Institute of Behavioural Sciences
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LINGUISTIC AND PERCEPTUAL PROCESSING OF COMMUNICATIVE CUES IN ASPERGER SYNDROME

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ABSTRACT

Asperger Syndrome (AS) belongs to autism spectrum disorders where both verbal and non-verbal communication difficulties are at the core of the impairment. Social communication requires a complex use of affective, linguistic-cognitive and perceptual processes. In the four studies included in the current thesis, some of the linguistic and perceptual factors that are important for face-to-face communication were studied using behavioural methods. In all four studies the results obtained from individuals with AS were compared with typically developed age, gender and IQ matched controls.

First, the language skills of school-aged children were characterized in detail with standardized tests that measured different aspects of receptive and expressive language (Study I). The children with AS were found to be worse than the controls in following complex verbal instructions. Next, the visual perception of facial expressions of emotion with varying degrees of visual detail was examined (Study II). Adults with AS were found to have impaired recognition of facial expressions on the basis of very low spatial frequencies which are important for processing global information. Following that, multisensory perception was investigated by looking at audiovisual speech perception (Studies III and IV). Adults with AS were found to perceive audiovisual speech qualitatively differently from typically developed adults, although both groups were equally accurate in recognizing auditory and visual speech presented alone. Finally, the effect of attention on audiovisual speech perception was studied by registering eye gaze behaviour (Study III) and by studying the voluntary control of visual attention (Study IV). The groups did not differ in eye gaze behaviour or in the voluntary control of visual attention.

The results of the study series demonstrate that many factors underpinning face-to-face social communication are atypical in AS. In contrast with previous assumptions about intact language abilities, the current results show that children with AS have difficulties in understanding complex verbal instructions. Furthermore, the study makes clear that deviations in the perception of global features in faces expressing emotions as well as in the multisensory perception of speech are likely to harm face-to-face social communication.

TIIVISTELMÄ

Aspergerin oireyhtymä (Asperger Syndrome, AS) on yksi autismin kirjon häiriöistä. Siihen kuuluu oleellisena osana vaikeudet kielellisessä ja ei-kielellisessä kommunikaatiossa. Sosiaalinen kommunikaatio edellyttää kielellis-kognitiivisten ja havaintoprosessien monimutkaista yhteistoimintaa. Tämän väitöskirjan neljässä osatutkimuksessa tutkittiin kasvotusten tapahtuvalle sosiaaliselle kommunikaatiolle tärkeitä kielellisiä ja havaitsemiseen liittyviä prosesseja behavioraalisin menetelmin. Kaikissa osatutkimuksissa koeryhmään kuuluvien AS-henkilöiden suoriutumista verrattiin iän, sukupuolen ja älykkyysosamäärän mukaan samankaltaisen verrokkiryhmän suoriutumiseen.

Ensimmäisessä tutkimuksessa selvitettiin kielellisiä taitoja kouluiässä (Osatutkimus I). Lapset, joilla on AS, suoriutuivat verrokkeja heikommin monimutkaisten sanallisten ohjeiden noudattamisesta. Tämän jälkeen tutkittiin kasvojen ilmeiden tunnistamista aikuisilla (Osatutkimus II). Aikuisilla, joilla on AS, oli vaikeuksia kasvonilmeiden tunnistamisessa kokonaisuuksien hahmottamisen perusteella eli silloin, kun kuvissa oli käytettävissä vain matalia paikkataajuuksia. Lisäksi selvitettiin moniaistista havaitsemista aikuisilla tutkimalla kuullun ja nähdyn (audiovisuaalisen) puheen havaitsemista (Osatutkimus III). Aikuiset, joilla on AS, havaitsivat audiovisuaalista puhetta laadullisesti eri tavalla, vaikka tunnistivat puhetta yhtä hyvin kuullunvaraisesti ja olivat yhtä hyviä huulilta lukijoita kuin verrokit. Lisäksi selvitettiin tarkkaavaisuuden vaikutusta puheen audiovisuaaliseen havaitsemiseen: tarkastelemalla poikkeavatko tämän ryhmän silmänliikkeet (Osatutkimus III) ja tarkkaavaisuuden tahdonalainen suuntaaminen puheen havaitsemisen aikana (Osatutkimus IV) verrokkien vastaavista toiminnoista. Sekä silmänliikkeet että tarkkaavaisuuden tahdonalainen suuntaaminen olivat samankaltaisia molemmilla ryhmillä.

Tutkimussarjan tulokset osoittivat että monet kasvotusten tapahtuvalle kommunikaatiolle tärkeät taustatekijät toimivat poikkeavasti Aspergerin oireyhtymässä. Aiemmasta käsityksestä poiketen, tämän tutkimuksen mukaan oireyhtymään voi kuulua vaikeutta monimutkaisten sanallisten ohjeiden ymmärtämisessä. Lisäksi heikompi kasvonilmeiden tunnistaminen kokonaisuuksien hahmottamisen perusteella sekä laadullisesti erilainen moniaistinen havaitseminen todennäköisesti vaikeuttavat kasvokkain tapahtuvaa kommunikaatiota.

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Helsinki February 2012 Satu Saalasti

CONTENTS

LIST OF ORIGINAL PUBLICATIONS

I Saalasti, S., Lepistö, T., Kujala, T., Laakso, M., Toppila, E., Nieminen-von Wendt, T., von Wendt, L. & Jansson-Verkasalo, E. (2008). Language Abilities of Children with Asperger Syndrome. Journal of Autism and Developmental Disorders, 38(8),1574-80.

II Kätsyri, J., Saalasti, S., Tiippana, K., von Wendt, L. & Sams, M. (2008). Impaired recognition of facial emotions from low-spatial frequencies in Asperger syndrome. Neuropsychologia, 46, 1888-1897.

III Saalasti, S., Kätsyri, J., Tiippana, K., Laine-Hernandez, M., von Wendt, L., Sams, M. (2011). Audiovisual Speech Perception and Eye Gaze Behavior of Adults with Asperger syndrome, Journal of Autism and Developmental Disorders, DOI 10.1007/s10803-011-1400-0.

IV Saalasti, S., Tiippana, K., Kätsyri, J. & Sams, M. (2011). The effect of visual spatial attention on audiovisual speech perception in adults with Asperger syndrome. Experimental Brain Research, 213(2-3), 283-90.

1. INTRODUCTION

1.1. ASPERGER SYNDROME IN THE AUTISM SPECTRUM DISORDERS

Asperger Syndrome (AS) is a lifelong disorder of neurobiological origin belonging to the autism spectrum disorders (ASD) (Hill & Frith, 2003; Volkmar & Klin, 2000; Wing, 1981). The impairments of ASD manifest in three domains: social behavior, non-verbal and verbal communication, and stereotyped, repetitive or ritualistic behavior (ICD-10, WHO, 1993; DSM-IV, American Psychiatric Association (APA), 1994) (Table 1). In AS cognitive development is within normal range, but the development of social interaction and play is affected. The use of eye contact in interaction is atypical and forming appropriate relationships with peers is difficult. Repetitive behavior is evident in inappropriate routines and a preoccupation with special interests. Furthermore, there is a marked qualitative impairment in communication. Thus, the core impairments of ASD are present in AS but without significant delay in language or other cognitive development. Furthermore, in ICD-10 (WHO, 1993) clumsiness has been acknowledged as a common additional feature, but it is not required for diagnosis. Outside the diagnostic criteria, abnormal processing of sensory information is commonly reported in AS, as is the case with other ASDs and has even been suggested that it be incorporated in the diagnostic criteria (Minshew & Hobson, 2008; Nieminen-von Wendt et al., 2005).

The differentiation of individuals with AS from high-functioning individuals with autism (HFA) has proved to be challenging (Lord et al., 2000; Volkmar, & Klin, 2000), and in some reports, the existence of a separate Asperger syndrome has been questioned (Howlin, 2003; Ozonoff, South, & Miller, 2000). In this respect, the new revision of diagnostic taxonomy, DSM-V, (APA, 2011 (see also Lord et al., 2000) will aim to clarify the situation by subsuming AS into the category of autism spectrum disorders together with HFA. Thus, autistic impairments are seen to represent a spectrum rather than different categories. Accordingly, in this thesis, the term ASD will be used as an umbrella term for all autistic impairments, and the severity the disorder will be defined separately. The focus of the current thesis is the high-functioning end of the spectrum and specifically Asperger Syndrome.

Table 1. DSM-IV/ICD-10 Diagnostic criteria for autism and Asperger Syndrome (adapted from Lord et al. 2000)

	Autism	Asperger syndrome
Age of onset	Delays or abnormal functioning in social interaction, language, and/or play by age 3.	No clinically significant delay in language, cognitive development, or development of age appropriate self-help skills, adaptive behaviour, and curiosity about the environment in childhood.
Social Interaction	Qualitative impairment in social interaction, as manifested by at least two of the following:* a) marked impairment in the use of multiple nonverbal behaviours, i.e., eye-to-eye gaze; b) failure to develop peer relationships appropriate to developmental level; c) lack of spontaneous seeking to share enjoyment with other people; d) lack of social or emotional reciprocity.	Same as autism.
Communication	Qualitative impairments in communication as manifested by at least one of the following: a) delay in, or total lack of, the development of spoken language; b) marked impairment in initiating or sustaining a conversation with others, in individuals with adequate speech; c) stereotyped and repetitive use of language or idiosyncratic language; d) lack of varied, spontaneous make-believe or imitative play.	No clinically significant general delay in language.
Behaviour	Restricted, repetitive, and stereotyped patterns of behaviour, as manifested by at least one of the following: a) preoccupation with one or more stereotyped or restricted patterns of interest; b) adherence to non-functional routines or rituals; c) stereotyped and repetitive motor mannerisms; d) persistent preoccupation with parts of objects.	Same as autism

*A total of six or more items are required for diagnosis.

The number of individuals diagnosed with ASD has grown in the past 10 years and has raised concern. According to a recent epidemiological study in Finland, the ASD affects around 0.84 percent of the population with AS affecting around 0.29 percent of individuals (Mattila et al., 2011). The cause of the increased number of diagnosed individuals is not known, but it has been suggested that one factor could be the better recognition of milder forms of ASD, such as AS and high-functioning individuals with autism (HFA). The cause of ASD is yet to be identified, but it is a multifactorial, hereditary disorder whose genetic factors are under investigation (e.g. Bailey et al., 1995; for a review see Freitag, 2007). Considering the heterogenous nature of ASD, it is possible that no single explanation will be found; it is more likely that several different interacting mechanisms with different neural origins will be identified. Moreover, current advances in neurophysiological studies provide a better opportunity to make direct links between brain functions and behavioral symptoms. In particular, social interaction and communication share similar behavioural and neurophysiological factors. However, it is possible that several atypical brain functions may manifest in similar behavioral features. The suggestion made by Happé, Ronald and Plomin (2006) seems well advised: the causes and cures for ASD should not be searched for as a whole; rather the three domains of the disorder should be fractioned and studied separately. The current thesis attempts to find some of the factors underpinning the qualitative impairment in social communication in AS. More specifically, it focuses on processing of linguistic and perceptual cues important for fluent communication.

1.2. COMMUNICATION IMPAIRMENT IN ASPERGER SYNDROME

Communication is the conscious exchange of messages conveying thoughts, information, needs and emotions, and it may be linguistic (spoken and written language) or non-linguistic (emotions, gestures). Good communicative competence in social interaction involves the complex interaction of linguistic, cognitive and sensorimotor factors (Loukusa, 2007; Martin, 2003; Perkins, 2005). The typical features of poor communicative competence in AS include difficulty in appropriately adjusting speech style to the interpersonal social context (Landa, 2000; Volkmar, & Klin, 2000), the idiosyncratic expression of intentions (Paul, Orlovski, Marcinko, & Volkmar, 2009) and the atypical use of non-linguistic and linguistic strategies for requests. Furthermore, the use of eye contact is not coordinated and does not reflect joint attention, which is elementary for language development (Tomasello & Farrar, 1986). In conversation, individuals with AS have difficulties in providing the correct amount and type of information and/or considering the other person's perspective. Individuals with AS have difficulty in managing topics and turns (discourse management), and reciprocal social behavior is also limited. Constant failure in communication is a major cause of anxiety and can increase the tendency for withdrawal (Attwood, 1998; Lord et al., 2000; Paul, Landa, & Schoen, 2000). Therefore, it would be important to identify the factors behind the qualitative impairment of communication.

