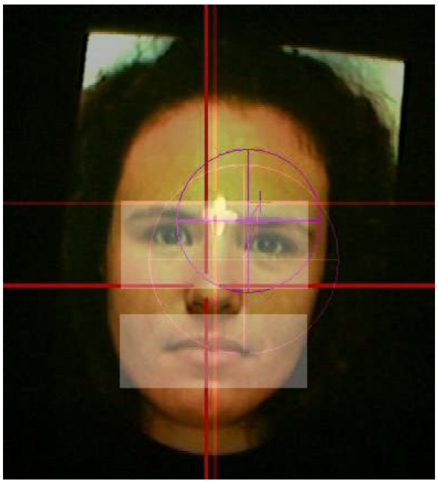

Figure 6: Scene camera view with an overlay of eye-tracker information gathered from the eye-camera.

Response data

Response data was extracted from the files coming from the Image Sequence Viewer software. Each line in the file contained information on what image ID the response was connected to, type of image (old, new, conj, feat) and the response (correct / incorrect). The participants could give multiple answers within the given time frame of the ‘answering screen’, and the chronologically latest one was decided to be the final answer. If for any reason the participants had not managed to give an answer within the set time frame, their answer was categorized as ‘omitted’.

Visual acuity data

The test for visual acuity was administered at the beginning of each session. For each participant the number of correct answers was noted, and then converted to logMar and decimal value according to the ETDRS conversion convention. This ETDRS score can be used for statistical analysis unlike the scores provided by the standard Snellen or Sloan Acuity tests.

The ETDRS Scoring Method 1 was used and is described by Vectorvision (www.vectorvision.com) as:

> *“The patient starts are the top of the chart and begins to read down the chart. The patient reads down the chart until he or she reaches a row where a minimum of three letters on a line cannot be read. The patient is scored by how many letters could be correctly identified.”*

To calculate the ETDRS score to decimal acuity score the following method was used, as described by the ETDRS manual:

- Identify the last row where the participant could correctly identify all 5 letters
- Locate the log score for this row (located at the right hand side of the chart)
- Subtract 0.02 log value for each following letter that has been correctly identified

The decimal score could then easily be converted to a logMar value using charts for mapping decimal value onto logMar value.

Ethics

When starting a new session, the participant filled out a consent form. This form allowed for collected data to be used by the authors as well as by researchers connected to the study, thus fulfilling the requirement of confidentiality. This form also informed the participant that published results could not be tied to individuals, thus granting anonymity. Participants were informed about their role in the experiments and what was expected from them. Subjects were also told to stop tests at any time if needed. Economical compensation was given without regard to this.

Design

All statistical tests were performed using the SPSS software from IBM.

The four types of test stimuli (old, new, conjunction and feature) in conjunction with test length (short and long) resulted in eight independent variables. These were analysed using ANOVA in SPSS with a 4x2 factorial design, where the first factor is stimuli type and the second is test length.

A similar design was used to analyse the eye-tracking data, response data and visual acuity measurements. Dependent variables were:

- Number of fixations
- Response
- Part eye
- Part mouth
- Part other
- Visual acuity

In conjunction with the first eight dependent variables the independent variables (except Visual acuity) were analysed using ANOVA. Visual acuity was analysed using a One-way ANOVA.

Results

Correct vs. False

Overall

For correctly identifying stimuli images, there were small differences in how well the two groups succeeded. An overall between group effect was observed $F(1,47) = 10.314$, $p<.05$. There was no statistical significance between groups in correctly identified stimuli images. Overall the AS group performed slightly worse with 69.9% correct answers in the short test and 65.5% in the long test. The control group had an average of 79.3% correct answers in the short test and 72.3% in the long test.

Test length

There was a statistically significant difference between correct answers and test length, $F(1,47) = 13.1$, $p<.05$. As a whole, test participants made more correct identifications in the short test than in the long test. As stated above the AS group performed slightly worse, but not enough to produce significant results. See figures 7 and 8 for details.

The following table lists correct answers in per cent for both groups, over test lengths and image types. Most erroneous identifications come from conjunction stimuli.

Table 1: Correct identifications per group, test length and image type.

	AS	**AS**	**Control**	**Control**
	Short	**Long**	**Short**	**Long**
Old	82.30%	69.40%	90.50%	83.40%
New	85.30%	76.70%	94.00%	88.10%
Conjunction	36.50%	42.70%	47.70%	37.10%
Feature	75.50%	73.20%	85.10%	80.40%

Image types

The differences in how well participants performed between image types (old, new, conjunction and feature) were significant, $F(3,141) = 98.5$, $p<.05$, but not between groups. This can be explained by that both groups performed significantly worse for conjunction stimuli. This trend was the same for both groups, as seen in graph figures 7 and 8. For all image types the AS group performed slightly worse, except for conjunction stimuli in the long test where they performed better than the control group.

