# A STUDY OF SELECTIVE ATTENTION IN YOUNG AUTISTIC SUBJECTS

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The undersigned, appointed by the dean of the Graduate School, have examined the dissertation entitled

A STUDY OF SELECTIVE ATTENTION IN CHILDREN WITH AUTISM

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A candidate for the degree of Doctor of Philosophy

And hereby certify that in their opinion it is worthy of acceptance.

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# Abstract

Pertinence level of the information in the unattended channel is supposed to play an important role in the process of selective attention in normal subjects (Norman, 1968). The developmental disorder of autism has been found to affect different measures of attention, but the attributes of the information to be ignored have not been investigated. This study examines the effect of information pertinence in the distracting auditory channel on primary task performance in young autistic subjects as compared to normal controls. A dichotic listening procedure and a bimodal selective attention task were implemented. It was found that, although the autistic group performed as fast as control groups, it made more errors on the dichotic listening task even when matched on receptive language abilities. Post-hoc comparisons showed that the autism group had increased error rates with all verbal distractors. All groups were slowest and made the most errors when the irrelevant channel presentation was the participants' name or a negatively, emotionally charged word. The first one or two presentations of these stimuli seemed to attract the most attention. It was concluded that even though children with autism appear to orient to the same types of stimuli as control groups, they are at a disadvantage when processing verbal stimuli in general.

# Introduction

Attentional processes are fundamental to human behavior because they determine which sources of information will be processed. The role of attention in information processing can be examined by asking a person to focus on one stimulus while ignoring another. Understanding of attentional processes and their development is of high priority because they can be seen as prerequisite to the development of higher cognitive functions. Selective attention has been extensively investigated in normal subjects, but interest in the attentional processes in autism is more recent. Autism is a developmental disorder that frequently manifests itself in disturbances of different aspects of attention, as well as other symptoms, such as social inadequacies, behavioral stereotypies, and communication delays. An experience of a selective attention situation was described by Temple Grandin in her book (1996): "When two people are talking at once, it is difficult for me to screen out one voice and listen to the other. My ears are like microphones picking up all sounds with equal intensity. In a noisy place I can't understand speech, because I can't screen out the background noise." This description in conjunction with the anecdotal observations of many parents of children with this disorder, stating that children fail to respond to their name, raise many research inquiries regarding attentional abilities and deficits in autism. Progress towards understanding this complicated disorder, affecting about half a million people in the United States alone, is being made, yet many questions regarding autism still remain unanswered.

In this project we hope to investigate attentional mechanisms in autism using a selective listening procedure based on bimodal selective attention and dichotic listening tasks. In our bimodal selective attention task subjects are presented with a stream of auditory information they are instructed to ignore while performing a task in the visual modality. In the dichotic listening task subjects are presented with two different spoken messages to the two ears simultaneously and are asked to focus their attention to one ear. The advantage of an auditory presentation is that the incoming sensory stimulation cannot be escaped regardless of where attention is directed, unlike the visual modality in which shifts of attention are accompanied by eye movements away from unattended stimuli.

Also, with the auditory modality, using a dichotic presentation, relevant and irrelevant stimuli can be made to reach the sense organs simultaneously, which allows a good measure of where attention is directed. We track attention and distractions by closely following performance on the primary task, which is supposed to preoccupy the subject. In this project primary tasks involve motor responses in the identification of spoken words in the dichotic listening paradigm, and motor responses in following a moving object on the screen (i.e., tracking) in the bimodal selective attention task. Pertinent information in the irrelevant channel is expected to draw subjects' attention away from the primary task. The tasks do not depend on subjects' speech abilities and do not require broad cognitive skills. In the remaining part of the introduction we will first discuss theoretical issues and relevant findings in the topic of selective attention and then review possible changes in selective attention in autism.

Selective Attention:

A key concern for studying selective attention is how much processing of information from the unattended channel occurs. The mechanism that allows us to focus on the relevant channel and to prevent irrelevant information from further processing is called filtering. Filtering is not perfect, and some information from unattended channels gets through. There are several theories that reflect opinions as to what kind of ignored information gets processed. Broadbent (1958) postulated a filter early in the processing system, allowing just the detection of the message and identification of its physical features. His theory was based on his study (Broadbent, 1952) and the work of Cherry (1953) employing the dichotic listening procedure. It was found in those experiments that when subjects were preoccupied with shadowing (i.e., quickly repeating) one auditory channel, they noticed nearly nothing in the ignored channel. Hence, it was concluded that the information processing filter occurred early on, choosing one stream for further processing and discarding other inputs. Shortly afterward, this theory was challenged by a study in which the unattended channel contained subjects' names as a part of the message (Moray, 1959). That experiment showed that sometimes subjects were able to detect their names in the unattended channel (a phenomenon later called the "cocktail party"). It indicated that ignored information was not completely discarded early in the processing, and that at least some of it reached the semantic processing level. Deutsch and Deutsch (1963) took this notion further, concluding that all verbal input was semantically processed independently of the allocation of attention. This notion was called the late filter theory in contrast to Broadbent's early filter theory.

Some findings challenged the late filter theory also. For example, Treisman and Geffen (1967) presented their subjects with dichotic information in which sentences in both channels contained target words. Subjects were asked to shadow one channel and at the same time tap the desk whenever there was a target word in either channel. The measure of target recognition sensitivity was d' = 4.2 on the attended channel and d' = 1.8 on the unattended channel. The late filter theory could not account for this difference because, according to this theory, the target in both channels should be equally processed. An attenuation theory proposed by Anne Treisman stated that different channels of information were not completely blocked out by the filter but, rather, were attenuated, allowing the information most meaningful for the subject to reach the recognition stage. This model could account for both the difference in recognition sensitivity for the two channels and the recognition of one's name in the unattended channel.

Another person to subscribe to the view that importance of information in the unattended channel made a difference in the amount of processing it received was Donald Norman (1968). He suggested the term pertinence to account for the fact that input selection is determined by contextual, grammatical, and meaningful cues, as well as by the physical form of the inputs. According to his theory, certain classes of inputs will have a permanently high level of pertinence, such as the sound of one's name, but most will fluctuate with the expectation and analyses of ongoing events. Pertinence must be determined before or as the input is being analyzed and selected since attention chooses among the various sources of sensory information only after they have activated their representation in storage. In Norman's understanding, raising the levels of pertinence for certain items is equivalent to lowering the threshold for sensory inputs of these items. This theory is also supported by Moray's (1959) findings.