Traditionally, the communication impairment in ASD has been explained as a general impairment of social interaction and has been conceptualized in the neurocognitive models of *Theory of mind (ToM) deficit* and the *Mindblindness* (both referred to as impaired mentalizing ability) (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen, Leslie, & Frith, 1985; Frith & Frith, 2006; Hill & Frith, 2003). According to these accounts, predicting and explaining other people's behavior is difficult in AS because the ability to understand other people's mental states is poor. As a result, skills that stem from TOM abilities, such as understanding beliefs, pretence, irony and non-literal language, are uncertain, and this affects conversational behaviour (Baron-Cohen, 2001; Hill & Frith, 2003). Neurocognitive theories other than those that concentrate on the level of social cognition have also contributed to understanding of the background of communication impairments. *Executive dysfunction* may indirectly contribute to impairments in communication, although it has traditionally been thought to offer an explanation for the rigidity and perseveration of behavior in ASD (Hill, 2004; Russell, Jarrold, & Hood, 1999). Executive control (planning, initiating, monitoring of an action and inhibiting irrelevant behaviour) is even needed in some tasks that are a measure of the impairments of the theory of mind ability (Leslie, Friedman, & German, 2004). Increasingly, it has been suggested that the underlying source of social interaction and communication impairments involves atypical perceptual processing. Indeed, even the first descriptions of both autism and AS mentioned peculiar and impaired processing of sensory signals (i.e. visual, auditory, tactile and gustatory percepts) from the environment (Kanner, 1943; Asperger, 1944; Wing, 1981). In addition, the difficulties individuals with ASD have in processing sensory signals come to light through by clinical experience and the autobiographies (Attwood, 1998; Williams, 1994, Grandin, 1992) and they have been recently confirmed in a study combining self questionnaire and neuropsychological profiles (Minshew & Hobson, 2008). It seems logical that if the perception of sensory signals from the environment is different, it will also affect the development of social and communicative behaviour. The perceptual differences in ASD are the focus of the neurocognitive models of w*eak central coherence* and *enhanced perceptual functioning*. While these models have a slightly different emphasis, they both suggest that individuals with ASD have a tendency to process the elementary physical elements of a stimulus, which leads to impairment in perceiving its global features (Happé & Frith, 2006; Mottron, Dawson, Soulières, Hubert, & Burack, 2006). For the sake of clarity, both models will be referred to as the extended weak central coherence model in the current thesis. Atypical perception of the environment would affect how communicative signals from an interlocutor are perceived. Thus, the atypical development of communication abilities in individuals with ASD could stem not only from the social or linguistic factors but also, at a more basic level, from atypical perception of communicative information. In fact, to fully understand the message conveyed by a conversational partner, the linguistic content has to be integrated with relevant non-linguistic communicative cues (intonational cues, shared experiences, setting, body language) (Perkins, 2005). Therefore, both linguistic and non-linguistic communicative cues are important for good communicative competence.

1.2.1. LINGUISTIC ABILITIES

Despite their good cognitive abilities and the presence of the exclusion criteria for AS of "no clinically significant delay in language" development, individuals with AS have the qualitative difficulties in linguistic communication typical of the autistic spectrum (Klin et al., 2007; Paul, Landa, & Schoen, 2000). Linguistic abilities are self evidently relevant for good communicative competence, as language is the main means of communication in humans. There is no consensus on whether language abilities in AS can be considered normal, and there seems to be a discrepancy between the diagnostic taxonomies and clinical experience (Klin et al., 2000). As Attwood (1998) points out, the diagnostic criteria should not be interpreted as an absence of any peculiarities in language abilities. While some findings show that basic formal language abilities, such as semantics (word meaning), phonology (producing sounds), syntax and morphology (sentence structure) are considered to develop according to the normal developmental milestones (Klin, Volkmar, & Sparrow, 2000; Paul, Landa, & Schoen, 2000; Tager-Flusberg, Paul, & Lord, 2002), it has been suggested, however, that language comprehension and production are similarly impaired in adulthood in AS and in HFA (Howlin, 2003). This would suggest impaired language development in childhood. Furthermore, some difficulties concerning language abilities have been repeatedly reported, including the overly literal interpretation of utterances, which leads to difficulties in understanding idioms, humor, metaphors and irony (Happè, 1993; Kerbel & Grunwell, 1998; Kjelgaard & Tager-Flusberg, 2001; Ozonoff & Miller, 1996; Rapin, 2003) and substantial difficulties in the production and comprehension of speech prosody, especially when conveying emotional messages (vocal quality, intonation and stress patterns) (Koning & Magill-Evans, 2001; Korpilahti et al., 2007, 2009; Shriberg et al., 2001). In addition, controlling the rate and rhythm of speech production is atypical, and residual speech distortion errors are more prevalent in AS than in typically developed individuals (Ozonoff & Miller, 1996; Shriberg et al., 2001; Volkmar and Klin, 2000). Nevertheless, their speech is often syntactically hyper-correct and this makes it atypical for their chronological age (Attwood, 1998; Ghaziuddin & Gerstein, 1996; Ghaziuddin et al., 2000; Rapin, 2003). In light of these findings, there is a need to characterize the language abilities of children with AS in detail.

1.2.2. PERCEPTUAL PROCESSING OF COMMUNICATIVE CUES IN FACE-TO-FACE COMMUNICATION

Considering the reports of atypical sensory processing in AS, deficiencies in the perceptual processes relevant for communication may contribute to qualitative impairments in communication (Dakin & Frith, 2005; Iarocci & McDonald, 2006; Minshew & Hobson, 2008). The difficulties may arise from different stages of perception: sensory stimuli are first encoded at low level and then these percepts are recognized as meaningful entities at higher level. It has been suggested that individuals with AS have a strong bias towards processing low-level sensory stimuli at the expense of holistic and meaningful concepts (for a review see Hill & Frith, 2003). The face mediates the most important communicative cues – speech and facial expressions – therefore, the perceptual processes relevant for face-to-face communication are the focus in this thesis. Clearly, here the key perceptual processes are vision (facial expressions and visual speech) and hearing (auditory speech).

1.2.2.1. Recognition of the facial expressions of emotion

We get important information both on the state of another person's mind and their level of engagement in the conversation by monitoring their facial expressions. In fact, inferences about the preceding context and the expresser's cognitive processes, and his physical state and actions can all be made from facial expressions (Ekman, 1982; Kohler et al., 2004). Therefore, in the current thesis, the focus is namely on the recognition of basic emotions from facial expressions.

Basic emotions (anger, disgust, fear, happiness, sadness and according to some interpretations also content) are clear, universal physiological reactions to external stimuli, whereas more complex social stimuli reflect the complexity of understanding another person's mental state (Ekman, 1997). Some studies of individuals with ASD have suggested poor recognition of basic emotions (Adolphs, Sears, & Piven, 2001; Ashwin, Chapman, Colle, & Baron-Cohen, 2006; Boraston, Blakemore, Chilvers, & Skuse, 2007; Dziobek, Fleck, Rogers,Wolf, & Convit, 2006; Humphreys, Minshew, Leonard, & Behrmann, 2007), but as of yet there is no consensus on the matter.

Some other studies have suggested that individuals with AS have deficits only in the recognition of more complex mental states from emotional displays (Adolphs et al., 2001; Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997; Baron-Cohen, Wheelwright, Hill, Raste, & Plumb, 2001; Baron-Cohen, Wheelwright, & Jolliffe, 1997; Golan, Baron-Cohen, & Hill, 2006). Furthermore, ASD seems to involve the superior processing of single facial features because individuals with ASD are less impaired than typically developed individuals by procedures that disrupt the configural processing of faces, such as face inversion (Hobson, Ouston, & Lee, 1988) or misalignment of face parts (Teunnisse & de Gelder, 2003). It is not known how the weakness in processing global features affects the perception of information from the face in adults with AS (Happé & Frith, 2006). In addition, prosopagnosia, i.e. the impairment in recognizing identity from a face, has a higher prevalence in AS (Barton et al., 2004; Behrmann, & Humphreys, 2006; Nieminen-von Wendt et al., 2005). Although, recognition of facial identity is thought to be separate from the processing of other facial information (Bruce & Young, 1986; Hefter, Manoach, & Barton, 2005), it is not known if prosopagnosia affects the processing of global features from the face.

1.2.2.2. Multisensory perception of speech

The integration of information from multiple sensory modalities (multisensory integration) is a key perceptual process that leads to enhanced perception and facilitated responses to objects in the natural environment (Iarocci & McDonald, 2006). It may well be that the integration and organization of different perceptual processes contributes to the perceptual atypicalities relevant for communication in ASD (Iarocci & McDonald, 2006). It has been suggested that sensory integration problems partly explain the atypical sensory experiences reported in the autobiographies of high functioning individuals with ASD (e.g. Grandin, 1992; Williams, 1994; Attwood, 1998). This has even resulted in the development of specific intervention methods for sensory integration (Ayeres, 1979). However, there have still been relatively few empirical studies on multisensory processing in ASD as Molholm and Foxe (2005) and Iarocci and McDonald (2006) point out.

By nature, speech is a multisensory phenomenon: it is audiovisual, as both the speaker's voice and face give information of articulation. Seeing articulatory lip movements improves speech recognition, especially under noisy conditions as was originally reported already by Sumby and Pollack (1954). Neurophysiological studies of typically developed individuals have indicated that even infants benefit from visual speech in language development (Kuhl & Meltzoff, 1982; Teinonen, Aslin, Alku, & Csibra, 2008).

The interaction of auditory and visual speech is demonstrated in the so called "McGurk effect" (McGurk & MacDonald, 1976; MacDonald & McGurk, 1978), where discrepant visual speech alters auditory speech perception. In the original study, a voice saying /ba/ was presented with a face articulating /ga/, which resulted in the participants hearing /da/, a fusion of the audio and visual components, or, on the basis of the visual component, as /ga/. The responses reflected the influence of vision on auditory speech perception and are also commonly considered to reflect audiovisual integration. Hence, the fewer responses according to the audio component of the incongruent stimulus an individual gives, the stronger the McGurk effect, and thus audiovisual integration. Due to the different response options, it is important to analyze what the participants actually respond due to the described different possible outcomes.

The McGurk effect has already been applied to the study of audiovisual speech perception in ASD. Both impaired (Mongillo et al., 2008; De Gelder, Vroomen, & van der Heide, 1991) and intact (Massaro & Bosseler, 2003; Williams, Massaro, Peel, Bosseler, & Suddendorf, 2004) audiovisual integration in children with autism has been reported. In the latter studies, it is argued that the differences in audiovisual speech perception are simply due to poorer lip-reading1 ability that causes the influence of the visual component to be weaker in ASD. In adulthood, high-functioning individuals with ASD have not been found to differ from controls in the strength of the McGurk effect (Keane, Rosenthal, Chun, & Shams, 2010). There are no previous studies specifically on audiovisual speech perception in AS.

1.2.2.3. The effect of attention on perception

Attentional mechanisms ensure that we perceive the relevant information from the environment. For functional perception, we have to selectively attend – either spontaneously or consciously – to relevant information and ignore distracting information (for a review see Lachter, Forster, & Ruthruff, 2004). The focus of attention may be maintained on one target or shifted from one target to another when needed. The attended space or the number of attended stimuli may be broadened or narrowed to enhance the processing of the stimuli. Furthermore, attention may be cued, that is directed, to a particular location (by either exogenous or endogenous cues) (Posner, 1980). Interestingly, attentional difficulties are overrepresented in ASD and could affect the perception of communicatively relevant information.

Both the intensive focusing of attention on things of special interest coupled

1 In the current study the term lip-reading is used to refer to visual speech recognition. However, it should be noted that, increasingly, the term speech- reading is used because it describes the involvement of wider movement around the lips more accurately.

with slow change in the focus of attention and, in contrast, high distractibility have been reported in ASD (for a review see Ames & Fletcher-Watson, 2010). Therefore, it is likely that some aspects of attentional control are intact in ASD but others are affected. The focus of visual attention is not always revealed in gaze fixation strategies. Previous findings have suggested differences in gaze fixation patterns to the face between individuals with ASD and typically developed individuals when viewing still images of emotional facial expressions (Dalton et al., 2005; Neumann, Spezio, Piven, & Adolphs, 2006; Pelphrey et al., 2002) or when viewing videos of socially complex situations (Klin, Jones, Schultz, Volkmar, & Cohen, 2002) . Individuals with ASD tend to focus more on the non-salient features of faces than on the mouth, nose and eyes when freely viewing photographs of human faces (Pelphrey et al., 2002). Furthermore, individuals with ASD spontaneously fixate more on the mouth than the eyes, when judging emotions from still photos and when viewing videos of complex social situations (Klin et al., 2002; Pelphrey et al., 2002). There is little available knowledge of eye gaze behaviour and its effects on speech perception in ASD when viewing a talking face (Irwin, 2007).

Directing of visual attention can be controlled and it is possible to selectively attend to a location other than where our eyes are fixated i.e. when following a specific instruction (Posner, 1980). Previous studies have found that individuals with ASD have difficulties when they are required to selectively attend to one stimulus among many competing stimuli (Burack, 1994). Because they have a larger perceptual capacity, they tend to process distracting stimuli as well as the target item, and this results in higher distractability (Remington, Swettenham, Campbell, & Coleman, 2009). According to recent imaging studies this might be related namely to socially relevant visual signals as adults with ASD showed no attentional modulation for social (faces) stimuli although attentional modulation for non-social (houses) stimuli was similar with control participants. In situations where there are multiple simultaneous communication partners, the ability to focus attention spatially towards one speaker is essential for successful conversation (Bird, Catmur, Silani, Frith, & Frith, 2006). Individuals with AS often express difficulties in situations with multiple talkers (Grandin, 1992; Williams, 1992; Attwood, 1998) , and this could be due to inefficiency in selectively attending to one talker and directing visual spatial attention.

1.3. SUMMARY

Individuals with AS have qualitative impairments in social communication, but the causal mechanisms behind of these impairments are not yet fully understood. There is controversy over the language abilities of individuals with AS and how much this contributes to atypical communication. Furthermore, differences in perception may contribute to atypical communication. In particular, visual perception of emotional cues from the face and multisensory perception of speech might contribute to the atypical processing of communicatively relevant cues in face-to-face communication. Moreover, attention to the face and voluntary control of attention is necessary for perception of the relevant communicative cues. Thus, the current thesis focuses on the linguistic and perceptual processing of communicative cues in AS.

2. AIMS OF THE STUDIES

Study I aimed to provide a detailed exploration of the language abilities of children with AS. To this end, the expressive and receptive language abilities of school-aged children with AS were tested with standardized tests. The hypothesis was that children with AS would perform poorer in subtests measuring receptive language abilities.

Study II aimed to find out whether individuals with AS would have more difficulties in recognizing facial emotions on the basis of global facial features. The recognition of basic facial emotions was tested using static and dynamic images by varying the amount of visual detail in the images. The hypothesis was that adults with AS would have more difficulty in recognizing an emotion when the amount of visual detail was low, as they would have to rely more on global processing.