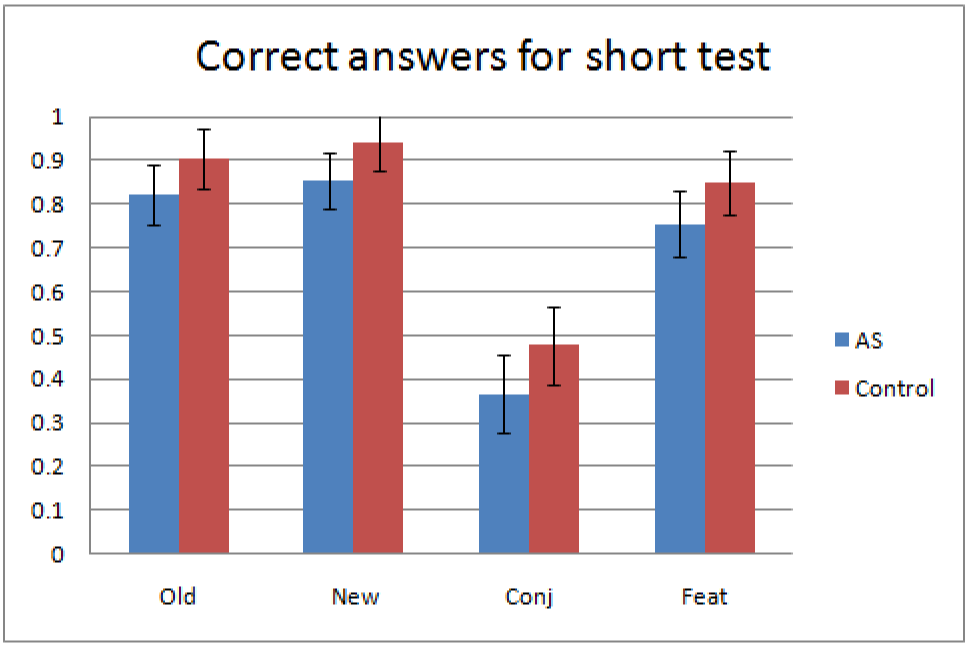

Figure 7: Correct answer distribution over image type for the short test (95% confidence interval for mean).

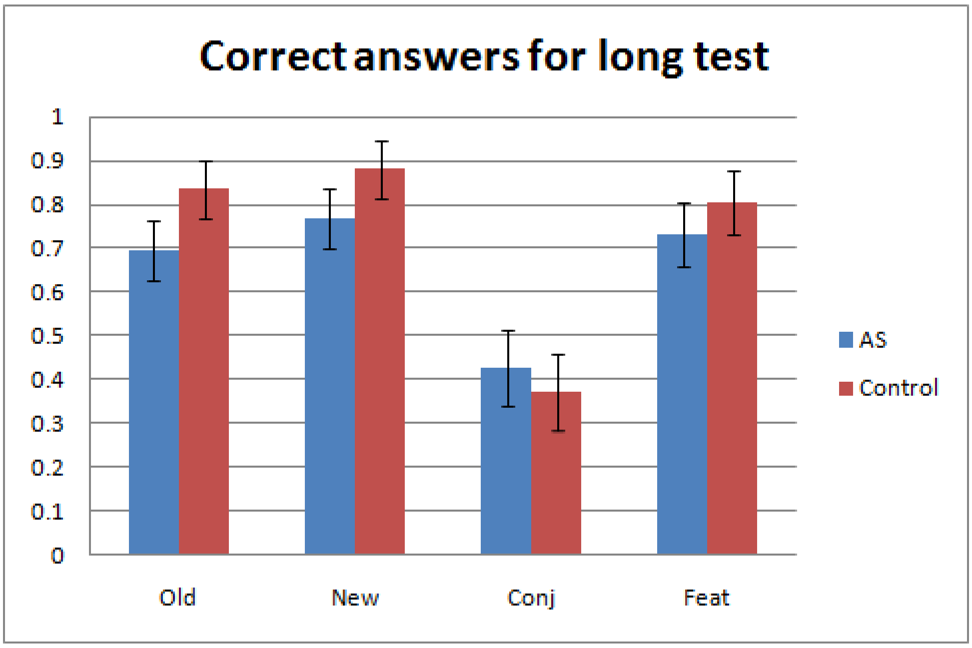

Figure 8: Correct answer distribution over image type for the long test (95% confidence interval for mean).

Summary correct vs. false

There were no significant differences between test and control group regarding correct answers. Some small differences exist and are in favour of the control group. The AS group had a slightly lower average number of correct answers, except for conjunction images in the long test. Overall participants had more correct responses in the short test, with some small deviations. Responses also differed between image types where conjunction represented the image type with the least amount of correct answers.

Number of fixations

Image types

Amount of fixations were calculated with aspect to correct/incorrect identification for all image types (separately). For all participants (both groups taken as a whole), results were significant.

- Old: CorrectFalse $F(1, 22) = 70.0$, $p<.05$
- New, CorrectFalse $F(1, 14) = 97.2$, $p<.05$
- Conj, CorrectFalse $F(1, 41) = 9.0$, $p<.05$
- Feat, CorrectFalse $F(1, 27) = 99.3$, $p<.05$

For image types Old, New and Feature both groups had more fixations for correct identifications than for incorrect.

There was no interesting statistical significance between the groups regarding number of fixations. Average number of fixations for correct identifications were 18.90 for the AS group and 22.19 for control. For incorrect identifications, the AS group had an average of 8.65 fixations and control had 7.07. This means that the AS group had an average of 3.28 fixations less per image than the control group for correct identifications, and 1.58 fixations more for incorrect identifications. For an overview of the distribution, see the below graph.

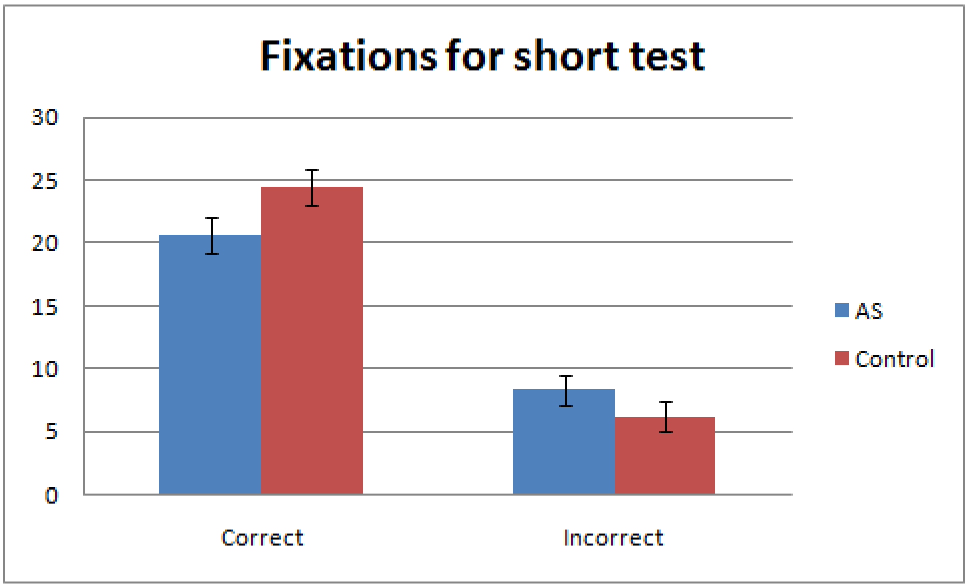

Figure 9: Fixation distribution between correct and incorrect answers for short test (95% confidence interval for mean).