While most psychologists do not subscribe to the extreme early- or late-filter theories any longer, the amount of processing irrelevant information receives is still discussed. For example, Lachter, Forster, and Ruthruff (2004) conducted a series of experiments to support their hypothesis that no unattended stimuli can be identified, in this sense supporting Broadbent's theory. An important distinction that helped them come to this conclusion was between voluntary, endogenously driven shifting of attention and involuntary, exogenously driven shifting (Posner et al., 1980). While voluntary shifts are relatively slow – they require 150-500 msec (Remington & Pierce, 1984), -involuntary shifting becomes evident much faster – after about 50 msec (Tsal, 1983). Thus they argue that this involuntary attention is responsible for identification of irrelevant stimuli that later show signs of orienting. While it is a logical assumption that some form of attention is needed to identify a stimulus, how this choice of which stimulus within the irrelevant stream would draw involuntary attention is made is still unclear.

There are several aspects that can influence one's performance on a selective listening task. One of these aspects is capacity differences between individuals. Large attentional capacity will give a subject an advantage in that he or she might be able to send more information through the filter at once and process it. According to one theoretical account, more efficient attentional capacity will results in the processing of the attended information leaving more room for the processing of the unattended channel. In an experiment with a primary task imposing a high attentional load primary task, much of the free capacity is required by the task, which is likely to result in little additional resources for processing the unattended information. In contrast, a low-load task might require little enough attentional capacity that there is more left to process some of the to-be-ignored information.

Another aspect of filtering that could affect the performance is the difference in the filtering ability. According to an account based on this notion, subjects who are better able to allocate attention consistently to the relevant task, or the message in the attended channel, will fail to process unattended information because it is more consistently filtered out. Subjects might also differ in the ability to inhibit orienting responses to personally significant material in the irrelevant channel of stimuli. In support of these possibilities, for example, Conway et al. (2001) replicated Moray's (1959) experiment and found, just like Moray did, that approximately 33% of subjects reported hearing their own name in an unattended message. In their study, whether the subjects noticed their name negatively correlated with working memory capacities; 65% of subjects with spans in the lowest quartile noticed their name, versus 20% of highest-quartile subjects. This suggests that the subjects with low working memory scores had difficulty blocking out, or inhibiting, distracting information.

These two aspects of attention (which could be termed surplus capacity versus filtering ability) generate opposing expectations for group differences in primary task performance. Group differences in the amount of surplus capacity available for processing the irrelevant channel would allow more processing of that channel in higher-capacity groups, which would slow their reaction times (RTs) to the relevant channel when significant events were presented in the irrelevant channel, distracting them from the assigned task. Group differences in filtering ability, on the other hand, would cause children in the higher-ability group to focus attention more completely on the assigned task, which would result in a lower likelihood of noticing the significant events that were to be ignored and therefore would produce less distraction and less slowing of RTs to the assigned task (similar to the findings of Conway et al., 2001). Although deficits in working memory are not typically found in autism (Ozonoff & Strayer, 2001), it is still possible that the mechanisms of selective attention differ from normal in this group.

The role of pertinence in the processing of the unattended information, specifically using subjects' personal names, has been investigated in the visual modality as well. Shapiro, Caldwell, and Sorensen (1997) have found that attentional blink phenomenon, when impaired processing of a target impairs detection of additional target items that follow closely on its heels, is diminished when those additional targets are subject's personal name. Repetition blindness effect – undercounting of identical items – has been also found to be decreased when subjects were counting their own names, as reported by Arnell, Shapiro, and Sorensen (1999). Mack and Rock (1998) reported that search for subjects' last names yielded slopes generally viewed as representing capacity-free search: the rate of target detection for personal names was 5.7 ms/item, while the rate for control names was 50.6 ms/item. The authors concluded that the name "pops out" in subject's visual field. Wolford & Morrison (1980) reported a study in which subjects had to make parity judgment of numbers that were presented on either side of a word. Subjects significantly slowed down when the word between the digits was their own name. Harris and Pashler (2004) have recently replicated this finding but also elaborated that the name only succeeded in slowing participants down on the first few trials. When names were included on 50% of the trials, reaction times (RTs) failed to increase on those trials. The authors suggested that, with subsequent presentations, subjects perceived a decreased relevance of their names for the task at hand. Harris and Pashler also extended these findings to other pertinent stimuli – negatively emotionally charged words. In order to address Mack and Rock's findings, Harris and Pashler conducted the following experiment: subjects were to make parity judgments on digits surrounded by 6 distractors. When a name was one of those distractors, subjects failed to react to it. However, when the other 5 distractors were covered by grey rectangles, subjects slowed down on the first few trials. This was taken as evidence that personal names, however pertinent, are still subject to capacity limitations, just like other stimuli.

To our knowledge, the "cocktail party phenomenon" was never investigated in children. Assuming that children's selective attention differs from adults only quantitatively, we expect that unattended information will affect RTs and error rates in the primary task performance when the information in the unattended channel is of increased significance to subject. Theoretically, either the capabilities of attention or the items of pertinence could differ between autistic and normal subjects.

Attentional Deficits in Autism:

Autism is a developmental disorder that is behaviorally defined as deficits in the areas of communication, social interactions, as well as restricted repetitive patterns of behavior. This disorder is known to share similarities with Pervasive Developmental Disorder, Not Otherwise Specified (PDD-NOS), Asperger's syndrome, and others, which are combined in a spectrum and more recently were titled Autism Spectrum Disorders (ASD). This complex disorder with an unknown etiology involves fundamental deficiencies in the areas of central coherence; deriving what another person might be thinking based upon his or her behavior, termed "theory of mind"; and central processes that are involved in giving organization and order to our behavior, or executive functions (EF). Weak central coherence, a specific perceptual-cognitive style with preference for processing of local features and difficulties in global processing, is thought by some to underlie the central disturbance in autism (Frith, 1989). Lack of a theory of mind was suggested as a core of autism by Baron-Cohen et al (1985). Deficits in executive functions are known to be implicated in the disorder and have been studied extensively (see review in Hill, 2004). Among other symptoms, autism frequently results in disturbances of different aspects of attention. Attentional differences in autistic subjects as compared to normal controls are not straightforward. We will now review literature on different aspects of attention investigated in autism.

It might be necessary to start the discussion of auditory selective attention in autism with a synopsis of current findings on auditory sensory processing. During the initial, sub-cortical stages of processing structures related to processing via primary auditory pathway appear to be normal in autistic population, while secondary auditory pathway receiving input from reticular activating system, which is a part of brainstem-thalamic system known to be impaired in autism, show abnormalities (for detailed review see Bomba & Pang, 2004).

Once a sound reaches cortical level the first step is sound-feature encoding. It has been widely investigated using event-related potentials (ERP) measured by electroencephalography. In normal adults components associated with sound-feature encoding are P1, N1, and P2. In children those components are P1, N2, and N4. In autism P1 has been found to be diminished in both adults and children (Buchwald et al., 1992), while Townsend and Courchesne (1994) have found that P1 was augmented to stimuli at the attended location or abnormally generalized to distant locations. (Related findings of an ineffective attentional lens were found in behavioral literature by Burack, 1994). Findings related to N1 have been inconsistent partially due to developmental changes unknown until lately. Teder-Salejarvi et al. (2005) in a recent study have found N1 to be abnormal during attention for competing sound sources. In their study subjects were instructed to identify certain pitch targets in the attended channel and ignore all other channels. The behavioral data collected in this experiment showed that in a simple condition with three sound sources and long inter-trial intervals subjects with autism were successful in discriminating sounds coming from one sound source as compared to two sound sources just six degrees apart. In a difficult condition with eight sound sources and continuous stream of sounds, the autistic group was slower and less accurate in detecting targets from a designated sound source than control group. It was concluded that patients with autism have a fundamental deficit in spatial focusing of auditory attention and have diminished ability to selectively attend to one sound source among many in the environment.