Study III aimed to discover whether individuals with AS perceived multisensory signals differently. The McGurk effect was used as a tool to investigate the audiovisual perception of speech. The hypothesis was that adult individuals with AS would show weaker McGurk effect, and this would be manifested in giving more responses according to the auditory stimuli. Furthermore, eye gaze behavior was registered during speech perception, and the hypothesis was that individuals with AS would gaze more at mouth and less at eyes.

Study IV aimed to reveal whether adult individuals with AS had difficulty in attending to communicatively relevant information in the presence of distracting information. In order to study this, we investigated the effect of a distractor face on audiovisual speech perception. The hypothesis was that individuals with AS would be more distracted than typically developed controls by a distractor face when attending to a target face.

3. STUDIES

DIAGNOSTICS AND ETHICAL CONSIDERATIONS

In all the studies, the participants in the AS groups were recruited from Helsinki University Central Hospital (HUCH) and from Helsinki Asperger Center at Dextra, a private medical center. AS was clinically diagnosed according to the ICD-10 (WHO, 1993) and DSM IV (American Psychiatric Association (APA), 1994) diagnostic criteria by multidisciplinary teams of professionals (a child neurologist, neuropsychologist and registered nurse). Methods such as the Autism Spectrum Screening Questionnaire (ASSQ, Ehlers et al., 1999), the Autism Diagnostic Interview-Revised (ADI-R, Lord et al., 1994) and the Autism Diagnostic Observation Schedule (ADOS) (Lord et al., 2000) were used to characterize the participants' behavior. Diagnoses were confirmed only after agreement within the diagnostic group.

In Study I the participants were children, but in Studies II, III and IV the participants were adults (Table 2). There is still little knowledge of the developmental factors that affect the on perceptual processes investigated in these studies; i.e. the maturation of the McGurk effect is not fully understood. Therefore, in order to minimize the importance of developmental considerations, the studies were conducted with adults.

In all the studies, the results were compared with matched controls who had a history of typical development (confirmed with a questionnaire) and no diagnostic conditions. A questionnaire was used to rule out a diagnosis of AS (in all studies ASSQ, Ehlers et. al.1999) or attention disorder (Study III and IV, ARSv1) for the control participants.

All the studies were approved by the appropriate ethical committee of HUCH, and, additionally, Study I was approved by the ethical committee of the Department of Psychology, University of Helsinki. The Studies have therefore been performed in accordance with the ethical standards for human studies laid down in the 1964 Declaration of Helsinki. All the participants gave their written consent (in Study I the children's parents gave their consent) for taking part in the study.

Table 2. Demographic variables for the participants of the study series.

	N		Age		Gender (male/female)		VIQ		PIQ		FIQ	
	AS	Control	AS	Control	AS	Control	AS	Control	AS	Control	AS	Control
Study I	22	23	8.9 (0.9)	9.0 (0.7)	16 / 6	17 / 6	112 (17.3)	112 (12.9)	104 (17.1)	108 (12.7)	108 (13.5)	110 (10.4)
Study II	20	20	32 (10)	31 (8)	13 / 7	13 / 7	110 (11)	116 (8)	113 (16)	113 (16)	112 (13)	116 (11)
Study III and IV	16	16	32 (10)	32 (8)	13 / 3	13 / 3	111 (13)	118 (8)	114 (16)	114 (16)	113 (14)	118 (9)

3.1. STUDY I: THE LANGUAGE ABILITIES OF CHILDREN WITH ASPERGER SYNDROME

INTRODUCTION

The date, the language abilities of children with AS have been insuffieciently investigated. On the basis of clinical observations and the findings of studies on adults with AS and HFA (Howlin, 2003), it is to be expected that the language abilities of school aged children with AS differ from those of typically developed peers. In particular, the receptive language abilities (comprehension) of children with AS could be more impaired. Furthermore, on the basis of clinical findings and previous studies (Alcántara, Weisblatt, Moore, & Bolton, 2004), we expected the participants with AS to be more affected by background noise. Therefore, the hypothesis was that children with AS would perform worse than their matched controls in receptive subtests of language and their language comprehension would be more affected by background noise.

Table 3. Language tests used in Study I and the language abilities they measured.

TEST	LANGUAGE ABILITY
NEPSY	
(Finnish Developmental	Phonological processing
Neusopsychological	Comprehension of instructions
Evaluation)	Sentence comprehension
	Non-word repetition
	Fluency
	Sentence repetition
Boston naming test	Naming
Rapid automized naming	Speeded naming

PARTICIPANTS AND METHODS

The participants were 7–10 years of age (mean age 8.9 years) and consisted of 22 children with AS and 24 typically developed controls (Table 2.).

The language abilities of the participants were assessed with standardized tests commonly used in Finnish clinics for the diagnostic assessment of language and other cognitive abilities (Table 3). Both expressive (naming, speeded naming, fluency, non-word repetition, phonological processing) and receptive language abilities (comprehension of instructions, sentence comprehension) were measured. Furthermore, the effect of noise on speech comprehension was measured by adding two different sets of noise (the so called white and cafeteria noise) to the background of the subtest measuring sentence comprehension.

The tests were carried out at the Cognitive Brain Research Unit (CBRU, Institute of Behavioral Studies, University of Helsinki) by the author. The tests were videotaped for later inspection.

RESULTS AND DISCUSSION

The children with AS had more difficulties in the comprehension of the instructions subtest than their matched neurotypical controls ($p = .002$). Furthermore, the results revealed that the children with AS tended to perform worse in the phonological processing subtest ($p = .049$. In the other subtests there were no significant differences between the groups. Consequently, the children with AS performed similarly to the control participants in the subtests measuring fluency, naming, speeded naming, non-word repetition and sentence repetition. Furthermore, there were no differences between the groups in the effect of noise on sentence comprehension.

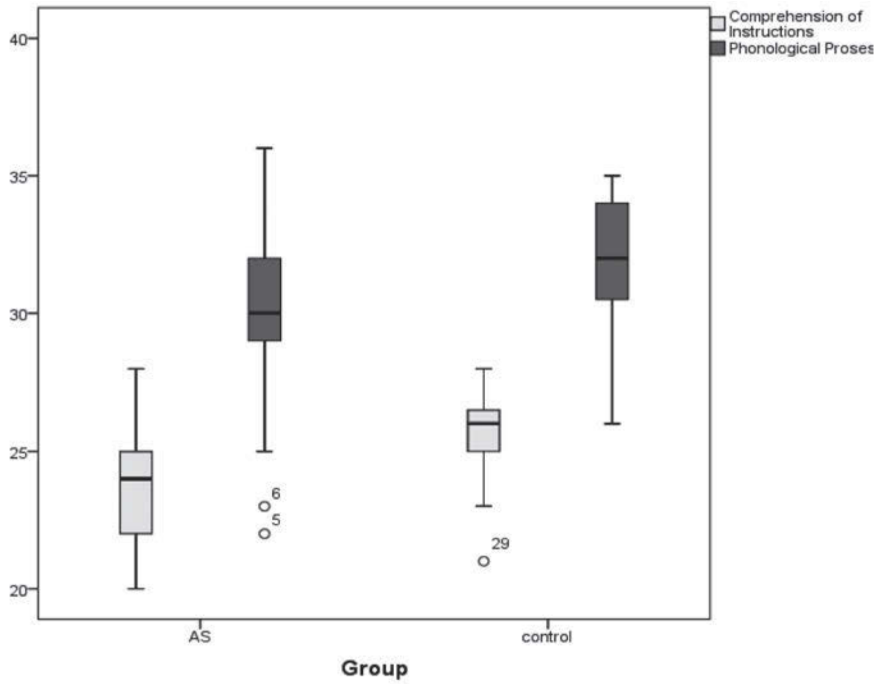

Figure 1. Box-and-Whisker plot graphs of differences between groups in the subtests of Comprehension of Instructions and Phonological Processing (results for the AS group on the left). The range of the scores is greater in the group of children with AS than in the control group in both subtests.

The results of the study showed that the children with AS had more difficulties in the comprehension of instructions than their typically developed controls (Fig. 1). It is the first study to demonstrate differences in receptive language abilities between children with AS and their typically developed peers. Therefore, the findings of the current study support the change towards a more dimensional, rather than categorical, diagnosis of autism spectrum disorders, and this is also the case in respect to the language abilities (Eisenmajer et al., 1996; Leekam, Wing, Gould, & Gillberg, 2000; Lord, Leventhal, & Cook, 2001). However, performance in comprehension of instructions varied greatly and there were children with AS who performed well in the task (Fig. 1). Therefore, not all children with AS necessarily comprehend instructions poorly, although at the group level this was indeed the case and the average was significantly lower in the AS group. Importantly, performing well in this particular subtest does not only require linguistic abilities: The children saw a sheet of paper with an array of different colored shapes, and they were then given instructions with increasing difficulty in which they were asked to point to the shapes (e.g. "Show me a green circle and the third figure from the second row"). Therefore, in addition to linguistic skills, the task also requires short term memory (keeping the verbal instruction in mind) and self-regulation, and planning and executing motor actions. Thus, the result can also reflect a dysfunction in executive functioning, which has previously been connected to ASD (Russell et al., 1999). The differences found in language abilities of school age children contribute to impairments in communication. Difficulty in comprehending verbal instructions may cause misunderstandings and lead to avoidance of conversation at school and home. It should be kept in mind that these children may have a wide vocabulary, fluent, expressive speech and a good command of syntax and yet have problems in comprehending instructions. In the future, it is important to use more linguistic tests to investigate receptive language abilities and have a control test measuring executive functions in detail. In addition, to impairments in speech comprehension the children with AS tended to be poorer than the controls in the subtest on phonological processing. This tendency suggests difficulties in decoding the phonological structure of a word and in articulation, which is related to difficulties in controlling the sequence of speech motor movements.

3.2. STUDY II: IMPAIRED RECOGNITION OF FACIAL EMOTIONS FROM LOW SPATIAL FREQUENCIES IN ASPERGER SYNDROME

INTRODUCTION

Previous studies have found enhanced processing of details in AS (weak central coherence and the enhanced local processing account), and this could lead to impaired global processing of facial features (Happe & Frith, 2006). Blurring the facial image would remove local facial features and thus, diminish the amount of visual information, but how this lessening of visual detail would affect the recognition of facial expressions in AS has not been previously studied. Furthermore, previous studies have mainly used static images, but in real life facial expressions are never static. Dynamic information might facilitate the processing of blurred facial expression. However, it is possible that this compensation is weaker for individuals with AS because of deficient processing of global biological motion found in ASD (Bertone, Mottron, Jelenic, & Faubert, 2003; Blake, Turner, Smoski, Pozdol, & Stone, 2003; Pellicano, Gibson, Maybery, Durkin, & Badcock, 2005). The hypothesis was that adults with AS would be as accurate as the controls at recognizing non-blurred basic emotion stimuli. However, it was expected that the recognition accuracy for blurred stimuli would be lower, because of the impaired global processing found in AS. [2]

PARTICIPANTS AND METHODS

The participants were 20 adults with AS (mean age 32) and their matched controls (Table 2). The participants with AS were further characterized by whether or not they had difficulties in face recognition (prosopagnosia), which was diagnosed using the Face Recognition task in the NEPSY (Developmental Neuropsychological Assessment) test battery (Korkman et al., 1997) in addition to the participants' subjective description of their difficulties. The participants were given the Toronto Alexithymia Scale which reflects the ability to find verbal and symbolic expressions of an experienced emotion (TAS-20, Finnish translation) (Parker, Bagby, Taylor, Endler & Schimtz 1993).

The recognition of four basic emotions (anger, disgust, fear, happiness) from static and dynamic (video sequences) displays of facial expression was studied. The stimuli were selected from the "TKK video sequence collection" (Kätsyri, 2006) of basic emotions. Low-pass filtering was used to blur the image and vary the amount of visual detail in the emotional displays. The stimuli were shown in three different filtering conditions: no filtering, slightly filtered and strongly filtered. The participants' task was to evaluate how well the emotions applied to each presented stimulus on a seven-step Likert scale.

RESULTS AND DISCUSSION

As a group, participants with AS had more difficulties than their controls in recognizing emotions from strongly blurred displays (when the local facial features were removed) ($p = 0.03$) (Fig. 2). However, this was not true for all individuals with AS, as some individuals performed at the same level as the control participants. There was no difference between the groups in the recognition of normal or slightly blurred conditions or in the effect of dynamicity: Non-blurred facial emotions were better recognized than slightly filtered, and slightly blurred still better than strongly blurred in both groups. Furthermore, the dynamics had a similar effect

2 The results of Study II have previously been published in a preliminary form as a part of the thesis of Kätsyri, Jari: Human recognition of basic emotions from posed and animated dynamic facial expressions. Academic Dissertation for the degree of Doctor of Philosophy, Helsinki University of Technology, November, 2006.

on recognition in both groups: dynamic facial expressions were better recognized than static images in slightly and strongly filtered conditions in both groups. No prosopagnosia-related effects were found.