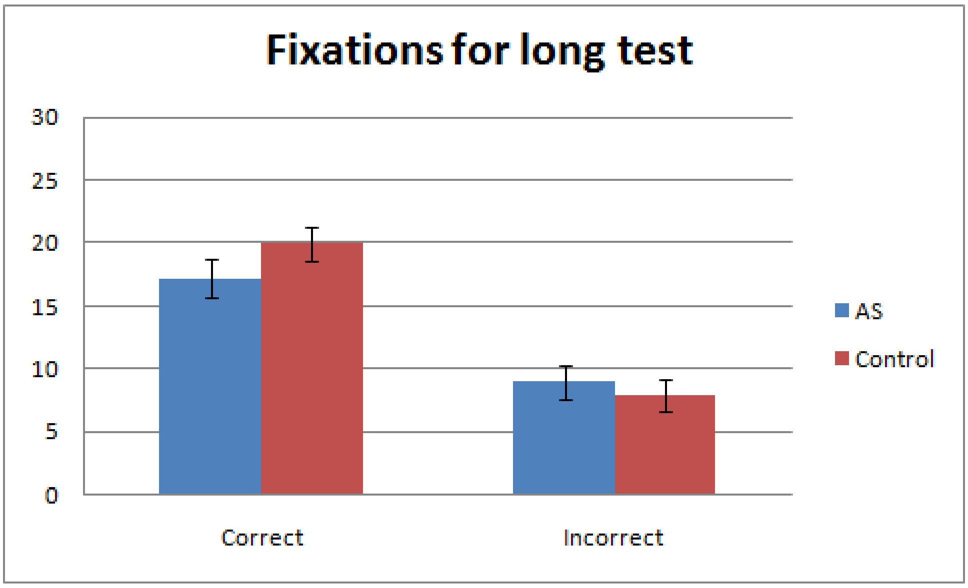

Figure 10: Fixation distribution between correct and incorrect answers for long test (95% confidence interval for mean).

Conjunction stimuli

Conjunction stimuli had an effect on the participants. This produced diverging results, namely that the AS group generated more fixations for incorrect identifications than for correct. The control group had similar results, but only for the long test.

An analysis of number of fixations for conjunction stimuli, test length (short / long) and answer (correct / incorrect) showed a statistically significant result $F(1, 41) = 10.1$, $p<.05$. This can be illustrated by the two following graphs and table. This diverging pattern (more fixations for incorrect answers, but only in the long test for the control) can help to explain the significant result.

Table 2. Number of fixations for conjunction stimuli.

	AS	**AS**	**Control**	**Control**
	Short	**Long**	**Short**	**Long**
Correct	10,48	12,09	15,71	10,58
False	19,09	14,50	14,63	17,42

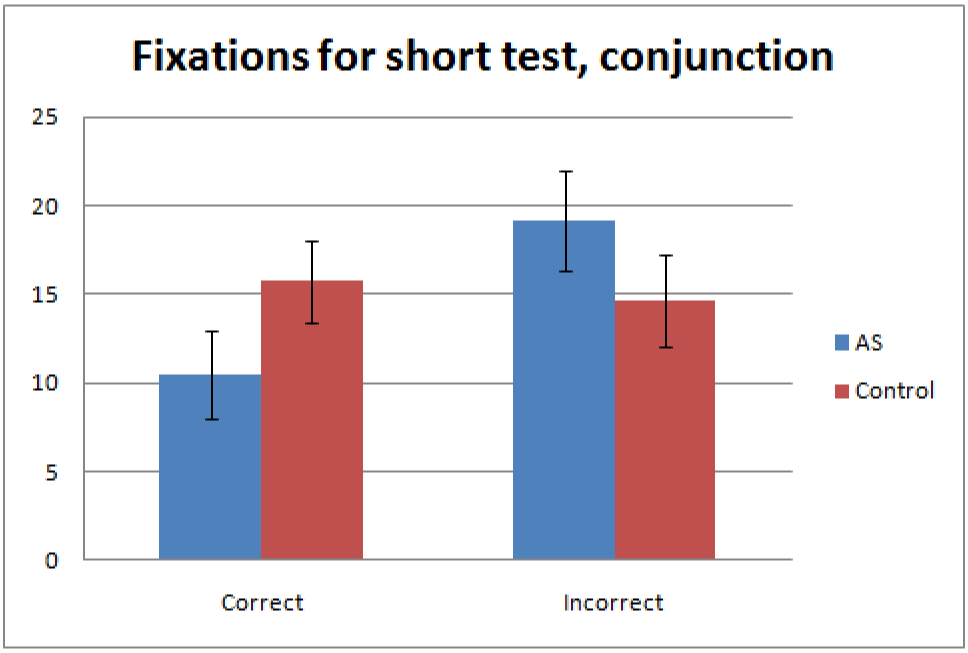

Figure 11: Fixation distribution between correct and incorrect answers for short test, conjunction stimuli only (95% confidence interval for mean).