The next step of cortical auditory processing is auditory discrimination. It has frequently been studied using the mismatch negativity (MMN), an ERP component elicited by an infrequent change in a repetitive sound sequence. MMN has been found normal or enhanced in autistic sample using tones (Gomot et al., 2002) and vowels (Ceponiene et al., 2003), but showed deviance using consonant phonemes (Kuhl et al., 2005). Gomot et al. considered that enhanced MMN for tones in the autistic sample might be related with anecdotal observations that autistic individuals sometimes appear to have heightened pitch sensitivity.

Finally, attentional effects are found at the P300 latency, which is supposed to follow unexpected sensory stimuli or stimuli that provide useful information to the subject, generally related to task. Its latency is viewed to reflect the amount of time necessary to come to a decision about the stimulus. The P3a component is normal in the autistic group using tones but is absent to pitch changes in vowels (Ceponiene et al., 2003). P3b shows amplitude attenuation for tones (Oades et al., 1988) and phonemes (Dawson et al., 1988) in autistic children but not for words (Erwin et al., 1991) in adults. Latency of P3b has been found unaffected by the above experiments. Oades et al. (1988) interpreted these findings as difficulty attaching significance to unexpected stimuli in autistic patients. A recent developmental study by Hoeksma et al. (2006) demonstrated that children with PDD showed smaller P3 amplitudes but no abnormalities in selective attention as measured by auditory Processing Negativity (PN), while adolescents with PDD showed larger PN but no P3 abnormalities. It was concluded that abnormalities in selective attention in adolescents with PDD have a normalizing effect on P3 and possibly act as a compensatory process.

Other psychophysiological measures also show abnormalities of sensory processing and attention in autistic group. Belmonte and Yurgelun-Todd (2003) using functional magnetic resonance imaging technology found evidence to suggest suppression of irrelevant sensory information at a later, less efficient time than typically found. The authors called it a “processing bottleneck”: in the absence of a normally functioning mechanism to bias sensory processing towards attended stimuli, all stimuli receive much the same degree of sensory evaluation, and the irrelevant stimuli must then be actively discarded. According to the authors, “perceptual filtering (in autism) occurs in an all-or-none matter, with little specificity in selecting for the location of the stimulus, for behavioral relevance of the stimulus, or even for sensory modality.” It is worth noting that the groups in that study did not differ on behavioral measures (those consisted of pointing fingers in the direction of perceived covert visual attention when instructed to keep eyes on a fixation cross), and the authors also suggested the presence of some compensatory mechanisms. Boddaert et al. (2004) in a study using positron emission tomography in a group of autistic children found decreased activation of the left speech areas when listening to speech-like sounds, which confirmed similar results previously found in adults with autism.

To summarize literature presented so far, there is psychophysiological evidence to suggest deviations of auditory attentional mechanisms in adults and children with autism. Speech-related sounds might be at a particular disadvantage. Data indicates a deficit in spatial focusing of attention with competing sound sources. It has been suggested that filtering is more effortful in individuals with autism and might occur later in the processing. Yet some have found selective attention to be unaffected in children with autism (Hoeksma et al., 2006). In certain situations behavioral measures can be normal even if electrophysiological measures are atypical, possibly due to some compensatory mechanisms.

Most of the behavioral research on auditory attention in autism has been done by those subscribing to the theory of executive dysfunction in autism. As mentioned earlier, the executive system manages other cognitive processes and behavior. It is known to be involved in planning, organizing, initiating and inhibiting actions, and selecting relevant sensory input. Several executive functions have been found to be atypical in autism. Among those with the most consistent results is mental flexibility. Poor cognitive flexibility results in problems with shifting to a different thought or action according to changes in situation. Several studies have found difficulties in cognitive flexibility in autistic populations using tasks such as the Wisconsin Card Sorting test (WCST) or

Intradimensional-Extradimensional shift – tests in which discrimination must be made on within and/or between set criteria (Rumsey & Hamburger, 1990; Ozonoff & McEvoy, 1994; Shu et al., 2001). However, Pascualvaca et al. (1998), while finding differences in WCST performance in their group of children with autism and control group, have shown no difference between the groups on a computer analogue of WCST and another computer test requiring continuous shifting. It has been suggested that computer testing in certain situations might help the performance of autistic subjects by minimizing social factor involved in the procedure.

Courchesne et al. (1994) presented autistic participants and control groups matched on chronological and mental ages (MA) with a task requiring shifting attention between visual and auditory modalities and a task requiring focused attention. While the group with autism had no difficulties with the focused attention task, they were significantly slower and less accurate when they had to quickly shift attention between sensory modalities. Wainwright and Bryson (1996) used a simple visual orienting paradigm where subjects had to detect a target to the left or to the right of fixation point. Difficulties of the autistic group in shifting of attention were evident in the condition of increased processing demand, when central targets were added to the procedure, so that in addition to detection, subjects had to identify the target first and discriminate it from the fixation cross presented centrally prior to the appearance of the target. The control group was faster in identifying peripheral targets, which involved only detection, while the autism group performed better with central targets. This finding led the authors to suggest that difficulties shifting attention render fewer resources available for processing additional information in the autism group.

A shift task is thought to involve disengaging of attention. A task developed by Posner (1978) was employed in investigating this matter (Casey et al., 1993). In this task, subjects are asked to focus their attention to the middle of the screen and press a button as fast as they can once they detect a target. A cue to location is presented before the target comes up with a variable time of onset (50-1000 msec). During valid trials the location cue is followed by a target presentation in the same location, and during invalid trials the target is presented at a different location than the cue. The RTs are analyzed as a function of the location of the target relative to the cue and the time elapse between the cue and the target.  There are three mechanisms known to be involved in this task: disengaging of attention, moving attention to a new location, and engaging attention at the new location.  The RT differences between different types of trials allow inferences about each of these three mechanisms possible.  In the Casey et al. study, autistic subjects showed a significant discrepancy between RTs to validly and invalidly cued targets compared to normal volunteers.  This pattern indicated a deficit in the disengagement of attention.  It is worth noting that some researchers failed to find disparities in disengaging and shifting attention in autistic children (Burack & Iarocci, 1995; Leekam et al., 2000).