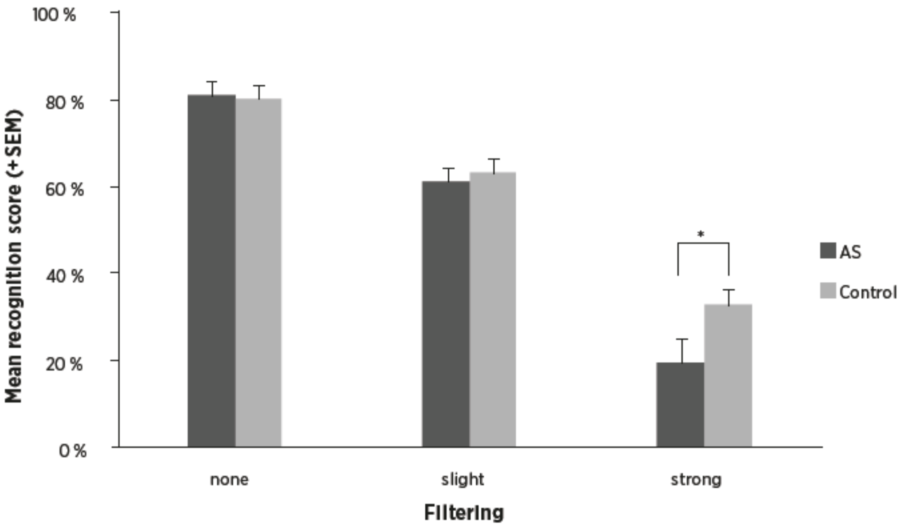

Figure 2. The effect of AS on evaluating blurred facial expressions: emotion recognition accuracies in different filtering conditions for AS and control participants. The results have been pooled across static and dynamic stimuli.

The degraded perception of facial expressions from blurred images found in the AS participants suggests difficulty in the visual processing of global facial features. Instead, the recognition of basic emotions from original, non-filtered facial expressions and from dynamic vs. static facial expressions was similar between the groups, suggesting that AS involves intact recognition of simple emotional states and movement from faces. Therefore, the study's results suggest atypical functioning of the general visual processes rather than poorer recognition of basic emotions. The results are in line with the extended weak central coherence hypothesis (Happé & Frith, 2006; Mottron, Dawson, Soulières, Hubert, & Burack, 2006). In visual perception, there are two pathways through which the incoming information is processed: the magnocellular stream (sensitive to low-spatial frequencies) and the parvocellular stream (sensitive to high-spatial frequencies (Merigan & Maunsell, 1993). The magnocellular stream leads to the dorsal visual pathway, and it may be that the results indicate abnormal functioning of the dorsal visual pathway which, has been previously suggested in studies of ASD (Bertone et al., 2003; Pellicano et al., 2005; Spencer et al., 2000). However, further studies, using more detailed neurophysiological methods, are needed to confirm this suspicion.

3.3. STUDY III: THE PERCEPTION OF AUDIOVISUAL SPEECH IN ADULTS WITH ASPERGER SYNDROME

INTRODUCTION

It has been suggested that individuals with ASD have impaired integration of multisensory information; however, there is still insufficient research on the topic (Iarocci & McDonald, 2006; Molholm & Foxe, 2005; Rogers & Ozonoff, 2005). Speech is multisensory by nature, as it is perceived both by the ear and eye. Previous results on audiovisual perception of speech in ASD have suggested both impaired and intact perception, and there is little knowledge of eye gaze behavior during audiovisual speech perception in AS. The perception of audiovisual speech of adults with AS was investigated by utilizing the McGurk effect. Our hypothesis was that the McGurk effect would be weaker in individuals with AS (they would give more responses according to the audio component of the stimulus). Furthermore, we expected that individuals with AS would either gaze less on the eye region, as found in the studies on emotion or, alternatively, avoid the socially meaningful stimulus, i.e. the mouth.

PARTICIPANTS AND METHODS

The participants were 16 adult individuals (mean age 32) with AS and their matched controls (Table 2). As with Study II, the participants were further characterized by whether they had additional prosopagnosia.

The speech stimuli were video clips of a female articulating the meaningless words /aka/, /apa/ and /ata/. The words were presented in audio (Ap, Ak, At), visual (Vk, Vt) and audiovisual (ApVk, ApVt) conditions. The audiovisual stimuli were incongruent McGurk stimuli and were made by dubbing an audio /apa/ onto either a visual /aka/ or /ata/ in such a way that the timing of the stimuli was preserved (Fig. 3). The audiovisual stimuli produced a McGurk effect which caused hearing to be strongly influenced by the visual component. In the visual and audiovisual trials, the participants saw a talking face in the middle of the screen, and in the auditory trials, the visual stimulus was replaced by a blurred, still facial image. The participants' task was to respond to which consonant they heard in the audiovisual and audio conditions and lipread in the visual condition.

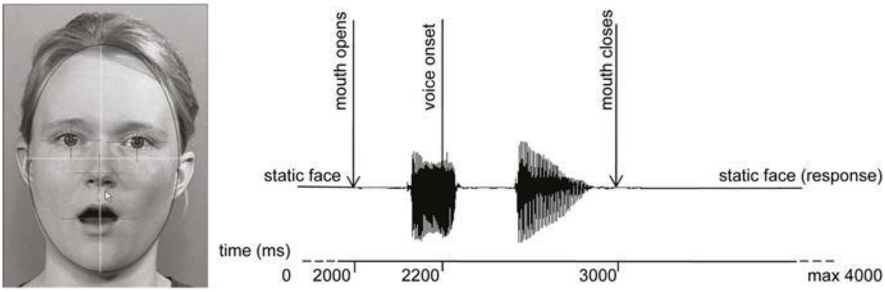

Figure 3. A sample bitmap from the visual articulation video and the structure of the stimuli used in Study III and IV. The axes that delimit the regions of interest (ROI) ellipses used in the eye gaze analysis are also illustrated.

The direction of eye gaze was monitored with a remote eye tracking system (SMI iView X-RED tracking system (www.smivision.com). A fixation was defined as a continuous eye gaze position focused within a 1° visual angle for a period greater than 100 ms. [3] Four regions of interests (ROI) were defined on the basis of previous research (Paré, Richler, ten Hove, & Munhall, 2003): the mouth, nose, eyes, and other (the rest of the face, excluding the other ROIs).

RESULTS AND DISCUSSION

The unisensory auditory and visual stimuli were very well recognized in both groups (Table 4), and no differences between the groups were found. There were no differences between the groups in the amount of 'p'-responses in (Fig. 4) so the strength of the McGurk effect was similar in both groups. Instead, there was a large difference between the groups in the quality of the McGurk effect: The audiovisual stimuli almost uniformly elicited a McGurk effect of hearing according to the visual component of the stimulus in the controls, but this was not the case for the AS group. When the audio /apa/ was presented with the visual /aka/ (ApVk), there was a large difference in the response distribution between groups (in 'k' responses, $p < .001$, and 't' responses $p < .001$). The responses of the AS group were divided almost equally between the response categories 'k' (49%) and 't' (46%), whereas in the controls hearing was strongly influenced by the visual component, and they gave only 4% of 't' responses. However, as a group, the AS participants were heterogeneous,

3 There are no commonly agreed values for defining fixations in the literature, and this may cause some inaccuracies when the results of different studies are compared. As long as there is no consensus on the correct fixation parameters, it is very important to report the used values clearly.

and there were marked individual differences in perception. In contrast, when the visual counterpart of the stimulus was /ata/ (ApVt), perception was similar in both groups. Thus, when the audio /apa/ was presented with the visual /ata/ the most common response was 't' and when audio /apa/ was presented with visual /aka/ the most common response was 'k' (Fig. 4). Moreover, there were no differences in eye gaze behavior between the AS group and the control group, as the participants in both groups fixated mostly on the mouth ROI (Fig. 5).

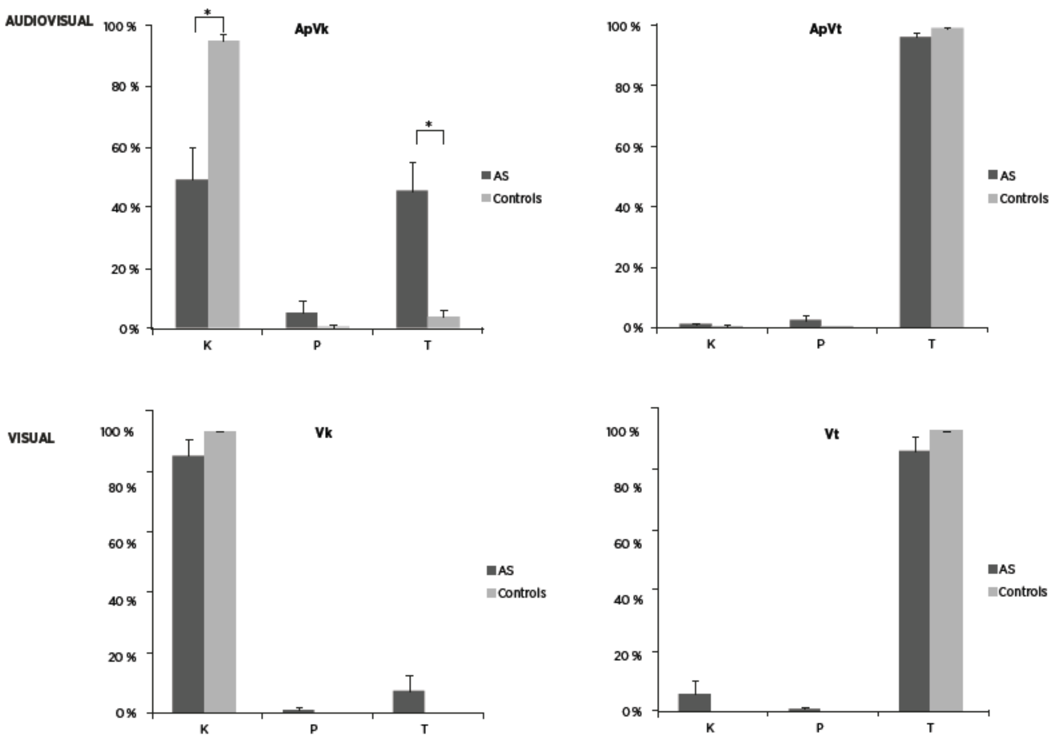

Figure 4. Mean response distributions (+SEM) of the AS and control groups for the audiovisual (ApVk, ApVt) and Visual (Vk, Vt) stimuli. The asterisks denote significan differences between the groups.

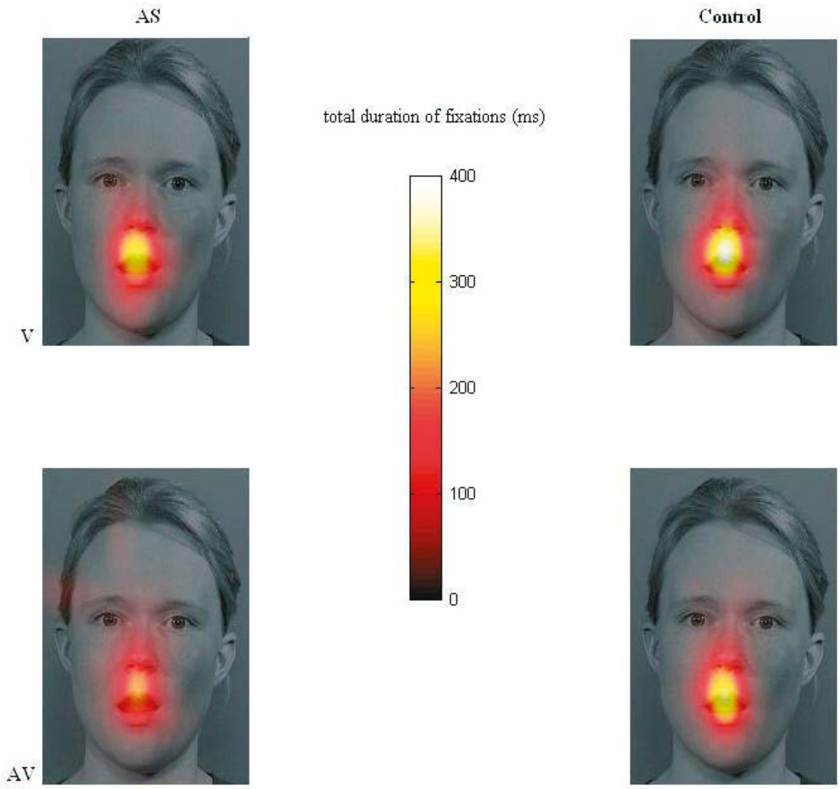

Figure 5. Gaze duration for 14 AS and 16 control participants in visual (top) and audiovisual (below) conditions (Figure by Jari Kätsyri).

Contrary to our hypotheses, the adults with AS did not give more 'p'-responses to the audiovisual stimuli, and thus the strength of the McGurk effect was similar in both groups. Instead, there was a novel finding of a qualitative difference in audiovisual speech perception in adults with AS, compared to their neurotypically developed controls. According to a current model of audiovisual speech perception, seeing visual speech gestures activates motor commands for speech production that serve as articulatory predictions (Skipper, van Wassenhove, Nusbaum, & Small, 2007). These articulatory predictions may be less accurate for the AS participants and, therefore, activated the motor system less effectively than in the typically developed controls. However, in order to confirm this, neurophysiological evidence is needed. The difference in perception was only evident for the audio /apa/ presented with the visual /aka/, because the visual articulation (/aka/) has less clear visual details and gives support to both interpretations /k/ and /t/. As the simultaneously presented audio /p/ is closer to /t/ than it is /k/, it led the AS participants to hear /t/. Instead, in control participants, the articulatory prediction was so clear, that it led them to perceive /k/. There were no differences in gaze fixation patterns in the current study, which is in line with some other recent findings (Fletcher-Watson, Leekam, Benson, & Findlay, 2009; Rutherford & Towns, 2008) but differs from other findings of diminished fixation on the eye region (Klin et al., 2002; Norbury et al., 2009; Pelphrey et al., 2002). It seems most likely that the similar eye gaze patterns between the groups were the result of the high cognitive abilities of the adults with AS and the specific task of speech recognition (Rutherford & Towns, 2008). In previous research the emphasis has been more on social processing (emotion recognition and complex social situations) whereas the current study required processing of oral motor phonemic speech information. Furthermore, stimulus duration probably had an effect because it has been found that eye gaze is more fixated on the eyes during long speech stimuli, but for shorter speech stimuli fixations concentrate on the mouth (Buchan, Paré, & Munhall, 2007; Paré, Richler, ten Hove, & Munhall, 2003; Vatikiotis-Bateson, Eigsti, Yano, & Munhall, 1998). Importantly, eye gaze behavior does not explain the differences in audiovisual speech perception. The qualitative difference in audiovisual speech perception is likely to contribute to the difficulties of individuals with AS in face-to-face verbal communication, as many communicative cues are audiovisual by nature.