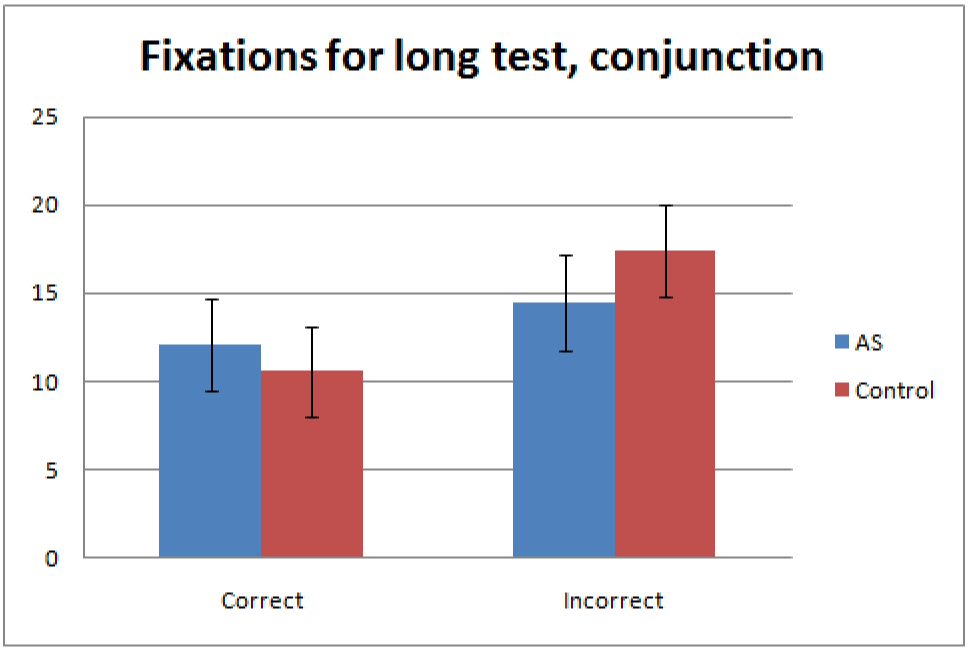

Figure 12: Fixation distribution between correct and incorrect answers for long test, conjunction stimuli only (95% confidence interval for mean).

Summary fixations

For image types old, new and feature all participants made significantly more fixations for correct responses than for incorrect. Conjunction images had the opposite effect on AS group participants which resulted in more fixations for incorrect answers than for correct.

Distribution of fixations over facial regions

For both groups, a majority of all fixations were located on or near the eye region of the stimuli image. The second most populated category was “other”, which includes the ears, hair, chin and places not located on the face, and lastly the mouth region. The breakdown over regions was roughly the same for both groups, as shown in the table below. This distribution was statistically significant for the group as a whole $F(2,92) = 48.2$, $p<.05$. There were no significant differences between the groups for distribution of fixations, although small differences existed.

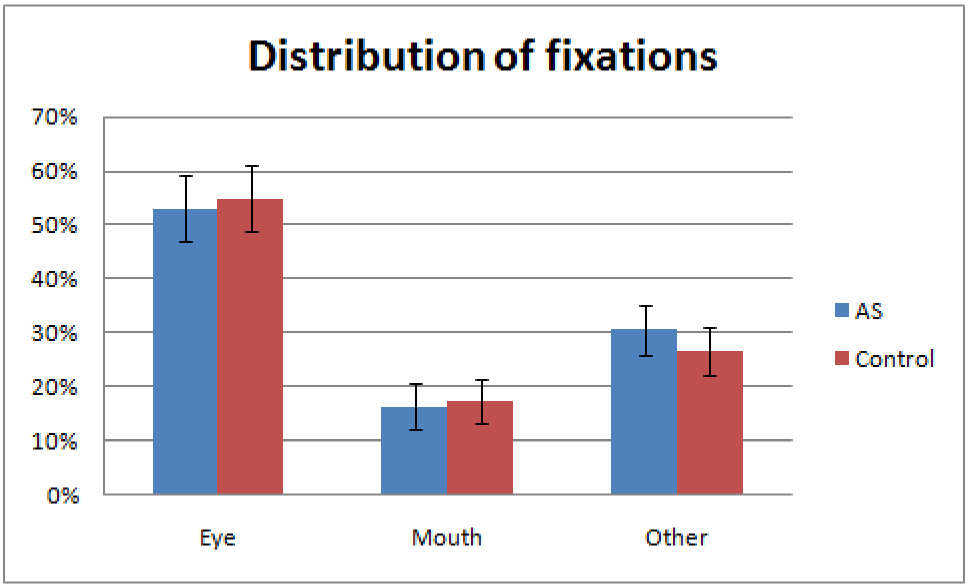

Figure 13: Distribution of fixations over facial regions (95% confidence interval for mean).

Summary facial regions

A majority of all fixations where located in the eye-region. For regions eye and mouth the control group had more fixations, but less fixations for the other region.

Visual acuity data

An ANOVA calculation of the logMAR value, decimal value and number of correct answers did not show any significant results between groups for any of the measurements. Small differences existed, and were in favour of the control group. More specifically AS individuals made an average of 2.4583 (5.45%) less correct identifications. The standard deviation for correct identifications was more than twice as high for the AS group (8.48 vs 3.67), which points toward a less homogeneous group.

Table 3 shows the minimum & maximum measured eye-sight values for both groups.

Table 3: Mean, minimum and maximum eye-sight of participants.

Group	Min	Max	Mean
AS	0.4	1.6	1.27
Control	0.8	1.6	1.29

Displayed in figure 14 is the decimal value for visual acuity. The reference values from the Ashwin, Ashwin, Rhydderch, Howells & Baron-Cohen article (2009) are displayed at the right hand side.