Another executive function studied in autism quite extensively is inhibition.  It has generally been found to be unaffected in autism using a Stroop task (Eskes et al., 1990; Ozonoff & Jensen, 1999; Christ et al., 2006), Go/No-Go task (Ozonoff et al., 1994), negative priming test, or Stop-Signal task, which requires withholding a response when an auditory signal is presented (Ozonoff & Strayer, 1997). However, Russell et al. (1993) and Hughes et al. (1994) reported that autistic children perseverated significantly more on a Windows (an assessment of prepotent inhibition, when a desired object can be obtained by pointing away from it) and a Detour-Reaching task (obtaining an item by first making an unrelated action).  Also, Christ et al. (2006) found that the autistic group showed impaired performance on incompatible trials of a flanker task, when the target was flanked by a stimulus mapped to the alternative response button, the task also taken to represent inhibitory control.  It has been suggested that the difference in performance between autistic and control groups on some tests supposedly measuring the same ability might lie in whether a test has an apparent rationale or whether rules of a test could be viewed as arbitrary (Russell, 2002).

Another topic of study which presents a complicated pattern of results is that of orienting.  Speed of attention orienting can be examined using Posner's paradigm described above and analyzing RTs on valid trials with short versus long cue-to-target delays.  The bigger the difference, the poorer the ability to orient attention to the cued location.  In Townsend et al. (1996) normal controls showed minimal differences in RTs to valid trials with short and long cue-to-target delays, while the autistic subjects were significantly slower in responding to trials with short cue-to-target delays, indicating poor orienting. Iarocci and Burack (2004) stressed the importance of differentiating between overt and covert orienting. In their study of covert visual orienting using a flanker task (the interval between the offset of the cue and the presentation of the target was 150 msec, within which time the shift of attention is independent of head or eye movements) conditions were varied with regard to location of the target, location of the cue, presence of distractors, and cue validity. Groups of autistic children and MA-matched controls showed similar results with respect to cue validity and distractors. Cue validity, while not carrying permanent personal pertinence to subject, might be considered pertinent information as it relates to a task at hand.

Several other findings relevant to attentional abilities in those diagnosed with autism need to be noted. A phenomenon called stimulus overselectivity (Lovaas et al., 1971) refers to their inability to respond to all characteristics of an object equally and to randomly assigning extra value to one characteristic during discrimination tasks. Yet another finding was described by Burack (1994). In his study the conditions varied with regard to the presence or absence of a window and number (zero, two, or four) and location of distractors. His results showed that a presence of an exogenously imposed focus (ex, a highlighted window) without distractors greatly aided the performance of autistic subjects in a simple RT identification task. In the presence of distractors this aide was hindered. The author interpreted this as an inefficient attentional lens in autistic individuals.

Several studies have shown that autistic populations might have difficulty orienting to social cues. Relevant to investigation of effect of personal pertinence on shifts of attention in an autistic population was a study by Dawson et al (1998). It compared children with autism and developmentally matched controls on their ability to visually orient to social (calling name, clapping hands) and nonsocial (rattle, jack-in-the-box) stimuli. The autistic group exhibited poor orienting to all stimuli with social orienting being worse of the two. Those that oriented to social stimuli did so slower than control groups. Yet a study by Leekam et al. (2000) showed that autistic children had no difficulty in shifting attention and were faster than developmentally delayed controls in orienting to targets (toy trains presented centrally and peripherally sequentially or at the same time) but had difficulty in using social information for it. The authors presented their participants with a joint-attention dyadic (child-adult) and triadic (child-adult-object) levels of interaction. Children had to follow either the adult's head turn or gaze to score on the task. Children with autism performed worse than the control group in both situations.

To summarize behavioral literature relevant to attentional capacities in autism, while performance on inhibition appears to be test specific, there is evidence to suggest difficulty in shifting of attention, particularly between sensory modalities. This difficulty might stem from a more specific deficit in disengaging of attention from an ongoing task. While overt orienting might be impaired in autism, it appears that covert orienting at least in visual modality is intact. Individuals with autism are particularly at disadvantage when a situation calls for the use of social cues for orienting.

Predictions:

The dichotic listening procedure has never been used in the autistic population to study inhibition or orienting. A study by Teder-Salejarvi et al. (2005) using competing sound sources suggests deficit in special focusing of auditory attention if a task presents certain difficulty level. While it is hard to compare difficulty levels of our tasks and those of Teder-Salejarvi et al., this finding prompts us to expect slower RTs in autism group in dichotic listening task if autistic subjects display impairment in localizing the source of each auditory stream. Existing findings on inhibition make it difficult to predict performance of autistic children compared to controls, as inhibition results also appear to be test specific. However, we expect some orienting to pertinent information in the distracting channel in both of our groups based on findings from typical populations (e.g., Moray, 1959). When this happens, we might see differences in orienting between our groups based on the speed of disengaging and shifting attention (Casey et al., 1993), if shifting does differ in our groups. According to Wainwright and Bryson (1996), attention shifting leaves fewer resources available for processing any other information in participants with autism. Based on this we should expect error rates as well as RTs to be disproportionately affected by distractions in our autism sample.

If the conclusion of difficulty in autistic subjects in attaching significance to unexpected stimuli (Oades et al., 1988) can be generalized to our study, it is possible that the autistic group would not, in fact, orient to personally significant but unexpected stimuli in the irrelevant channel.  Yet, there is evidence to suggest normal orienting at least in some situations (Iarocci & Burack, 2004; Leekam, et al., 2000).

There is enough evidence to predict that we will see differences in orienting towards social information, with control group orienting to name more readily than autistic group.  While Conway et al. (2001) showed that low-span participants are more distracted by their names in the irrelevant channel, this factor should not influence group differences as working memory has been found unaffected in individuals with autism (Ozonoff & Strayer, 2001).  Since autistic subjects seem to experience difficulty in using social information for attentional tasks, one might hypothesize that social information might not carry the same pertinence to autistic patients as it does to control group.  Still it is reasonable to assume that if presented with distracting stimuli of similar pertinence value, autistic subjects will orient to it with the same frequency as the control group. Thus, an interaction might be expected with the control group showing distraction in the name condition and the autism group showing distraction in pertinent conditions of a nonsocial nature.

Presentation frequency could have an impact on the orienting to the unattended information through two possible mechanisms.  One mechanism is the increase of the likelihood of the orienting due to activation passing the attentional filter threshold. According to Norman's theory, the most pertinent items need the least amount of activation and will need to be presented the least amount of times to allow orienting.  The second possible mechanism could work through the effects of adaptation on attention: subjects could fail to respond to the information presented multiple times because of a possible decrease in the perception of relevance (Harris & Pashler, 2004).

We plan to determine whether the group variable interacts with the information pertinence. The literature is indeterminate regarding the question of whether there are basic group differences in attentional capabilities that should affect performance in our tasks.  However, we hypothesize that, even if autistic and normal children show similar distractibility for personally pertinent information, we expect to find differences in the type of information that autistic and control subjects find pertinent.  The normal control subjects are more likely to have pertinent information of a social nature.  As a result, we expect normal controls to show bigger orienting to their names than autistic subjects will.