3.4. STUDY IV: THE EFFECT OF VISUAL SPATIAL ATTENTION ON AUDIOVISUAL SPEECH PERCEPTION IN ASPERGER SYNDROME

INTRODUCTION

Individuals with ASD have a reduced ability to attend to visual stimuli in the presence of distractors (Burack, 1994), and this could affect speech perception in situations of multiple speakers. In the current study, the hypothesis was that the adults with AS would be more distracted by a competing talking face than would the control participants when attending to another face. Furthermore, we expected that there would be a qualitative difference in their perception of audiovisual speech compared to that of the typically developed control participants.

PARTICIPANTS AND METHODS

The participants were the same 16 adult individuals (mean age 32) with AS and their matched controls who took part in Study III (Table 2). Furthermore, the existence of an additional attention deficit was ruled out by the use of a questionnaire (ARSv1).

The speech stimuli were the same as in Study III but presented in a different setting. Two talking faces were presented next to each other with a fixation cross and a cueing arrow between them. In the audiovisual condition, the audio stimulus remained the same (/apa/), but the visual stimulus was different for each side: when the face on the left said /aka/ the face on the right said /ata/ and vice versa. The participants were instructed to covertly direct their attention to the face that an arrow pointed to (target face) and report which consonant they heard, while ignoring the other face (distractor face). It was expected that the adults with AS would be more distracted by the competing talking face than the controls (distractor-present condition). The stimuli were also presented as visual only stimuli, and the participants were instructed to lipread. In an otherwise identical set-up, only one face was presented on either side of the screen (distractor-absent).

RESULTS AND DISCUSSION

When two faces articulating a different consonant were presented side by side, the participants in both groups mainly responded according to the face to which they were cued to attend (Fig. 6). However, the distractor face partly captured the attention of the participants in both groups: When the distractor was present responses according to the target face decreased and responses according to the distractor face increased in both visual and audiovisual conditions compared to the distractor-absent condition (Table 4). Furthermore, as with Study III, there was a difference in the response distribution for the ApVk stimulus between the groups. The most common response was 'k', but the AS group gave fewer 'k' responses than the controls ($p = .001$), and they had more responses in the 't' category ($p = .002$. In contrast to Study III, the unisensory recognition of the visual /k/ was poorer in the AS group reflected in that the participants with AS gave fewer K-responses ($p = .029$) and more T-responses ($p = .015$) than the control participants (Table 4). However, the difference between the groups in audiovisual perception remained significant even after the effect of lip-reading ability (recognition of visual /k/) was controlled for by taking it into account in the statistical analysis as a covariate.

Contrary to our hypothesis, the effect of visual spatial attention was similar in both the adults with AS and their typically developed controls. In both groups, responses according to the attended face decreased in the distractor-present condition, and,

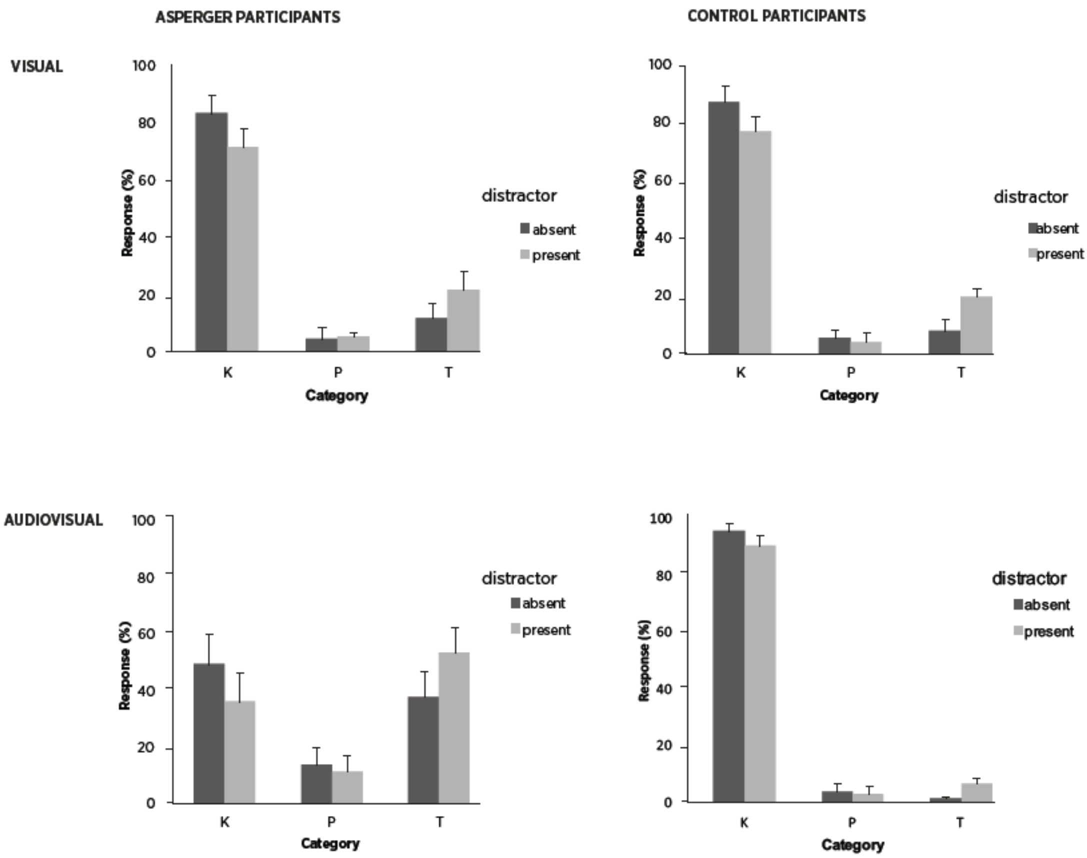

Figure 6. The response distribution (+ SEM) for visual (top) and audiovisual (below) stimuli between groups when the attended visual stimulus was /aka/.

correspondingly, responses according to the distractor face increased. It is possible that, the difficulties that individuals with AS have in attention would be evident in more complex situations with unexpected distracting stimuli. In addition, if there were more distracting stimuli, as is the case in natural situations, the differences between AS and typically developed individuals could be more pronounced. Furthermore, the current study did not involve disengaging, redirecting or adjusting the size of the participants' attentional focus, which may be more impaired in ASD (Allen and Courchesne, 2001; Belmonte & Yurgelun-Todd, 2003; Burack, 1994; Goldstein, Johnson, & Minshew, 2001).

Independent of the attentional effect, there were differences between the groups in the perception of visual and audiovisual speech. The participants with AS were poorer in the unisensory recognition of /aka/, but their poorer lip-reading ability did not fully explain the difference in audiovisual speech perception. Therefore, as with Study III, the results suggest a qualitative difference in the audiovisual speech perception of adults with AS.

Table 4. The distribution of responses for unisensory and multisensory speech simuli in Study III and IV (+SEM)

		ApVt			ApVk			Vt			Vk		
		k	**p**	**t**	**k**	**p**	**t**	**k**	**p**	**t**	**k**	**p**	**t**
Study III													
	AS	1% (0,01)	3% (0,02)	96% (0,02)	49% (0,01)	5% (0,03)	46% (0,1)	6% (0,05)	1% (0,01)	94% (0,05)	91% (0,06)	1% (0,01)	8% (0,05)
	CONTROL	1% (0,00)	0% (0,00)	99% (0,00)	95% (0,02)	1% (0,00)	4% (0,02)	0% (0,00)	0% (0,00)	100% (0,00)	100% (0,00)	0% (0,00)	0% (0,00)
Study IV													
distractor	AS	1% (0,01)	11% (0,04)	89% (0,04)	49% (0,1)	13% (0,06)	38% (0,09)	10% (0,05)	3% (0,01)	87% (0,06)	83% (0,06)	5% (0,04)	12% (0,05)
absent	CONTROL	4% (0,01)	1% (0,00)	94% (0,03)	87% (0,05)	5% (0,03)	8% (0,03)	2% (0,01)	1% (0,00)	96% (0,02)	95% (0,03)	4% (0,03)	1% (0,01)
Study IV													
distractor	AS	6% (0,02)	9% (0,04)	85% (0,05)	36% (0,1)	11% (0,05)	53% (0,09)	16% (0,06)	3% (0,02)	80% (0,07)	72% (0,06)	6% (0,04)	22% (0,06)
present	CONTROL	17% (0,04)	1% (0,01)	82% (0,04)	77% (0,05)	4% (0,03)	20% (0,04)	11% (0,04)	1% (0,01)	88% (0,04)	90% (0,03)	3% (0,03)	6% (0,02)

		At			Ap			Ak		
		k	**p**	**t**	**k**	**p**	**t**	**k**	**p**	**t**
Study III and IV										
	AS	1% (0,0)	1% (0,0)	99% (0,01)	0% (0,0)	94% (0,4)	5% (0,04)	99% (0,01)	1% (0,01)	0% (0,0)
	CONTROL	0% (0,0)	0% (0,0)	100% (0,0)	0% (0,0)	96% (0,01)	4% (0,01)	100% (0,0)	0% (0,0)	0% (0,0)

4. GENERAL DISCUSSION

4.1. SEVERAL FACTORS UNDERPINNING THE COMMUNICATION IMPAIRMENT IN ASPERGER SYNDROME

The results of the study series showed that there are several linguistic and perceptual factors underpinning the communication impairment in AS. Study I aimed to characterize the language abilities of children with AS in detail. In particular, receptive language skills were expected to be poorer in children with AS. The results of Study I confirmed this, as the children with AS performed worse than their typically developed peers in the comprehension of instructions subtest. This shows that in childhood, as in adolescence, there are differences in language performance between typically developed individuals and individuals with AS (Howlin, 2003). However, their poorer performance in this particular subtest may also reflect difficulties in the executive control (working memory, impulse control, planning, inhibition and the regulation and modulation of motor acts) (Hill, 2004). This finding is of particular importance as it supports the hypothesis that AS and HFA have a similar origin and further validates the change towards more dimensional rather than categorical diagnostics. However, the differences found at perceptual processing of cues relevant for face-to-face communication offer further insight into the background of impaired communication in AS. The same children that participated in Study I have later been shown to have difficulties in auditory processing: Differences in event-related potentials (ERPs) indicated abnormal encoding and discrimination of speech sounds (Kujala et al., 2010) and poorer segregation of auditory streams (Lepistö et al., 2009). Furthermore, atypical perception of visual communicative cues has been found in children from the high-functioning end of autism spectrum disorders (Kuusikko et al., 2009), where poorer recognition of basic facial emotions was found in children under 12 years of age compared to that of typically developed peers and an older age group with AS. Therefore, some improvement with age was evident as the difference between individuals with AS and their typically developed peers was not as pronounced in adolescence.

The current study revealed differences in the visual perception of cues relevant to face-to-face communication in adults with AS. Study II aimed to find out whether adults with AS had more difficulties in the recognition of facial emotions on the basis of global facial features. In accordance with the extended weak central hypothesis (Happé & Frith, 2006; Mottron et al., 2006), the participants with AS recognized facial emotions worse on the basis of global facial features. Interestingly, there was a difference in the visual perception of speech signals between the two experiments in Study III and IV which may relate to the same aspect of perceptual processing. When the findings of the current thesis are viewed together, a tentative explanation for the difference in the lip-reading ability may be suggested; namely that the individuals with AS were more affected by the area where the visual stimulus was presented. They were somewhat poorer in lip-reading in both studies, but the difference between the groups only became significant when the stimulus was presented in the area of peripheral vision (Study IV). Visual resolution is poorer in peripheral vision, and, therefore, it can be assumed that a stimulus presented in the periphery appears a little blurred (c.f. low spatial frequencies in Study II), showing less visual detail. In typically developed individuals, direct gaze (high spatial frequencies) is not necessary for the successful processing of visual speech information (Paré et al., 2003) but in light of the current findings, direct gaze and the availability of visual detail may be more important for individuals with AS in lip-reading and in processing emotional expressions from the face (Study II). Consequently, the finding of poorer lip-reading ability in the periphery and impaired recognition of low spatial frequencies most likely stem from features of general visual processing rather than a difficulty in the processing of emotions from facial expressions or lip-reading. It would be interesting to know if a larger difference between groups in lip-reading ability could be accomplished by blurring the image and presenting it in the area of direct gaze, as in Study II. This would suggest that the bias towards processing details rather than global features, i.e. weak central coherence, would also have an effect on lip-reading.