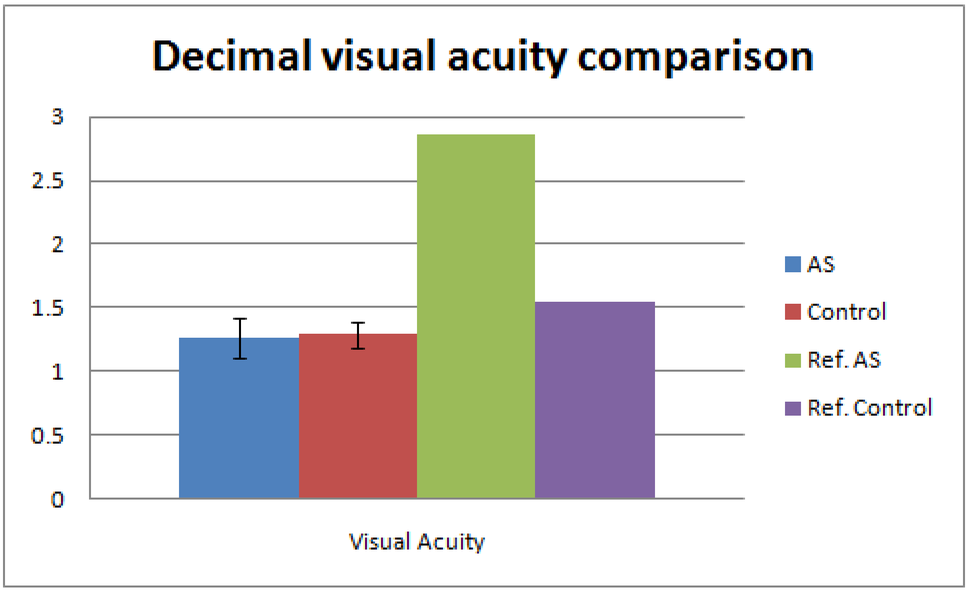

Figure 14: Observed visual acuity data (left) and reference data (right) (95% confidence interval for mean).

Summary visual acuity

The statistical analysis did not show any significant differences in visual acuity between the AS group and the control group. Average visual acuity was measured at around 1.3 with a maximum value of 1.6 for both groups. Not even the highest scoring participant in either group came close to the predicted results of eagle eyed acuity.

Discussion of results

Following the main points of the thesis, this section will bring up results pertaining to facial recognition, facial processing strategies and visual acuity. Finally, the general discussion relates these findings to previous research.

Right vs. wrong

Hypothesis 1 stated that persons with AS were expected to perform more poorly in all facial recognition tasks. This pattern did not emerge, since groups performed almost equally in the recognition of all image types. Stimuli were designed to provoke memory conjunction errors, and it should be emphasized that both groups made significantly more conjunction errors than with other types of stimuli. This seems to imply that the design of stimuli was successful. Hypothesis 2 stated that persons with AS were expected to make more conjunction errors than test group subjects, because of a bias towards detail based facial recognition. This should manifest itself through a larger proportion of conjunction errors. Remarkably enough the AS group did not display this pattern to a significant extent, although a small difference in that direction could be observed. Table 4 shows the distribution of correct answers for conjunction images.

Table 4: Proportion correct answers for conjunction stimuli.

Group	Conjunction, short test	Conjunction, long test
AS	36.50%	42.65%
Control	47.67%	37.14%

Furthermore, no significant differences could be seen between groups when comparing their performance between the short and long tests. Both groups performed significantly worse in the long test comparing with the short ones. From this it is possible to infer that making the test longer made it harder, suggesting that a ceiling effect was avoided. It is also interesting to note that both groups seem to have reacted similar to the increase in workload between short and long tests. Furthermore, except for conjunction stimuli, performance for both groups and for both test lengths was above the level of chance. This implies that floor effects were avoided. The task was sufficiently hard to allow detection of between-group differences and at the same time was not so hard as to produce floor effects.

Conjunction errors and number of fixations

An interesting result from fixation measurements is that both groups displayed significantly less fixations when answering incorrectly, as opposed to when answering correctly. Such a pattern has not been mentioned in other works forming the background for this study and it is difficult to interpret. It is possible that answering incorrectly was associated with making a hasty decision, after which attention was no longer purposely directed towards the displayed image. The result could also be associated with some cognitive process of recognition, where perhaps feature tracking is halted when a face is seemingly recognized. Answering incorrectly may then have been associated with making the judgement from some first recognizable facial feature, committing a conjunction error at the same time as halting feature search. Continuing, the behaviour could also be a way of tackling the existence of conflicting information in the image. It is possible that when a known feature is recognized, other features conflicting with the one recognized are explicitly ignored. Interestingly though, the test group displayed a deviating pattern when looking at conjunction stimuli. When such images were displayed and answered incorrectly by persons with AS, significantly more fixations were registered in comparison with correctly answered conjunction stimuli. This possibly suggests that conjunction images caused greater confusion in the test group, causing a lot of fixations and delaying the answer enough to provoke a faulty panic response when time ran out. The control group only displayed this pattern for the long test, perhaps implying a better ability of coping with this type of images. Perhaps being subjected to conjunction images during the more strenuous long test was enough to cause stress for control group members as well, resulting in more fixations and wrong answers for that image type.

Visual acuity data

A recent article by Ashwin, Ashwin, Rhydderch, Howells and Baron-Cohen (2009) presented extraordinary results. Here a group of persons with HFA and AS were demonstrated to possess a superior visual acuity. This led to the formulation of Hypothesis 3, stating that persons with AS were expected to display a mean visual acuity significantly higher than that of the test group. Data collected during this study does not support these results, since visual acuity of the test group did not differ significantly from the control group. In fact, none of the groups came close to the eagle eyed visual acuity presented in the Ashwin et al. article. The AS group of the present study is believed to be a good sample of the total population. Most test persons were young and therefore quite recently diagnosed. It is possible that the group tested by Ashwin et al. represented some unlabelled subgroup within the ASD range. However, their results remain remarkable. The authors suggest that their results could be explained by higher densities of foveal cone cells in the eyes of persons with ASD. This statement could naturally be examined more directly in a future study.