Also, we are interested to see if there is an effect of presentation frequency, with the pertinence decreasing over repetitions of a word because of the habituation of the orienting of attention with repetition (e.g., Cowan, 1988).

## Method

Design:

Participants were scheduled for the individual appointments that took approximately 1.5 to two hours. The assessments – Peabody Picture Vocabulary Test - Third Edition (PPVT-III; Dunn, Dunn, & Williams, 1997) and Leiter-R (Roid & Miller, 1997) - were performed first. These were followed by two experimental tasks – dichotic listening procedure and discontinuous tracking task (see description below). Reaction time data were collected for both tasks and proportion correct was analyzed for the dichotic listening task. These data were expected to reflect the effects of the group variable (autism versus control) and the distractor trial types variable. There were five trial types: neutral distractors, noise, name, negative distractors, and positive distractors, as well as two, before and after, baseline conditions, when no distractors were presented.

Subjects:

The participants included 24 young autistic children and 64 typically developing control subjects. All participants in the autistic group had a prior clinical diagnosis of autism or PDD-NOS (DSM IV-TR, 2000). One autistic subject was unable to generate data due to limited receptive language skills. The final group of autistic participants included 5 girls and 18 boys ages 4 years and 10 months to 15 years, 7 months (see Results section for detailed characteristics of groups). Two of the children had a diagnosis of PDD-NOS, the rest had been diagnosed with autism. In one case a child received a diagnosis of ADHD with language delay first before that diagnosis was changed to autism. For simplicity purposes, all participants of this group will be called "autistic" in this manuscript, as PDD-NOS sometimes is equated to high-functioning autism. Although participants did not have comorbid DSM clinical diagnoses, parents reported that one child had a seizure disorder and two had allergies. Several parents reported difficulties with attention/hyperactivity observed at home and/or school. Two children were reportedly taking SSRI medications (Zoloft, Prozac) for global autism severity (repetitive behavior and aggression), one was taking stimulant (Strattera) for difficulties with attention, two were taking Clonidine for sleep disturbances, and one was taking allergy medication (Zyrtec). Parents of two children reported having children on a strict diet (gluten and/or casein free), while others said that they try to restrict intake of particular types of food or subscribing to diet inconsistently.

Twenty-three autistic participants were matched on nonverbal mental age (MA) as assessed by Leiter-R brief IQ measurement to typically developing control subjects for the analyses described below. The final group of nonverbal MA control participants included 8 girls and 15 boys ages 4 years, 6 months to 9 years, 2 months. Another control group was matched on verbal MA as measured by PPVT-III. This group also included 8 girls and 15 boys ages 4 years, 6 months to 8 years, 10 months. A subset of autism was matched to another group on chronological age. The matched autistic subset included 4 girls and 10 boys ages 4 years, 10 months to 9 years, 10 months. The matching control group consisted of 10 girls and 4 boys. Children with autism were recruited for participation through an assessment and consultation clinic and internet support sites for parents of children with autism. Typically developing children were recruited through the public school system.

<u>Apparatus and Stimuli:</u>

Auditory stimuli were recorded via microphone using a notebook computer and presented using the notebook computer with speakers. Stimuli included sets of words recorded in male and female voices and common environmental sounds (e.g., animals, vehicles, etc.). Visual stimuli, as well as common environmental sounds, were downloaded from the Microsoft Office Clip Art and Media gallery and were either photographs of objects or pictures drawn maximally close to images. No cartoon drawings were used. Responses for one of the tasks, the dichotic listening task, were collected by means of a serial response box. Three buttons were used to correspond to three visual stimuli presented on the screen (see description below); the extra two buttons on the serial response box were covered with tape and attempts to push them resulted in no effect. Responses for the other task, the tracking task, were collected via computer mouse.

The recorded words were composed of two-syllable high-frequency words from MRC Psycholinguistic Database (http://www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm) with an age of acquisition no higher than 350 and with a concreteness rating no lower than 300. There was a total of

126 words (see List 1). The recorded sound files presented during the tasks also included 3 words provided by a caregiver to represent items highly reinforcing for the child, 3 words provided by a caregiver to represent items unpleasant for the child, and the subject's name. An effort was made to fit the name in a two-syllabic format with a stress on the first syllable for easier synchronization with other words. For example, if a child's full name was Alexander, "Alex" was used in the experiment. Pertinent stimuli did not match any of the words in the primary task or any neutral distractors. The pertinent stimuli were at least 5 seconds apart. The stimuli provided by the parents came from a questionnaire assessing the pertinence value of stimuli (see Appendix A).

Procedure:

Prior to the appointment, parents were to fill out and return a questionnaire about the child's personal preferences. Parents were to generate their child's likes and dislikes and then to rank common likes and dislikes on a 20-point rating scale. Parents also were to fill out the Gilliam Autism Rating Scale (GARS; Gilliam, 1995). Parents of all autistic subjects and nineteen control subjects of the final nonverbal MA-matched group submitted information on the GARS assessment questionnaire. While typically GARS is collected in an interview format, practical issues prompted us to collect data via the questionnaire. There has been recent discussion regarding this assessment's tendency to underestimate diagnosis of autism (Lecavalier, 2005). Since we did not use this assessment for diagnostic purposes but only as an estimate of symptomatology in our groups, the assessment sufficed this purpose.

The appointment for the experiment took approximately an hour and a half, although some children with autism required two appointments because of a limited attention span. Children were offered a choice of a toy or a book at the end of their participation. Parents supplemented with external motivators if they felt that more powerful reinforcers were needed, such as the promise that "If you do well, we'll go to the swimming pool" or access to sweets depending on the child's interest and level of comprehension. Verbal praise was given by the experimenter for attentive participation during the assessments. Within the experimental task, children were entertained with flashing colored stars for correct answers, whereas incorrect answers did not result in any visual effects and were followed by the next trial.

The procedure consisted of two assessments and two experimental tasks. The PPVT-III assessment was conducted first. In the PPVT-III four pencil drawings are presented in a 2-by-2 format and a word is provided aurally for identification. This achievement test is designed to measure a subject's receptive vocabulary for American English. The PPVT-III has been standardized on a national sample of children as young as 3 and adults. The subject's performance results in basal and the ceiling levels which are used in calculating the overall score. Although it is not a comprehensive test of general intelligence since it measures only one important facet of intelligence – vocabulary, - PPVT-III generates an IQ score and gives an estimate of MA.

The Leiter-R assessment was conducted next. The Leiter-R is a nonverbal assessment of cognitive abilities in children and adolescents ages 2 to 21. The assessment includes 2 groups of subtests (Visualization / Reasoning and Attention / Memory) each consisting of 10 subtests. A nationally-representative norming sample provided scaled scores for each subtest. Instructions for various subtests are given in a nonverbal format by using various prompts for a predetermined number of trials. Each subtest involves presentation of tasks on an easel. A child is given cards to be placed in order, in correct slots, to be selected from, or to be identified on the easel, depending on the task of the subtest. Each subtest is stopped when a certain number of mistakes is made.