Lip-reading ability, which was studied in Study III and IV, is an important factor in the multisensory perception of speech and the differences found in children with autism have been previously suggested to be the result of poor lip-reading ability. Study III aimed to discover whether adults with AS perceived audiovisual speech differently from typically developed individuals, which would be indicated by a weaker McGurk effect. The results suggests that individuals with AS perceive audiovisual speech qualitatively differently from typically developed individuals, but there was no difference in the strength of the McGurk effect. A similar finding was produced in Study IV when the stimuli were presented in the area of peripheral vision. Although Study IV revealed a significant difference in lip-reading ability not found in Study III, the difference was not strong enough to fully explain the difference in audiovisual speech perception. Moreover, when the effect was controlled for in the analysis, it was clear that the differences in unisensory visual recognition did not fully explain the differences in the McGurk effect between the groups. The studies found no behavioural differences in the unisensory recognition of auditory speech stimuli. However, using more sensitive methods, such as auditory event related potentials (ERPs), atypical neural activity for auditory speech signals has been found in individuals with AS (Ceponiene et al., 2003; Jansson-Verkasalo et al., 2003; Kujala et al., 2010; Lepistö, 2008). Therefore, it is possible that differences at earlier levels of auditory processing are reflected in multisensory perception. If this is the case, the enhanced processing of unisensory features suggested in the extended weak central coherence account (Happé & Frith, 2006; Mottron et al., 2006) could be used to explain the weaker interaction of signals from multiple sensory domains in AS. However, in the present study conditions (Study III and IV), behavioural auditory recognition was similar between the groups, and the difference between them was only evident in the audiovisual condition, which required the interaction of two sensory modalities. Therefore, the behavioural results from the current study that point to a qualitative difference in audiovisual speech perception between adults with AS and their typically developed peers may be interpreted as a sign of ineffective multisensory interaction in ASD, which is in line to previous findings (Oberman & Ramachandran, 2008; Russo et al., 2010). However, much research is still needed to identify the key points of where the development of multisensory integration deviates from the normal course. In fact, the qualitative difference in adulthood may be a residual sign of more impaired multisensory integration in childhood. It would be important to study all the sensory modalities, especially those tactile and audiovisual cues important for early interaction between a carer and child.

Study IV aimed to reveal out whether selective visual spatial attention had a different effect on audiovisual speech perception in adults with AS compared to typically developed individuals. Furthermore, by employing eye-tracking techniques, Study III aimed to discover whether attention to the face during speech perception was different in adults with AS. However, in both the experimental conditions of Study III and IV, the required attentional mechanisms observed in the individuals with AS were similar to those of the individuals with typical development, which did not support the previous findings of atypical attention to the face and atypical control of visual spatial attention. This does not, of course, confirm that there are no differences in attention in AS. Instead, these findings should be seen as evidence that in some very basic conditions adults with AS are able to direct their attention appropriately. The quality of the stimulus and the distraction may be critical, as recent studies have suggested that at least younger individuals with ASD are more prone to distraction by objects than by social stimuli (Riby, Brown, Jones, & Hanley, 2011). Moreover, the use of more naturalistic, rather than the very simple stimuli used here might provide more information on eye gaze patterns during speech perception.

4.2. CLINICAL IMPLICATIONS

Study I showed that although children with AS seem to have good language abilities – good vocabulary, fluent, expressive speech and good command of syntax – they still face challenges in comprehending instructions. Therefore, using short and clear instructions e.g. in a classroom is beneficial for children with AS. The finding of impaired receptive language supports the forthcoming change in diagnostics, where AS will be subsumed into the category of autism spectrum disorders together with HFA. Increasingly, autistic impairments are seen to represent a spectrum, rather than separate categories, and this is also the case in respect to language abilities (Szatzmari, 2011; Lord et al. 2000). However, at the very high-functioning end of the spectrum, difficulties of language may be hard to identify with available clinical methods.

In addition to slight linguistic difficulties the results of the current thesis point atypical perceptual processes relevant for face-to-face communication. A deficiency in processing global features from the face may affect the processing of emotional and other information from the face. Knowing about this specific deficiency may help to understand the challenges an individual has in processing information from the face. Importantly, the qualitative difference found in the current study may be a sign of atypical multisensory integration. In addition to speech, this would affect processing of in many other communicative cues, as they are multisensory in nature (emotions, prosody). Although more research is needed, explicit teaching of connecting auditory and visual information simultaneously may prove beneficial. To date, there are no appropriate methods for identifying in detail these specific differences in perception in clinical settings. However, it could be informative to compile more detailed perceptual profiles of individuals, using questionnaires, in the course of the diagnostic procedure. Gathering information like this throughout the diagnostic and follow up procedure would provide insight into the characteristics of perception and possibly help us to understand each individual better. In intervention, understanding the limits and strengths of the perception of communicative cues enables the methods to be better adapted to meet each individual’s specific needs.

4.3. INDIVIDUAL DIFFERENCES IN THE ASPERGER GROUP

In all the studies, the heterogeneity of individuals with AS was evident. The performance of the individuals with AS was much more varied than those of the control group, as was evident from larger standard errors of the mean. In Studies II, III and IV, the responses of the AS individuals were heterogeneous as some of the adults with AS performed similarly to the control participants and others performed very differently. These findings are in line with the recent emphasis on the heterogeneous nature of the autism spectrum (e.g. Szatmari, 2011). It is possible that there are several different endophenotypes that reflect different genetic variants. The outcome for these individuals may vary greatly, and they could benefit from different intervention strategies. Unfortunately the research data on individual differences are often lost in the statistical analysis when comparisons between groups are made with averaged values. Instead, individuals participating in experimental studies should be characterized as thoroughly as possible in respect to their symptoms and other background factors, and these characteristics should be correlated to experimental results. A limitation of the current study was that it was not possible to correlate the behavioural results with the individual characteristics e.g. severity of the participants' AS diagnosis or with their motor skills and this should be done in future studies.

4.4. FUTURE DIRECTIONS

The cognitive theories can only partially offer explanation for autism spectrum disorders. Instead, current neurophysiological methods make it possible to make direct links with behaviour and brain function for biological models. When the results of the current study series are viewed as a whole, a shared neural background for all these findings comes to mind. The suggestion will remain purely tentative until it is tested with appropriate neurophysiological methods.

The qualitative difference in the perception of audiovisual speech seen in Study III and IV was interpreted in the light of recently developed neurophysiological model of audiovisual speech perception (Skipper et al., 2007). According to this model, the motor system influences phonetic interpretation via articulatory predictions, particularly through visual speech gestures which precede the auditory signal. A good motor system enhances speech recognition by extracting phonetic information for accurate articulatory predictions. It was speculated that the motor system of a subset of adults with AS offered weaker support for speech perception and this lead to a qualitative difference in audiovisual speech perception. The weaker support of the motor system could be due to weaker linkages between observed actions and the motor plans for the same actions as in the impairment in the mirror neuron system (Rizzolatti, Fadiga, Gallese, & Fogassi, 1996 for reviews see Iacoboni & Dapretto, 2006). There is evidence from imaging studies that those brain areas that are involved in speech production and the planning of articulation (the ventral premotor cortex and Broca's area) are less active in individuals with AS (e.g. Nishitani, Avikainen, & Hari, 2004). Recently, the role of the motor system has been highlighted in respect to many findings in ASD (see e.g. Haswell, Izawa, Dowell, Mostofsky, & Shadmehr, 2009; Klin, Jones, Schultz, & Volkmar, 2003; Oberman & Ramachandran, 2007). The associations between actual motor commands and the sensory feedback necessary for performing an action may also be relevant for the other findings of the current thesis.

Recent theories of embodied emotion perception have proposed that recognition of emotions involves feedback from the observer's own motor system via simulation (for a review see Goldman & Sripada, 2005; Niedenthal, 2007). Facial muscle activity is thought to serve as a feedback system that supports recognition of facial expressions (Dimberg, Thunberg, & Elmehed, 2000; Oberman, Winkielman, & Ramachandran, 2007). It is therefore possible that the motor representations of facial expressions are not as strong in ASD and may not support recognition efficiently (e.g. McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006). Visual information is important for invoking motor activation. Possibly, when the visual stimulus was blurred, the degraded visual information did not activate the motor system efficiently in a subset of adults with AS, thus leading to poorer recognition of the facial expression. Similarly, poorer lip-reading ability of individuals with AS in the area of peripheral vision may have excited the motor system less in Study IV. Finally, the children with AS performed worse than the controls in the subtest measuring the comprehension of instructions (Study I). As discussed earlier, the subtest required good executive control in terms of goal directed functioning, and importantly, well planned motor actions. Difficulty in converting intentions into sequence of motor actions has been observed in children with autism (Cattaneo et al., 2007; Fabbri-Destro, Cattaneo, Boria & Rizzolatti, 2009), reflecting an impairment of the basic motor structure that is responsible for chained action organization. This could have accounted for the difficulties in performing a motor action according to complex verbal instruction. Hence, a dysfunctional motor system might be involved in all the findings in the current thesis.

Although a dysfunctional mirror neuron system scarcely explains all the difficulties connected with ASD, in light of current available knowledge it might be the most prominent explanation for the findings of this thesis. However, it is clear that the involvement of the motor system in supporting perception in ASD should be studied in more detail in the future alongside consideration of the developmental aspects of the condition. For example, the activation of the speech motor system could be investigated by recording the mu rhythm (the brain wave that is thought to reflect motor activity) during speech perception. Furthermore, it is especially important to connect neurophysiological findings to possible differences at a behavioural level, e.g. the development of the motor control of speech.

5. CONCLUSIONS

The current thesis investigated factors underpinning communication impairment in Asperger Syndrome. Results of the study series demonstrate that many linguistic and perceptual factors relevant for face-to-face communication are atypical in AS. There are subtle differences in language skills between school-age children with AS and their typically developed peers in spite of previous assumption of intact language abilities. Furthermore, individuals with AS have difficulties in perceiving facial expressions on the basis of global features. Moreover, a qualitative difference in audiovisual speech perception suggests atypical multisensory perception in Asperger syndrome which is likely to contribute to the difficulties in face-to-face communication.

6. REFERENCES

Adolphs, R., Sears, L., & Piven, J. (2001). Abnormal processing of social information from faces in autism. *Journal of Cognitive Neuroscience*, 13(2), 232–240.

Alcántara, J. I., Weisblatt, E. J. L., Moore, B. C. J., & Bolton, P. F. (2004). Speech-in-noise perception in high-functioning individuals with autism or Asperger's syndrome. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 45(6), 1107-14. doi:10.1111/j.1469-7610.2004.t01-1-00303.

Allen, G. and Courchesne, E. (2001). Attention function and dysfunction in autism. *Frontiers in Bioscience*, 6, 105-119. doi:10.1002/ajmg.a.33931

American Psychiatric Association (1994). *Diagnostic and statistical manual of mental disorders, 4th edition* (DSM-IV). Washington, DC: American Psychiatric Association.

Ames, C., & Fletcher-Watson, S. (2010). A review of methods in the study of attention in autism. *Developmental Review*, 30(1), 52-73. doi:10.1016/j.dr.2009.12.003

Attwood, T. (1998). *Asperger's Syndrome: a Guide for Parents and Professionals*. London: Jessica Kingsley Publishers.

Ashwin, C., Chapman, E., Colle, L., & Baron-Cohen, S. (2006). Impaired recognition of negative basic emotions in autism: A test of the amygdala theory. *Social Neuroscience*, 1(3), 349–363.

Ashwin, C., Baron-Cohen, S., Wheelwright, S., O'Riordan, M., & Bullmore,E. (2007). Differential activation of the amygdala and the 'social brain'during fearful face-processing in Asperger syndrome. *Neuropsychologia*,45(1), 2–14.

Asperger, H. (1944). Die "Autistischen Psychopathen" in Kindesalter. Archiv für Psychiatrie und Nervenkrankheiten, 117, 76-136. English translation (1991) in U. Frith (Ed.), Autism and Asperger Syndrome. Cambridge: Cambridge University Press.

Ayres A. J. (1979). *Sensory Integration and the Child*. Los Angeles, CA, Western Psychological Services.

Bailey, A., Le Couteur, A., Gottesman, I., Bolton, P., Simonoff, E., Yuzda, E., & Rutter, M. (1995). Autism as a strongly genetic disorder: evidence from a British twin study. *Psychological Medicine*, 25(1), 63-77.

Baron-Cohen, S., Jolliffe, T., Mortimore, C., & Robertson, M. (1997). Another advanced test of theory of mind: evidence from very high functioning adults with autism or asperger syndrome. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, 38(7), 813-22.

Baron-Cohen, S.,Wheelwright, S., & Jolliffe, T. (1997). Is there a "Language of the eyes"? Evidence from normal adults, and adults with autism or Asperger syndrome. *Visual Cognition*, 4(3), 311–331.

Baron-Cohen, S., Leslie, a M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition*, 21(1), 37-46.

Baron-Cohen, S., Wheelwright, S., Hill, J., Raste, Y., & Plumb, I. (2001). The "Reading the Mind in the Eyes" Test revised version: a study with normal adults, and adults with Asperger syndrome or high-functioning autism. *Journal of Child Psychology and Psychiatry, and Allied Disciplines,* 42(2), 241-51.

Baron-cohen, S. (2001). Theory of mind and autism: a review. Russell The Journal Of The Bertrand Russell Archives.

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), 1706-16. doi:10.1093/brain/awh194

Behrmann, M., Thomas, C., & Humphreys, K. (2006). Seeing it differently: visual processing in autism. *Trends in Cognitive Sciences*, 10(6), 258-64. doi:10.1016/j.tics.2006.05.001

Belmonte, M. K., & Yurgelun-Todd, D. (2003). Functional anatomy of impaired selective attention and compensatory processing in autism. *Brain Research: Cognitive Brain Research*, 17(3), 651-64.

Bertone, A., Mottron, L., Jelenic, P., & Faubert, J. (2003). Motion perception in autism: a "complex" issue. *Journal of Cognitive Neuroscience*, 15(2), 218-25. doi:10.1162/089892903321208150

Bird, G., Catmur, C., Silani, G., Frith, C., & Frith, U. (2006). Attention does not modulate neural responses to social stimuli in autism spectrum disorders. *NeuroImage*, 31(4), 1614-24. doi:10.1016/j.neuroimage.2006.02.037

Blake, R., Turner, L. M., Smoski, M. J., Pozdol, S. L., & Stone, W. L. (2003). Visual recognition of biological motion is impaired in children with autism. *Psychological Science: a Journal of the American Psychological Society / APS*, 14(2), 151-7.