Method discussion

In this section, important elements of the experimental setup will be discussed, together with some environmental factors.

Recruitment and group composition

Recruitment of both test and control group was carried out according to availability and convenience. Due to the low number of people who were ultimately interested in participating in the study, most of these had to be recruited. Originally we set out to match control and test groups according to age and sex, but this goal had to be revised because of the difficulties with recruitment.

A majority of the participants in the AS group were male, which may be explained partially by the fact that more males than females tend to be diagnosed with AS (DSM IV). In the control group, this trend was reversed with more females than males. Recruitment for the control group was carried out primarily by direct contact with students at Linköping University, more specifically students from the programs for Cognitive Science and Psychology. If the ratio of males to females attending these programmes is in favour of females, then that could possibly explain our lopsided distribution. Analysis revealed no main effects regarding gender and main variables (fixations, responses, distribution), so this should have little impact on our results.

Experimental rig

Stimuli images were presented using a digital projector, displaying images in large format on a white surface. Participants were seated close to this surface in order to provoke large eye movements, which helped when mapping fixations to different facial regions. Using a projector meant that the room had to be kept dark, which in turn meant that the risk for visual disturbances was reduced. Switching the lights off did however make calibration of the eye-tracking equipment more difficult, and may have had an impact on the amount of usable fixations registered.

Time effects on results

In this study, images to be memorized were displayed 5 seconds, and 2 seconds during the recall section. McPartland, Webb, Keehn and Dawson (2010) showed that although subjects displayed impaired face recognition and social deficits, patterns of visual attention to faces for subjects with ASD was normative. This was associated with the quite extended viewing times, each stimulus image being displayed eight seconds. Although display times for memorization in our test were rather short, images were shown a longer time during recall. It is possible that this longer time was enough to even the odds between test and control group, but for results to be in line with previous research the short display times of the first section should have affected AS participants negatively. During the test each image was separated in time by a white centred cross on a black background, approximately in the position of the nose in each stimulus image. It is possible that this cross together with the explicitness of the task (to memorize faces) were enough to motivate test group subjects to concentrate on the faces displayed, partly bridging the gap between groups.

Eye-tracking concerns

The experiment setup depended heavily on a highly accurate calibration of the scene cameras position and angle in relation to displayed stimuli. Between-test calibration was performed when needed. Over the course of each sub-test however, participants often changed of their body position or head angle, which resulted in a deteriorating calibration. To counter this a head-rest was used in combination with a number of pillows, in an attempt both to make the pose easier to maintain and to fix the head, all the while trying to make the session as comfortable as possible. Despite this, the smallest movements or shifts in pose could affect calibration very negatively. In this study, maintaining calibration and head position were extremely important, because this allowed for an automated categorization of fixations per face region. Performing this work manually would have taken an endless time. It seemed at the time of the tests that persons from the test group moved about more during sessions, and it was therefore suspected that eye tracking data for this group would be inferior. However, it would prove during data processing that this was not the case. Apart from three AS individuals with high numbers of lost fixations the two groups were about equal in this respect. A great deal of care was taken to recalibrate if calibration was suspected to be altered, which could explain the final positive results. Persons from the test group did not display a less amount of concentration during tests, but more often required pauses between test rounds. These pauses also meant that calibration had to be redone when starting again. If the same eye tracking equipment was to be used for similar studies in the future, subjects could perhaps be allowed to lean back or lie down while using some sort of equipment to prevent sideways rotation of the head.

General discussion

Impairments in the face recognition of persons with Asperger Syndrome has long been considered a highly typical feature of the diagnosis. Although studies have demonstrated that visual attention to faces can be normal (McPartland, Webb, Keehn & Dawson 2010), the recognition impairment has appeared stable. Even though AS participants in the present study were diagnosed according to the standard and tests obviously provoked the desired effects, we failed to show anything other than marginal differences between groups. Not only did we not see a significant difference in conjunction errors, which could have implied differences in detail based versus holistic recognition, mean recognition was also almost equal. Are these results believable?

Looking closer at analysed data results did suggest smaller differences in the expected direction, albeit not nearly significant. What then could explain this discrepancy? Judging from the literature, experiments involving persons with Asperger Syndrome have often involved heterogeneous test groups, subjects being vaguely described as falling within the ASD range. AS is believed to lie at the end of that range, meaning that face recognition behaviour of these persons may not follow the patterns of high-functioning autism or other similar conditions. Previous research such as McPartland, Webb, Keehn and Dawson (2010) and Barton, Cherkasova, Hefter, Cox, O'Connor and Manoach (2004) has demonstrated that certain experimental designs together with the composition of the test group can produce results that differ vastly from the norm. When stimuli display times were long enough visual attention was normal, the same result produced by certain untypical test groups. The results of Falkmer, Larsson, Bjällmark and Falkmer (2010) were also reproduced, as persons with AS showed the normal tendency to concentrate on the eye region during tests. What however could not be found was support for a more detail based face recognition on the base of making more conjunction errors. Even though this type of error was clearly provoked, no significant difference was to be found between groups.