Four of the Visual / Reasoning subtests were offered to participants during the assessment (two additional subtests, Matching and Classification, were offered to younger participants but were not scaled for older participants). These four subtests were used to generate Brief IQ measure and the MA estimate that was used to later match the participants of two groups. Below is the brief description of the subtests.

- The *Figure Ground* subtest was performed first. Children are provided with cards representing a particular item or part of an item depicted on a larger page and are encouraged to locate that object.
- The *Form Completion* subtest requires children to mentally put together parts of objects that are depicted on a card and find that object on the page. The page depicted either a scene or a number of various objects.

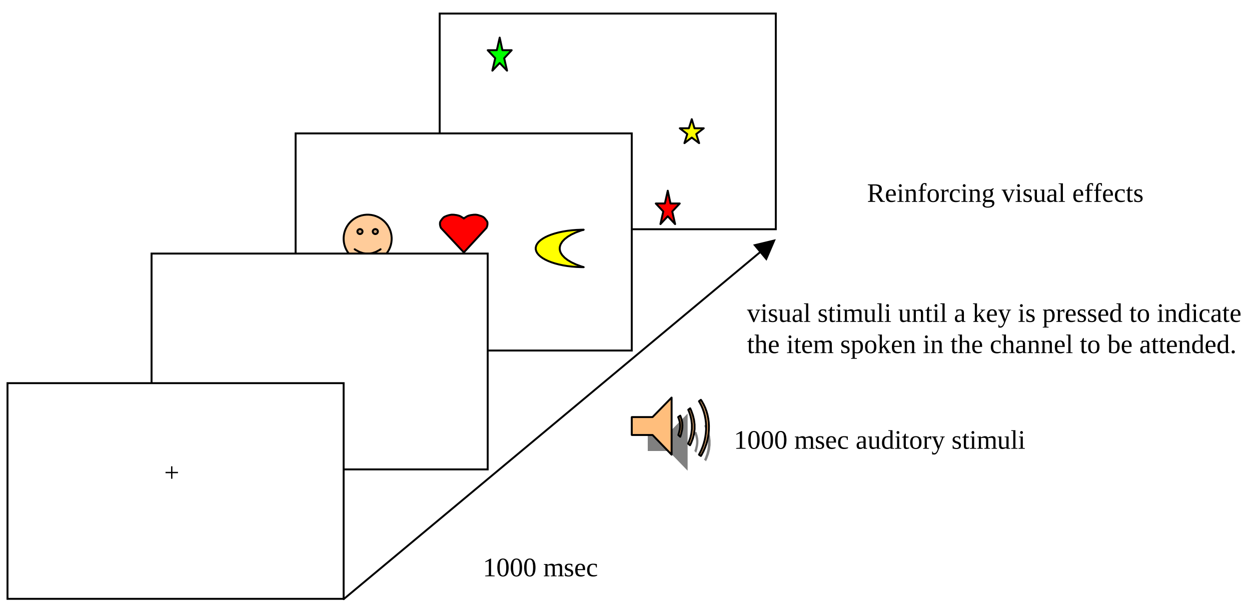
- In the *Sequential Order* subtest children are encouraged to put cards in order, provided with the first and last items, just one item, or given extra cards that need to be left out.
- The *Repeated patterns* subtest encourages children to continue the pattern and sometimes has extra cards that do not fit the pattern.
- The *Matching* subtest is a matching task where the amount of visual information on the cards is increased with each step. It is scaled for children 2-10 years old.
- The *Classification* was the last subtest performed. Children are supposed to sort by categories in this subtest. It is scaled for children under 6 years of age.

Two experimental tasks followed the assessments. The first task was a selective listening task and the second was a discontinuous tracking task with auditory distractors. Each task lasted approximately 15 minutes, started with a practice and baseline RT collection, and ended with another baseline RT collection.

<u>Dichotic listening task.</u> During this task participants were presented with a pre-recorded auditory stimulus and three visual stimuli presented horizontally on a computer screen, one of which corresponded to the auditorily presented word and the other two were distractors. Participants were asked to "choose a picture that goes with the word". A choice was made via a serial response box, which was placed on top of a shelf that covered the keyboard. The left button on the serial box corresponded to a picture on the left of the screen, the middle button corresponded to the middle picture, and the right button corresponded to the picture on the right. Participants were given verbal instructions with pointing as well as modeling prompts. Practice trials ensured that subjects understood the instructions correctly. A trial consisted of a 1000 msec blank screen with a fixation cross in the middle, 1000 msec for auditory presentation, a response screen with 3 pictures that stayed up until the response was made, and 2000 msec of reinforcing visual effects in case of the correct picture identification (fig 1a). If the response was incorrect, the new trial self-initiated without visual effects. During practice and baseline collection, auditory information was presented in a male voice. During the main part of task a female voice was also added and auditory information was presented in two channels. The two channels were maximally synchronized in their stress pattern. The subjects were instructed to continue to listen to the male voice and

ignore the female voice.  The second auditory channel contained four types of information: the subject’s name, words signifying reinforcing items for the subject, words associated with negative items for the subject, environmental sounds (e.g., car honking, ambulance siren), and filler words that are neutral in their meaning. The subject’s name and “reinforcing” and “negative” words were repeated 3 times each at various times during the main part of the experiment.  The task consisted of 21 baseline trials, followed by 63 dichotic trials (21 pertinent trials, 21 environmental sounds trial, and 21 filler word trials), followed by 21 more baseline trials.  Reactions times and proportion correct data were recorded.

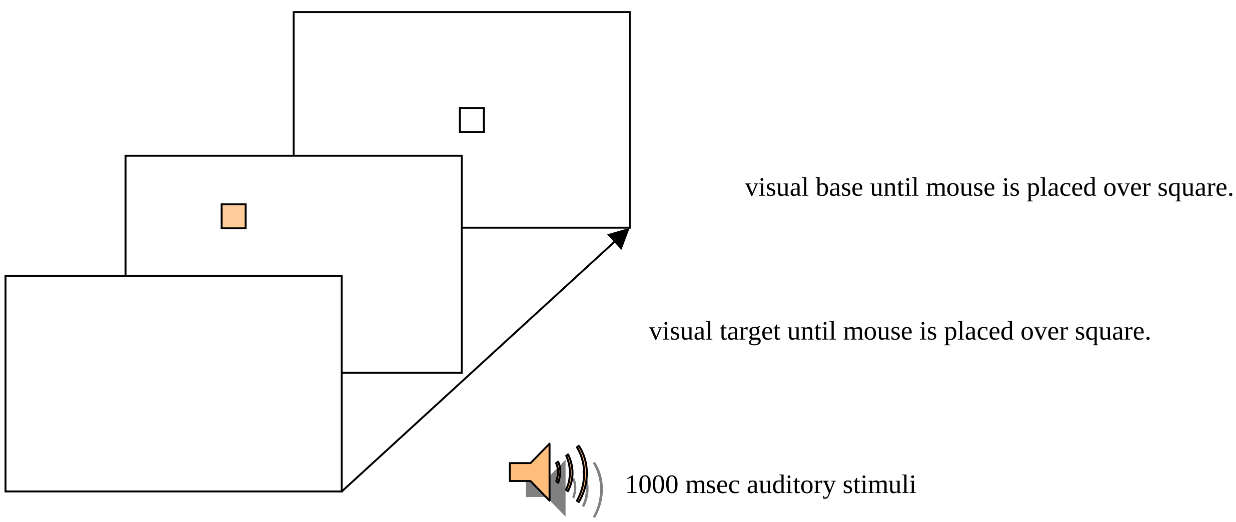
Figure 1a.  Timeline for dichotic listening task trials.