Boraston, Z., Blakemore, S. J., Chilvers, R., & Skuse, D. (2007). Impaired sadness recognition is linked to social interaction deficit in autism. *Neuropsychologia*, 45(7), 1501–1510.

Bruce V.,Young A., 1986. Understanding face recognition. *British Journal of Psychology* 77, 305-327.

Buchan, J. N., Paré, M., & Munhall, K.G. (2007). Spatial statistics of gaze fixations during dynamic face processing. *Social Neuroscience*, 2(1), 1-13. doi:10.1080/17470910601043644

Burack, J. (1994). Selective attention deficits in persons with autism: preliminary evidence of an inefficient attentional lens. *Journal of Abnormal Psychology*, 103(3), 535-43.

Cattaneo, L., Fabbri-Destro, M., Boria, S., Pieraccini, C., Monti, A., Cossu, G., & Rizzolatti, G. (2007). Impairment of actions chains in autism and its possible role in intention understanding. *Proceedings of the National Academy of Sciences of the United States of America*, 104(45), 17825-30. doi:10.1073/pnas.0706273104

Ceponiene, R, Lepistö, T, Shestakova, A., Vanhala, R., Alku, P, Näätänen, R, & Yaguchi, K. (2003). Speech-sound-selective auditory impairment in children with autism: they can perceive but do not attend. *Proceedings of the National Academy of Sciences of the United States of America,* 100(9), 5567-72. doi:10.1073/pnas.0835631100

Dakin, S., & Frith, U. (2005). Vagaries of visual perception in autism. *Neuron*, 48(3), 497-507. doi:10.1016/j.neuron.2005.10.018

Dalton, K. M., Nacewicz, B. M., Johnstone, T., Schaefer, H. S., Gernsbacher, M. A., Goldsmith, H. H., Alexander, A. L., et al. (2005). Gaze fixation and the neural circuitry of face processing in autism. *Nature Neuroscience*, 8(4), 519-26. doi:10.1038/nn1421

De Gelder, B., Vroomen, J. & van der Heide, L. (1991). Face Recognition and Lip-reading in Autism. *European Journal of Cognitive Psychology*, 3, 69-86.

Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious facial reactions to emotional facial expressions. *Psychological Science: a Journal of the American Psychological Society / APS,* 11(1), 86-9.

Dziobek, I., Fleck, S., Rogers,K., Wolf, O., & Convit, A. (2006). The "amygdale theory of autism" revisited: linking structure to behavior. *Neuropsychologia*, 44(10), 1891–1899.

Ehlers, S., Gillberg, C., & Wing, L. (1999). A screening questionnaire for Asperger syndrome and other high-functioning autismspectrum disorders in school age children. *Journal of Autism and Developmental Disorders*, 29(2), 129–141.

Eisenmajer, R., Prior, M., Leekam, S., Wing, L, Gould, J., Welham, M., & Ong, B. (1996). Comparison of clinical symptoms in autism and Asperger's disorder. *Journal of the American Academy of Child and Adolescent Psychiatry*, 35(11), 1523-31. doi:10.1097/00004583-199611000-00022

Ekman, P., Friesen, W. V., & Ellsworth, P. (1982). What emotion categories or dimensions can observes judge from facial behavior? In P. Ekman (Ed.), *Emotions in the Human Face* (pp. 39–55). London: Cambridge University Press.

Ekman P, Should we call it expression or communication? Innovations in Social Science Research, 1997, 10(4): 333-344.

Fabbri-Destro, M., Cattaneo, L., Boria, S., & Rizzolatti, G. (2009). Planning actions in autism. *Experimental brain research*. 192(3), 521-5. doi:10.1007/s00221-008-1578-3

Fletcher-Watson, S, Leekam, S. R., Benson, V., Frank, M. C., & Findlay, J. M. (2009). Eye-movements reveal attention to social information in autism spectrum disorder. *Neuropsychologia*, 47(1), 248-57. doi:10.1016/j.neuropsychologia.2008.07.016

Freitag, C. M. (2007). The genetics of autistic disorders and its clinical relevance: a review of the literature. *Molecular Psychiatry*, 12(1), 2-22. doi:10.1038/sj.mp.4001896

Frith, C. D., & Frith, U. (2006). The neural basis of mentalizing. *Neuron*, 50(4), 531-4. doi:10.1016/j.neuron.2006.05.001

Gallese, V., Rochat, M., Cossu, G., & Sinigaglia, C. (2009). Motor cognition and its role in the phylogeny and ontogeny of action understanding. *Developmental Psychology*, 45(1), 103-13. doi:10.1037/a0014436

Ghaziuddin, M., & Gerstein, L. (1996). Pedantic speaking style differentiates Asperger syndrome from high-functioning autism. *Journal of Autism and Developmental Disorders*, 26(6), 585– 595.

Ghaziuddin, M., Thomas, P., Napier, E., Kearney, G., Tsai, L., Welch, K., & Fraser, W. (2000). Brief report: Brief syntactic analysis in Asperger syndrome: a preliminary study. *Journal of Autism and Developmental Disorders*, 30(1), 67-70.

Golan, O., Baron-Cohen, S., & Hill, J. (2006). The Cambridge mindreading (CAM) face-voice battery: Testing complex emotion recognition in adults with and without Asperger syndrome. *Journal of Autism and Developmental Disorders*, 36(2), 169–183.

Goldman, A.I., & Sripada, C.S. (2005). Simulationist models of face-based emotion recognition. *Cognition*, 94(3), 193-213. doi:10.1016/j.cognition.2004.01.005

Goldstein, G., Johnson, C.R., & Minshew, N.J. (2001). Attentional processes in autism. *Journal of Autism and Developmental Disorders*, 31(4), 433-40.

Grandin, T. & Scariano, M.M. (1992). *Minun tarinani – Ulos autismista* [Emergence: Labelled autism]. Jyväskylän yliopiston täydennyskoulutuskeskus, Jyväskylä.

Happé, F. G. (1993). Communicative competence and theory of mind in autism: a test of relevance theory. *Cognition*, 48(2), 101-19.

Happé, F., & Frith, U. (2006). The weak coherence account: detail-focused cognitive style in autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 36(1), 5-25. doi:10.1007/s10803-005-0039-0

Happé, F., Ronald, A., & Plomin, R. (2006). Time to give up on a single explanation for autism. *Nature Neuroscience*, 9(10), 1218-20. doi:10.1038/nn1770

Haswell, C.C., Izawa, J., Dowell, L.R., Mostofsky, S.H., & Shadmehr, R. (2009). Representation of internal models of action in the autistic brain. *Nature Neuroscience*, 12(8), 970-2. Nature Publishing Group. doi:10.1038/nn.2356

Hefter RL, Manoach DS, Barton JJS, Perception of facial expressions and facial identity in subjects with social developmental disorders. *Neurology*, 2005, 65: 1620-1625.

Hill, E.L. (2004). Executive dysfunction in autism. *Trends in Cognitive Sciences*, 8(1), 26-32. doi:10.1016/j.tics.2003.11.003

Hill, E.L., & Frith, U. (2003). Understanding autism: insights from mind and brain. Philosophical transactions of the Royal Society of London. Series B, *Biological sciences*, 358(1430), 281-9. doi:10.1098/rstb.2002.1209

Hobson, R. P., Ouston, J., & Lee, A. (1988). What's in a face? The case of autism. British Journal of Psychology, 79, 441–453.

Howlin, P. (2003). Outcome in high-functioning adults with autism with and without early language delays: implications for the differentiation between autism and Asperger syndrome. *Journal of Autism and Developmental Disorders,* 33(1), 3-13.

Humphreys, K., Minshew, N., Leonard, G. L., & Behrmann, M. (2007). A finegrained analysis of facial expression processing in high-functioning adults with autism. *Neuropsychologia*, 45(4), 685–695.

Iacoboni, M., & Dapretto, M. (2006). The mirror neuron system and the consequences of its dysfunction. *Nature Reviews Neuroscience*, 7(12), 942-51. doi:10.1038/nrn2024

Iarocci, G., & McDonald, J. (2006). Sensory integration and the perceptual experience of persons with autism. *Journal of Autism and Developmental Disorders,* 36(1), 77-90. doi:10.1007/s10803-005-0044-3

Irwin, J. R. (2007). Auditory and Audiovisual Speech Perception in Children with Autism Spectrum Disorders. *Acoustics Today*, 3(4), 8. doi:10.1121/1.2961161

Jansson-Verkasalo, Eira, Ceponiene, Rita, Kielinen, M., Suominen, K., Jäntti, V., Linna, S. L., Moilanen, I., et al. (2003). Deficient auditory processing in children with Asperger Syndrome, as indexed by event-related potentials. *Neuroscience Letters*, 338(3), 197-200.

Kanner, L. (1943). Autistic disturbances of affective contact. *Nervous Child*, 2, 217-250.

Keane, B. P., Rosenthal, O., Chun, N. H., & Shams, L. (2010). Audiovisual integration in high functioning adults with autism. *Research in Autism Spectrum Disorders,* 4(2), 276-289. doi:10.1016/j.rasd.2009.09.015

Kerbel, D., & Grunwell, P. (1998). A study of idiom comprehension in children with semantic-pragmatic difficulties. Part II: Between-groups results and discussion. *International Journal of Language & Communication Disorders / Royal College of Speech & Language Therapists,* 33(1), 23-44.

Kjelgaard, M. M., & Tager-Flusberg, H. (2001). An Investigation of Language Impairment in Autism: Implications for Genetic Subgroups. *Language and Cognitive Processes*, 16(2-3), 287-308. doi:10.1080/01690960042000058

Klin, A., Jones, W., Schultz, R., & Volkmar, F. (2003). The enactive mind, or from actions to cognition: lessons from autism. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 358(1430), 345-60. doi:10.1098/rstb.2002.1202

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of General Psychiatry*, 59(9), 809-16.

Klin, A., Saulnier, C. a, Sparrow, S. S., Cicchetti, D. V., Volkmar, Fred R, & Lord, Catherine. (2007). Social and communication abilities and disabilities in higher functioning individuals with autism spectrum disorders: the Vineland and the ADOS. *Journal of Autism and Developmental Disorders*, 37(4), 748-59. doi:10.1007/s10803-006-0229-4.

Klin, A., Volkmar, F.R, & Sparrow, S.S. (2000). *Asperger Syndrome*. New York. New York: Guilford Press.

Kohler C.G., Turner T., Stolar N.M., Bilker W.B., Brensinger C.M., Gur R.E. & Gur R.C. (2004). Differences in facial expressions of four universal emotions. *Psychiatry Research,* 128: 235 –244.

Koning, C., & Magill-Evans, J. (2001). Social and Language Skills in Adolescent Boys with Asperger Syndrome. *Autism*, 5(1), 23-36. doi:10.1177/1362361301005001003

Korkman M., Kirk U., & Kemp, S. L. (1997). NEPSY: Lasten neuropsykologinen tutkimus.[The NEPSY: the Finnish Developmental Neuropsychological Evaluation]. Helsinki, Finland:Psykologien kustannus Oy.

Korpilahti, P., Jansson-Verkasalo, E., Mattila, M.L., Kuusikko, S., Suominen, K., Rytky, S., Pauls, D.L., & Moilanen, I. (2007). Processing of affective speech prosody is impaired in Asperger syndrome. *Journal of Autism and Developmental Disorders*, 37: 1539–1549.

Kuhl, P. and Melzoff, A. (1982): The Bimodal Perception of Speech in Infancy. *Science*, 218 (4577), 1138-1141. DOI: 10.1126/science.7146899

Kujala, T., Kuuluvainen, S., Saalasti, S., Jansson-Verkasalo, E, Wendt, L. V., & Lepistö, T. (2010). Speech-feature discrimination in children with Asperger syndrome as determined with the multi-feature mismatch negativity paradigm. *Clinical Neurophysiology: Official Journal of the International Federation of Clinical Neurophysiology,* 121(9), 1410-1419

Kuusikko, S., Haapsamo, H., Jansson-Verkasalo, Eira, Hurtig, T., Mattila, M.-L., Ebeling, H., Jussila, K., et al. (2009). Emotion Recognition in Children and Adolescents with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders*, 39(6), 938-945. doi:10.1007/s10803-009-0700-0

Kätsyri, J. (2006). *Human recognition of basic emotions from dynamic posed and animated facial expressions*. Unpublished PhD thesis. Helsinki University of Technology.

Lachter, J., Forster, K. I., & Ruthruff, E. (2004). Forty-five years after broadbent (1958): Still no identification without attention. *Psychological Review*, 111, 880-913.

Landa, R. (2000) 'Social language use in Asperger syndrome and High-Functioning Autism.' In A. Klin, F. Volkmar and S. Sparrow (eds) *Asperger Syndrome*. New York: The Guilford Press.

Leekam, S., Libby, S., Wing, L., Gould, J., & Gillberg, C. (2000). Comparison of ICD-10 and Gillberg's Criteria for Asperger Syndrome. *Autism*, 4(1), 11-28. doi:10.1177/1362361300004001002

Lepistö, T, Kuitunen, a, Sussman, E., Saalasti, S., Jansson-Verkasalo, E, Nieminen-von Wendt, T, & Kujala, T. (2009). Auditory stream segregation in children with Asperger syndrome. *Biological Psychology*, 82(3), 301-7. doi:10.1016/j.biopsycho.2009.09.004

Lepistö, Tuulia. (2008). *Cortical processing of speech and non-speech sounds in autism and Asperger syndrome*. Doctoral Dissertation, University of Helsinki.