It is quite possible that the AS group of our study represented a sub-group performing nearly normally in the task of face recognition. Smaller tendencies in the expected directions suggest that tests actually provoked the expected effects, but that these effects were weak. The absolute majority of AS participants in this study were recruited from schools conducting education specially adapted to the needs of students with Asperger Syndrome. Often such educational programs do not only cover subject studies, but also involve training in handling typical problem areas or situations. It is possible that these subjects, even though they may have difficulties with facial recognition in their daily lives, were able to direct their attention provided with a well-defined task. The DSM-IV has also received a good amount of criticism, implying not only that diagnoses may differ depending on what professional is administering it, but also that the group of persons with Asperger Syndrome itself is far from homogeneous. Only a certain amount of criteria have to be fulfilled for a diagnosis to be made, and the distinction of AS from other disorders within the spectrum is far from clear. In fact, the main diagnostic norm (DSM-IV-TR) will likely be subject to extended revision in the following years. Apart from the possibility that AS participants in this study have been diagnosed in an atypical way, our results could be a matter of experimental resolution. Studies have shown both that face recognition of all humans depend on a battery of functions, and that face recognition of persons with AS may depend more heavily on some cues than others (Falkmer et al. 2010). Experiments could likely be arranged that measure the importance of such cues more closely, be they connected to colour, dynamics, features or composition. However, our results could also point to the importance of early measures to counter the socially impairing effects of AS symptoms.

Conclusions

Related to thesis

Results did not show significant differences between AS individuals and control group regarding the facial recognition task, proneness to conjunction errors or visual acuity. Differences exist, but are not of the magnitude to produce statistically significant results. However, they do point in the direction proposed in the thesis. Since no relevant experimental flaws have been identified these results are explained by the heterogeneity of the Asperger Syndrome population, where the group recruited for this study likely constitutes a high functioning sample.

Emerging results

Some interesting results that were not proposed in the thesis were the fixation inversion effect on conjunction stimuli and the distribution of fixations over facial regions.

When incorrectly identifying a piece of conjunction stimuli, both groups tended to produce more fixations. For the control group this was only the case for the long test, but there were strong tendencies towards this trend in the short test.

Research on facial recognition of persons with AS gives that individuals with AS generally avoid eye-contact, or looking at the eye-region. Our eye-tracker fixation data shows the opposite trend, namely that the AS group have roughly the same fixation distribution as the control group, This pattern consists of a majority of eye-region fixations. If subjects had any such tendencies, they were apparently able to suppress them during the task at hand. The eye-tracker data coming from this study also give strong evidence to the eye-mouth triangle proposed by researchers like Yarbus (1967).

Data points towards the conclusion that members of the test group did not have significantly impaired facial recognition, nor visual acuity, in comparison with the control group.

Future research

Part of results has been explained by the fact that a large portion of the test group was recruited from schools specially created for students with Asperger Syndrome. It may be rewarding to investigate more closely the design and effects of training at such schools, in order to identify what its most active components are. This could perhaps contribute to the development of didactic methods.

A very interesting result was the fixation-inversion-effect on conjunction stimuli for incorrect identifications. The general trend for number of fixations was that both groups displayed a significantly higher amount of fixations when answering correctly as opposed to incorrectly. For conjunction stimuli, this trend was inverted. It may be interesting to explore this subject further. What underlying factors give rise to this inversion? What special features of conjunction images generate more fixations? Are there specific features in conjunction images that draw on the attention of participants, and why does not this happen for feature images?

Authors Ashwin, Ashwin, Rhydderch, Howells and Baron-Cohen (2009) suggest that their results could be explained by higher densities of foveal cone cells in the eyes of persons with ASD. This statement could naturally be examined more directly in a future study.

Finally, design of stimuli and experimental setup seems to have big effects on participant performance. It would be interesting to continue the study of face recognition of persons with Asperger Syndrome under more natural circumstances, investigating the importance of other important cues like dynamic properties, colour or certain facial features.

References

American Psychiatric Association. (2000). *Diagnostic and statistical manual of mental disorders* (Revised 4th ed.). Washington, DC: Author.

Ashwin, E., Ashwin, C., Rhydderch, D., Howells, J. & Baron-Cohen, S. (2009). Eagle-Eyed Visual Acuity: An Experimental Investigation of Enhanced Perception in Autism. *Biological Psychiatry, 65, 17-21*.

Asperger H; tr. and annot. Frith U [1944] (1991). Autistic psychopathy' in childhood. In Frith U: *Autism and Asperger syndrome*. *Cambridge University Press, 37–92*.

Barton, J. J. S., Cherkasova, M. V., Hefter, R., Cox, T. A., O'Connor, M. & Manoach, D. S. (2004). Are patients with social developmental disorders prosopagnosic? Perceptual heterogeneity in the Asperger and socio-emotional processing disorders. *Brain, 127 (8), 1706-1716.*

Bookhemier, S. Y., Wang, A. T., Scott, A., Sigman, M. & Dapretto M. (2008). Frontal contributions to face processing differences in autism: Evidence from fMRI of inverted face processing. *Journal of the International Neuropsychological Society, 14, 922–932*.

Danielsson, H. (2006). *Facing the Illusion Piece by Piece: Face recognition for persons with learning disability*. PhD thesis. Linköping, Sweden: UniTryck.

Falkmer, M., Larsson, M., Bjällmark, A., Falkmer, T. (2010). The importance of the eye area in face identification abilities and visual search strategies in persons with Asperger syndrome. *Research in Autism Spectrum Disorders*, *4 (4), 724-730*.

Falkmer, M., Bjällmark, A., Larsson, M., Falkmer, T. (2011). Recognition of facially expressed emotions and visual search strategies in adults with Asperger syndrome. *Research in Autism Spectrum Disorders, 5 (1), 210-217*.

Ghaziuddin, M., Weidmer-Mikhail, E. & Ghaziuddin, N. (1998) Comorbidity of Asperger syndrome: a preliminary report. *Journal of Intellectual Disability Research*, *42*, *279– 283*.

Ghaziuddin, M. (2010). Brief Report: Should the DSM V Drop Asperger Syndrome? *Journal of Autism and Developmental Disorders*, *40*, *1146–1148*.