<u>Discontinuous tracking task.</u>  Since both tasks involve selective attention we named our bimodal selective attention task a discontinuous tracking task.  During this task subjects were asked to position a computer mouse within colored squares that appeared at different locations on the screen.  The sides of the squares were 1 cm long. At the beginning of each trial a mouse was located at the center of the screen, as a colored square would appear at random locations along a circumference of an invisible circle, so that the distance between original point and the target was always constant.

Each trial consisted of a movement away from the center of the screen and back. A baseline RT measure was collected first and last and was 10 trials long, no auditory stimuli were presented during the baseline. The main part of the task included auditory distractors presented in a female voice. Subjects received instruction to ignore the voice and continue with the task. The distractors were the same as in the selective listening task and were presented in the same order. Trials consisted of auditory presentation for up to 1000 msec, immediately followed by a target colored square which stayed on the screen until the mouse cursor was placed within the square, followed by a base white square which also stayed on the screen until the mouse cursor was placed within it (fig. 1b). This way each trial originated in the middle of the screen so that a subject had to have a cursor in the middle before taking it to the colored square. Practice trials ensured that subjects understood the directions. The length of the trials as well as the continuous distance from the target were recorded. Children generally found the task engaging.

Figure 1b. Timeline for discontinuous tracking task trials.



## Results

The group with autism was matched to the first control group on the Leiter-R MA estimate. According to a Mann-Whitney U-test test, the groups did not vary significantly on the receptive vocabulary test PPVT-III, U=186, p=.087, although the control group had a higher mean MA on this estimate. The groups were significantly different on the GARS measure, U=43, p=.000. Another group of typically developing children matched with autism group on the PPVT-III was added to control for verbal ability. The Mann-Whitney U-test test indicated that the autism and the verbal MA age control groups did not vary significantly on the Leiter MA measure, U=191, p=.106, with the control group having a lower mean nonverbal MA than autistic group. The verbal MA matched control group and autism group significantly differed on the GARS scores, U=28, p=.000. Group characteristics are presented in Table 1. A subset of the autism group was matched to the control group on chronological age. These groups did differ on the PPVT-III, U=35, p=.004, but not on the Leiter, U=68, p=.168. The groups also differed on the GARS measure, U=39, p=.012. Characteristics for those smaller samples are presented in Table 2. More details can be seen in Appendix B.

Table 1. Matched groups characteristics.

| Groups | Age in months | | GARS | | PPVT-III in months | | Leiter in months | | N |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | |
| Autism | 109 | 30 | 85 | 13 | 79 | 32 | 87 | 22 | 23 |
| Nonverbal MA control | 79 | 17 | 60 | 14 | 93 | 42 | 87 | 22 | 23 |
| Verbal MA control | 74 | 17 | 51 | 21 | 80 | 30 | 76 | 18 | 23 |

Table 2. Matched groups characteristics: autism and chronological age subsets.

| Groups | Age in months | | GARS | | PPVT-III in months | | Leiter in months | | N |
|---|---|---|---|---|---|---|---|---|---|
| | Mean | SD | Mean | SD | Mean | SD | Mean | SD | |
| Autism | 91 | 19 | 68 | 17 | 68 | 17 | 79 | 15 | 14 |
| Chronological age control | 90 | 18 | 48 | 25 | 94 | 23 | 92 | 26 | 14 |

Dichotic listening task. Each matched pair of subjects across groups was counted as one case resulting in group becoming a repeated measure (see more conservative analyses in Appendix E). Medians were used for all the reaction times analyses. Only correct trials were used, so that if a participant was missing data in one of the cells, the case was eliminated from the analysis. GLM Repeated-Measures factorial ANOVA of the dichotic listening task reaction times was performed with autism and nonverbal MA matched group first, with trial types as within-subject factor. The group with autism was significantly slower than the control group: F(1, 19)=9.91, MSE=1254541, p=.005 (n=40). The median RT for receptive identification of a word with an auditory distractor present for the group with autism was 2271 msec and for the control group 1849 msec. There was a significant difference in RT for trials with different types of auditory distractors: F(6, 114)=5.64, MSE=556358, p=.000. While noise, neutral words, words associated with positive things in the distracting channel generated similar RTs, trials with personal names and words associated with negative things generated RTs slower by about 300 msec (see Table 3 for mean median values). There was no interaction between group and trial type variables: F(6, 114)=.50, MSE=550310, p=.807.

Table 3. Mean Median RT across nonverbal MA control and autism groups in dichotic listening task by trial type in msec.

| Trial Type | Mean Median | St. Error |
|---|---|---|
| Baseline1 | 1747 | 163 |
| Baseline2 | 1797 | 196 |
| Noise | 1906 | 135 |
| Neutral | 2076 | 157 |
| Positive | 2035 | 150 |
| Name | 2374 | 354 |
| Negative | 2484 | 249 |

To investigate the nature of the main effect of group on RT, a different control group was matched on verbal MA as measured by PPVT-III. The same type of repeated-measures ANOVA of the dichotic listening task RT as before was performed with trial types as within-subject factor but using the new control group. There was no main effect of group this time: $F(1, 20)=.44$, $MSE=1507634$, $p=.515$ ($n=42$). Median RT for receptive identification of a word with an auditory distractor present for the group with autism was 2314 msec and for the control group 2218 msec. Again there was a significant difference in RT for trials with different types of auditory distractors: $F(6, 120)=6.02$, $MSE=564547$, $p=.000$. There was no interaction between group and trial type variables: $F(6, 120)=.54$, $MSE=603310$, $p=.776$. Figure 2 shows performance of the autism group and both control groups by trial type.