Leslie, A.M., Friedman, O., & German, T.P. (2004). Core mechanisms in "theory of mind". *Trends in Cognitive Sciences*, 8(12), 528-33. doi:10.1016/j.tics.2004.10.001

Lord C., Rutter M., Le Couteur A. (1994). Autism diagnostic interview-revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders* 24: 659–685

Lord, C, Leventhal, B.L., & Cook, E.H. (2001). Quantifying the phenotype in autism spectrum disorders. *American Journal of Medical Genetics*, 105(1), 36-8.

Lord, C, Risi, S., Lambrecht, L., Cook, E.H., Leventhal, B.L., DiLavore, P.C., Pickles, A., et al. (2000). The autism diagnostic observation schedule-generic: a standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders*, 30(3), 205-23.

Loukusa, S. (2007). *The use of context in pragmatic language comprehension in normally developing children and children with Asperger syndrome/ high-functioning autism. An application of relevance theory*. Academic Dissertation, University of Oulu.

MacDonald, J., & McGurk, H. (1978). Visual influences on speech perception processes. *Perception & Psychophysics*, 24(3), 253-7.

Martin, I. (2003). Weak coherence, no theory of mind, or executive dysfunction? Solving the puzzle of pragmatic language disorders. *Brain and Language*, 85(3), 451-466. doi:10.1016/S0093-934X(03)00070-1

Massaro, D.W., Bosseler, A. (2003). Perceiving Speech by Ear and Eye: Multimodal Integration by Children with Autism. *Journal on Developmental and Learning Disorders*, 7, 111-144.

Mattila, M.-L., Kielinen, M., Linna, S.-L., Jussila, K., Ebeling, H., Bloigu, R., Joseph, R. M., et al. (2011). Autism spectrum disorders according to DSM-IV-TR and comparison with DSM-5 draft criteria: an epidemiological study. *Journal of the American Academy of Child and Adolescent Psychiatry*, 50(6), 583-592. doi:10.1016/j.jaac.2011.04.001

McGurk H, MacDonald JW (1976) Hearing lips and seeing voices. Nature 264:746–748

McIntosh, D. N., Reichmann-Decker, A., Winkielman, P., & Wilbarger, J. L. (2006). When the social mirror breaks: deficits in automatic, but not voluntary, mimicry of emotional facial expressions in autism. *Developmental Science*, 9(3), 295-302. doi:10.1111/j.1467-7687.2006.00492

Merigan, W., & Maunsell, J. (1993). How parallel are the primate visual pathways? *Annual Review of Neuroscience,* 16, 369–402.

Minshew, Nancy J, & Hobson, J.A. (2008). Sensory sensitivities and performance on sensory perceptual tasks in high-functioning individuals with autism. *Journal of Autism and Developmental Disorders,* 38(8), 1485-98. doi:10.1007/ s10803-007-0528-4

Molholm S., Foxe J. J. (2004). Look ‘hear’, primary auditory cortex is active during lip-reading. *Neuroreport* 16, 123–124. doi: 10.1097/00001756-200502080-00009.

Mongillo, E.A., Irwin, J.R., Whalen, D.H., Klaiman, C., Carter, A.S., & Schultz, R.T. (2008). Audiovisual processing in children with and without autism spectrum disorders. *Journal of Autism and Developmental Disorders*, 38(7), 1349-58. doi:10.1007/s10803-007-0521-y

Mottron, L., Dawson, M., Soulières, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: an update, and eight principles of autistic perception. *Journal of Autism and Developmental Disorders*, 36(1), 27-43. doi:10.1007/s10803-005-0040-7

Neumann, D., Spezio, M.L., Piven, J., & Adolphs, R. (2006). Looking you in the mouth: abnormal gaze in autism resulting from impaired top-down modulation of visual attention. *Social Cognitive and Affective Neuroscience*, 1(3), 194-202. doi:10.1093/scan/nsl030

Niedenthal, P. M. (2007). Embodying emotion. *Science* (New York, N.Y.), 316(5827), 1002-5. doi:10.1126/science.1136930

Nieminen-von Wendt, Taina, Paavonen, J. E., Ylisaukko-Oja, T., Sarenius, S., Källman, T., Järvelä, I., & von Wendt, L. (2005). Subjective face recognition difficulties, aberrant sensibility, sleeping disturbances and aberrant eating habits in families with Asperger syndrome. *BMC psychiatry*, 5, 20. doi:10.1186/1471-244X-5-20

Nishitani, N., Avikainen, S., & Hari, R. (2004). Abnormal imitation-related cortical activation sequences in Asperger's syndrome. *Annals of Neurology*, 55(4), 558-62. doi:10.1002/ana.20031

Norbury, C. F., Brock, J., Cragg, L., Einav, S., Griffiths, H., & Nation, K. (2009). Eye-movement patterns are associated with communicative competence in autistic spectrum disorders. *Journal of Child Psychology and Psychiatry, and Allied Disciplines,* 50(7), 834-42. doi:10.1111/j.1469-7610.2009.02073.x

Oberman, L.M., & Ramachandran, V.S. (2007). The simulating social mind: the role of the mirror neuron system and simulation in the social and communicative deficits of autism spectrum disorders. *Psychological Bulletin*, 133(2), 310-27. doi:10.1037/0033-2909.133.2.310

Oberman, L.M., & Ramachandran, V.S. (2008). Preliminary evidence for deficits in multisensory integration in autism spectrum disorders: The mirror neuron hypothesis. Social Neuroscience, 3(3), 348-355. *Psychology Press*. doi:10.1080/17470910701563681

Oberman, L. M., Ramachandran, V. S., & Pineda, J. a. (2008). Modulation of mu suppression in children with autism spectrum disorders in response to familiar or unfamiliar stimuli: the mirror neuron hypothesis. *Neuropsychologia*, 46(5), 1558-65. doi:10.1016/j.neuropsychologia.2008.01.010

Oberman, L. M., Winkielman, P., & Ramachandran, V. S. (2007). Face to face: blocking facial mimicry can selectively impair recognition of emotional expressions. *Social Neuroscience,* 2(3-4), 167-78. doi:10.1080/17470910701391943

Ozonoff, S., & Miller, J.N. (1996). An exploration of right-hemisphere contributions to the pragmatic impairments of autism. *Brain and Language*, 52(3), 411-434.

Ozonoff, S, South, M., & Miller, J. N. (2000). DSM-IV-Defined Asperger Syndrome: Cognitive, Behavioral and Early History Differentiation from High-Functioning Autism. *Autism*, 4(1), 29-46. doi:10.1177/1362361300041003

Paré, M., Richler, R. C., ten Hove, M., & Munhall, K G. (2003). Gaze behavior in audiovisual speech perception: the influence of ocular fixations on the McGurk effect. *Perception & Psychophysics*, 65(4), 553-67.

Paul, R., Landa, R. & Schoen, E. (2000). Communication Impairment in Asperger Syndrome. In A. Klin, F. Volkmar and S. Sparrow (eds) *Asperger Syndrome*. New York: The Guilford Press.

Paul, R., Orlovski, S. M., Marcinko, H. C., & Volkmar, F. (2009). Conversational behaviors in youth with high-functioning ASD and Asperger syndrome. *Journal of Autism and Developmental Disorders*, 39(1), 115-25. doi:10.1007/s10803-008-0607-1

Parker, D.M., Bagby, R.M., Taylor, G.J., Endler, N.S., & Schmitz, P. (1993). Factorial validity of the 20-item Toronto alexithymia scale. *European Journal of Personality*, 7(4), 221–232.

Pellicano, E., Gibson, L., Maybery, M., Durkin, K., & Badcock, D.R. (2005). Abnormal global processing along the dorsal visual pathway in autism: a possible mechanism for weak visuospatial coherence? *Neuropsychologia*, 43(7), 1044-53. doi:10.1016/j.neuropsychologia.2004.10.003

Pelphrey, K., Sasson, N. J., Reznick, J. S., Paul, G., Goldman, B. D., & Piven, J. (2002). Visual scanning of faces in autism. *Journal of Autism and Developmental Disorders,* 32(4), 249-61.

Perkins, M. R. (2005). Pragmatic ability and disability as emergent phenomena. *Clinical linguistics Phonetics*, 19(5), 367-377. Taylor and Francis.

Posner, M. I. (1980). Orienting of attention. *The Journal of Experimental Psychology*, 32, 3-25.

Rapin, I. (2003). Update on the language disorders of individuals on the autistic spectrum. *Brain and Development*, 25(3), 166-172. doi:10.1016/S0387-7604(02)00191-2

Remington, A., Swettenham, J., Campbell, R., & Coleman, M. (2009). Selective attention and perceptual load in autism spectrum disorder. *Psychological Science: a Journal of the American Psychological Society / APS*, 20(11), 1388-93. doi:10.1111/j.1467-9280.2009.02454

Riby, D. M., Brown, P. H., Jones, N., & Hanley, M. (2011). Brief Report: Faces Cause Less Distraction in Autism. *Journal of Autism and Developmental Disorders*. doi:10.1007/s10803-011-1266-1

Rizzolatti, G, Fadiga, L., Gallese, V, & Fogassi, L. (1996). Premotor cortex and the recognition of motor actions. *Brain Research Cognitive Brain Research*, 3(2), 131-41.

Rizzolatti, G., & Sinigaglia, C. (2010). The functional role of the parieto-frontal mirror circuit: interpretations and misinterpretations. *Nature Reviews Neuroscience,* 11(4), 264-74. Nature Publishing Group. doi:10.1038/nrn2805

Rizzolatti, G., Fabbri-destro, M., & Cattaneo, L. (2009). Mirror neurons and their clinical relevance. *Neurology,* 5(1). doi:10.1038/ncpneuro

Rogers, S. J., & Ozonoff, S. (2005). Annotation: what do we know about sensory dysfunction in autism? A critical review of the empirical evidence. *Journal of Child Psychology and Psychiatry, and Allied Disciplines,* 46(12), 1255-68. doi:10.1111/j.1469-7610.2005.01431.x

Russell, J., Jarrold, C., & Hood, B. (1999). Two intact executive capacities in children with autism: implications for the core executive dysfunctions in the disorder. *Journal of Autism and Developmental Disorders*, 29(2), 103-12.

Russo, N., Foxe, J.J., Brandwein, A.B., Altschuler, T., Gomes, H., & Molholm, S. (2010). Multisensory processing in children with autism: high-density electrical mapping of auditory-somatosensory integration. *Autism Research*, n/a-n/a. doi:10.1002/aur.152

Rutherford, M.D., & Towns, A.M. (2008). Scan path differences and similarities during emotion perception in those with and without autism spectrum disorders. *Journal of Autism and Developmental Disorders,* 38(7), 1371-81. doi:10.1007/s10803-007-0525-7

Shriberg, L.D., Paul, R, McSweeny, J.L., Klin, A., Cohen, D.J., & Volkmar, F. (2001). Speech and prosody characteristics of adolescents and adults with high-functioning autism and Asperger syndrome. *Journal of Speech, Language, and Hearing Research,* 44(5), 1097-115.

Skipper, J. I., van Wassenhove, V., Nusbaum, H. C., & Small, S. L. (2007). Hearing lips and seeing voices: how cortical areas supporting speech production mediate audiovisual speech perception. *Cerebral Cortex*, 17(10), 2387-99. doi:10.1093/cercor/bhl147

Spencer, J., O'Brien, J., Riggs, K., Braddick, O., Atkinson, J., & Wattam-Bell, J. (2000). Motion processing in autism: evidence for a dorsal stream deficiency. *Neuroreport,* 11(12), 2765-7.

Sumby, W. H., & Pollack, I. (1954). Visual contribution to speech intelligibility in noise. *The Journal of the Acoustical Society of America,* 26(2), 212-215.

Szatmari, P. (2011). New recommendations on autism spectrum disorder. *British Medical Journal*, 342, 2456-2456. doi:10.1136/bmj.d2456

Tager-Flusberg, H., Paul, Rhea, & Lord, C. (2002). Language and Communication in Autism. *Language*, 335-364.

Teinonen, T., Aslin, R.N., Alku, P. & Csibra, G. (2008). Visual speech contributes to phonetic learning in 6-month-old infants. *Cognition*, 108(3), 850-5. doi:10.1016/j.cognition.2008.05.009

Teunisse, J., & de Gelder, B. (2003). Face processing in adolescents with autistic disorder: The inversion and composite effects. *Brain and Cognition*, 52(3), 285–294.

Tomasello, M., & Farrar, M.J. (1986). Joint attention and early language. *Child Development,* 57(6), 1454-63.

Vatikiotis-Bateson, E., Eigsti, I.M., Yano, S., & Munhall, K.G. (1998). Eye movement of perceivers during audiovisual speech perception. *Perception & Psychophysics*, 60(6), 926-40.

Volkmar, F. and Klin, A. (2000). Diagnostic Issues in Asperger Syndrome. In *Asperger Syndrome* Eds. Klin, A., Volkmar, F. & Sparrow, S. (25-71). The Guilford Press, New York.

World Health Organization (1993). *The ICD-10 Classification of Mental and Behavioural Disorders*. Diagnostic Criteria for Research. Geneva: WHO.

Williams, D. (1992). *Nowbody Nowhere*. Times Books, New York.

Williams, J. H. G., Massaro, D. W., Peel, N. J., Bosseler, A., & Suddendorf, T. (2004). Visual-auditory integration during speech imitation in autism. *Research in Developmental Disabilities,* 25(6), 559-75. doi:10.1016/j.ridd.2004.01.008

Wing, L. (1981). Asperger's syndrome: a clinical account. *Psychological Medicine*, 11(01), 115-129.