Ghaziuddin, M. (2008). Defining the Behavioral Phenotype of Asperger Syndrome. *Journal of Autism and Developmental Disorders*, *38*, *138–142*.

Hadjikhani, N., Joseph, R. M., Snyder, J., Chabris, C. F., Clark, J. & Steele, S. (2004). Activation of the fusiform gyrus when individuals with autism spectrum disorder view faces. *Neuroimage*, *22 (3)*, *1141–1150*.

Happe, F., Ehlers, S., Fletcher, P., Frith, U., Johansson, M., Gillberg, C., Dolan, R., Frackowiak, R. & Frith, C. (1996). Theory of mind in the brain. Evidence from a PET scan study of Asperger syndrome. *Neuroreport*, *8*, *197–201*.

Hole, G. J., George, P. A., Eaves, K. & Rasek, A. (2002). Effects of geometric distortions on face-recognition performance. *Perception*, *31*, *1221 – 1240*.

Jemel, B., Mottron, L. & Dawson, M. (2006). Impaired Face Processing in Autism: Fact or Artifact? *Journal of Autism and Developmental Disorders*, *36 (1)*.

Klin, A., Pauls, D., Schultz, R. & Volkmar, F. (2005). Three Diagnostic Approaches to Asperger Syndrome: Implications for Research. *Journal of Autism and Developmental Disorders*, *35 (2)*.

Kamp-Becker, I., Smidt, J., Ghahreman, M., Heinzel-Gutenbrunner, M., Becker, K. & Remschmidt, H. (2010). Categorical and Dimensional Structure of Autism Spectrum Disorders: The Nosologic Validity of Asperger Syndrome. *Journal of Autism and Developmental Disorders*, *40, 921–929*.

Kwon, H., Ow, A., Pedatella, K., Lotspeich, L. & Reiss, A. (2004). *Voxel-based morphometry elucidates structural neuroanatomy of high-functioning autism and Asperger syndrome*. *Developmental Medicine & Child Neurology*, *46*, *760–764*.

Lander, K. & Chuang, L. (2005). Why are moving faces easier to recognize? *Visual Cognition*, *12*, *429–442*.

Leopold, D. A. & Rhodes, G. (2010). A comparative View of Face perception. *Journal of Comparative Psychology*, *124 (3)*, *233-51*.

McPartland, J., Webb, S., Keehn, B. & Dawson, G. (2010). Patterns of visual attention to faces and objects in autism spectrum disorder. *Journal of Autism and Developmental Disorders*, *41 (2)*, *148-157*.

Nakahachi, T., Yamashita, K., Iwase, M., Ishigami, W., Tanaka, C., Toyonaga, K., Maeda, S., Hirotsune, H., Tei, Y., Yokoi, K., Okajima, S., Shimizu, A. & Takeda, M. (2008). Disturbed holistic processing in autism spectrum disorders verified by two cognitive tasks requiring perception of complex visual stimuli. *Psychiatry Research*, *159*, *330–338*.

Posner, M.I. (1980). Orienting of attention. *Quarterly Journal of Experimental Psychology*, *32*, *2-25*.

Ring, H., Woodbury-Smith, M., Watson, P., Wheelwright, S. & Baron-Cohen, S. (2008). Clinical heterogeneity among people with high functioning autism spectrum conditions: evidence favouring a continuous severity gradient. *Behavioral and Brain Functions*, *4*, *11*.

Rondan, C. & Deruelle, C. (2007). Global and configural visual processing in adults with autism and Asperger syndrome. *Research in Developmental Disabilities*, *28*, *197–206*.

Sadr, J., Jarudi, I. & Sinha, P. (2003). The role of eyebrows in face recognition. *Perception*, *32*, *285-293*.

Schultz, R.T., Gauthier, I., Klin, A., Fulbright, R. K., Anderson, A. W., Volkmar, F., Skudlarski, P., Lacadie, C., Cohen, D. J. & Gore, J. C. (2000). Abnormal ventral temporal cortical activity during face discrimination among individuals with autism and Asperger syndrome. *Archives of General Psychiatry*, *57*, *331–340*.

Schultz, R. T., Grelotti, D. J., Klin, A., Kleinman, J., Van der Gaag, C., Marois, R. & Skudlarski, P. (2003). The role of the fusiform face area in social cognition: implications for the pathobiology of autism. *Philosophical transactions of the Royal Society of London*, *Series B*, *Biological sciences*, *358*, *415–427*.

Trepagnier, C., Sebrechts, M. M. & Peterson, R. (2002). Atypical Face Gaze in Autism. *CyberPsychology & Behavior*, *5 (3)*, *213-217*.

Underwood, G. & Everatt, J. (1992). The Role of Eye Movements in Reading: Some Limitations of the Eye-Mind Assumption. *Advances in Psychology*, *88*, *111-169*.

Welchew, D. E., Ashwin, C., Berkouk, K., Salvador, R., Suckling, J., Baron-Cohen, S. & Bullmore, E. (2005). Functional disconnectivity of the medial temporal lobe in Asperger's syndrome. *Biological Psychiatry*, *57*, *991–998*.

Wing, L. (1981). Asperger's syndrome: a clinical account. *Psychological Medicine*, *11(1)*, *115–29*.

Woodbury-Smith, M. R. & Volkmar, F. R. (2009). Asperger syndrome. *European Child & Adolescent Psychiatry*, *18*, *2–11*.

Yarbus, A. L. (1967). *Eye Movements and Vision*. New York: Plenum Press

Yin, R. K. (1970). Face recognition by brain-injured patients: a dissociable ability? *Neuropsychologia*, *8*, *395-402*.

Yip, A. & Sinha, P. (2002). Role of color in face recognition. *Perception*, *31*, *995-1003*.

Young, A. W., Hellawell, D. & Hay, D. C. (1987). Configurational information in face perception. *Perception*, *16(6)*, *747–759*.