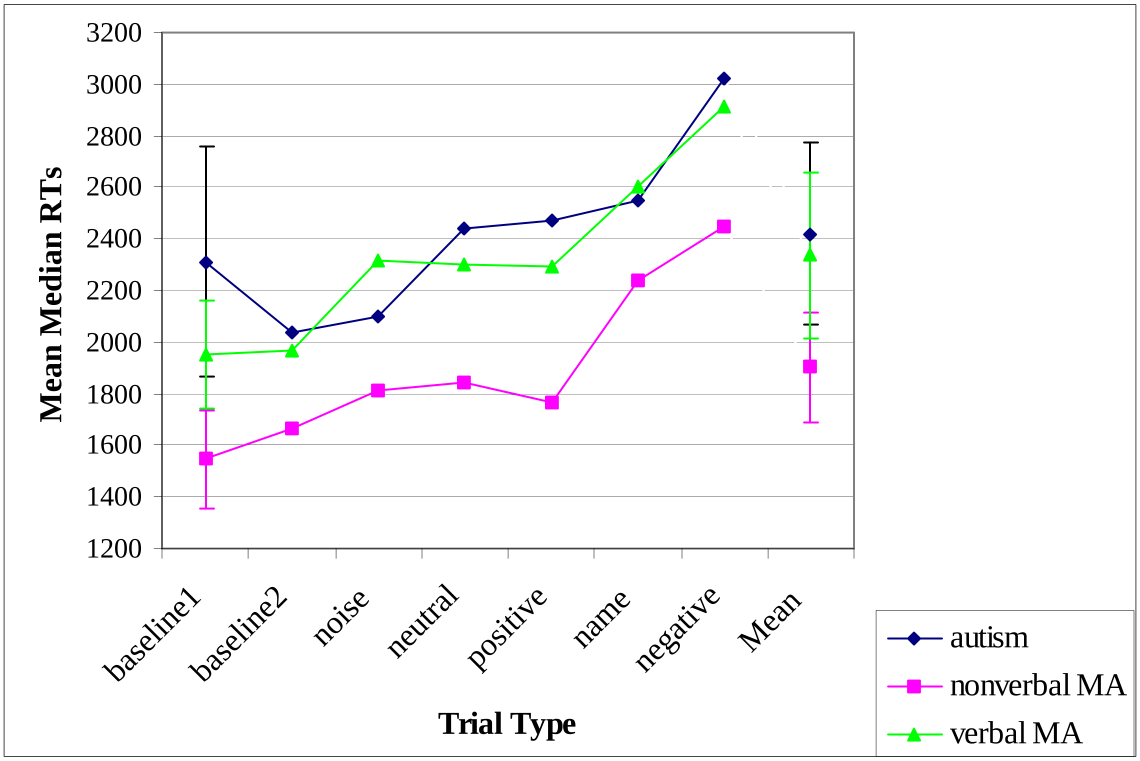



Figure 2. Interaction of group by trial type as measured by RT in dichotic listening task with autism group and control groups matched on verbal ability and nonverbal MA. Error bars on the baseline1 denote within-subject 95% Confidence Intervals (Loftus & Masson, 1994), error bars on the Mean are between-subject 95% CI.

Another control group was matched by chronological age. Only a subset of our autism group could be matched to the control sample, hence this control group is presented separately. The same Repeated-Measures ANOVA of the dichotic listening task RT was performed with trial types as within-subject factor with the new control group. There was a main effect of group, as in the analysis with nonverbal MA matched control group: $F(1, 12)=14.14$, $MSE=1872300$, $p=.003$ ($n=26$). The median RT for receptive identification of a word with an auditory distractor present for the group with autism was 2582 msec and for the control group 1820 msec. Again there was a significant difference in RT for trials with different types of auditory distractors: $F(6, 72)=2.54$, $MSE= 868045$, $p=.027$. There was no interaction between group and trial type variables: $F(6, 72)=.65$, $MSE=735308$, $p=.689$. Mean median RTs for both groups can be found in Table 4.

Table 4. Mean Median RT for chronological age control and autism groups in dichotic listening task by trial type in msec.

| Group | Trial Type | Mean Median | St. Error |
|---|---|---|---|
| CA control | Baseline1 | 1393 | 123 |
| CA control | Baseline2 | 1419 | 124 |
| CA control | Noise | 1695 | 206 |
| CA control | Neutral | 1730 | 198 |
| CA control | Positive | 1882 | 309 |
| CA control | Name | 2017 | 252 |
| CA control | Negative | 2320 | 324 |
| Autism | Baseline1 | 2542 | 351 |
| Autism | Baseline2 | 2294 | 318 |
| Autism | Noise | 2214 | 174 |
| Autism | Neutral | 2650 | 208 |
| Autism | Positive | 2522 | 197 |
| Autism | Name | 3087 | 673 |
| Autism | Negative | 2767 | 226 |

Newman-Keuls comparisons of differences between ordered means for trial types and both groups were performed. The only significant difference was between negative information and baseline1 for the nonverbal MA matched control group. Verbal MA matched control group showed $p<.05$ between the negative stimuli trial type and the baseline conditions. Autism group had no significant differences in any of the analyses, neither did the CA matched control group.

Trial types separated by serial position of presentation (i.e., name/negative/positive stimuli presented for the first time, name/negative/positive stimuli presented for the second time, name/negative/positive stimuli presented for the third time) was performed with the 3 control groups described above. Due to the use of correct trials data only in RT analyses, name presentations resulted in some blank cells, which required removal of those subjects from analyses. The resulting samples (n=10 for the full sample, n=8 for comparison with chronological age controls) were too small to draw conclusions from.

Factorial ANOVA of the dichotic listening task proportion correct was performed with trial types as within-subject factor. The nonverbal MA control group was used first. There was a main effect of group: $F(1, 22)=16.33$, $MSE=.059$, $p=.000$. The group with autism made significantly more errors (M proportion correct = .77) than the control group

(M proportion correct =.88). There also was the main effect of trial type: F(6, 132)=29.78, MSE=.018, p=.000. Participants made more errors on trials when the distractors were the name and words associated with negative stimuli (see Table 5 for means of proportion correct). The interaction between variables did not reach a significance level of .05: F(6, 132)=1.77, MSE=.023, p=.111.

Table 5. Means of proportion correct across nonverbal MA control and autism groups in dichotic listening task by trial type.

| Trial Type | Mean | St. Error |
|---|---|---|
| Baseline1 | .95 | .020 |
| Baseline2 | .95 | .030 |
| Noise | .87 | .029 |
| Neutral | .83 | .037 |
| Positive | .83 | .026 |
| Name | .67 | .067 |
| Negative | .70 | .038 |

The same Repeated-Measures ANOVA of the dichotic listening task proportion correct was performed with verbal MA as the control. There was a main effect of group: F(1, 22)=11.41, MSE=.049, p=.003. The mean proportion correct for verbal MA control group was .86. There also was the main effect of trial type: F(6, 132)=25.32, MSE=.025, p=.000. The interaction between variables was not significant: F(6, 132)=1.52, MSE=.016, p=.177. Performance of both control groups and of the autism group by trial type on this dependent variable are shown in Figure 3.

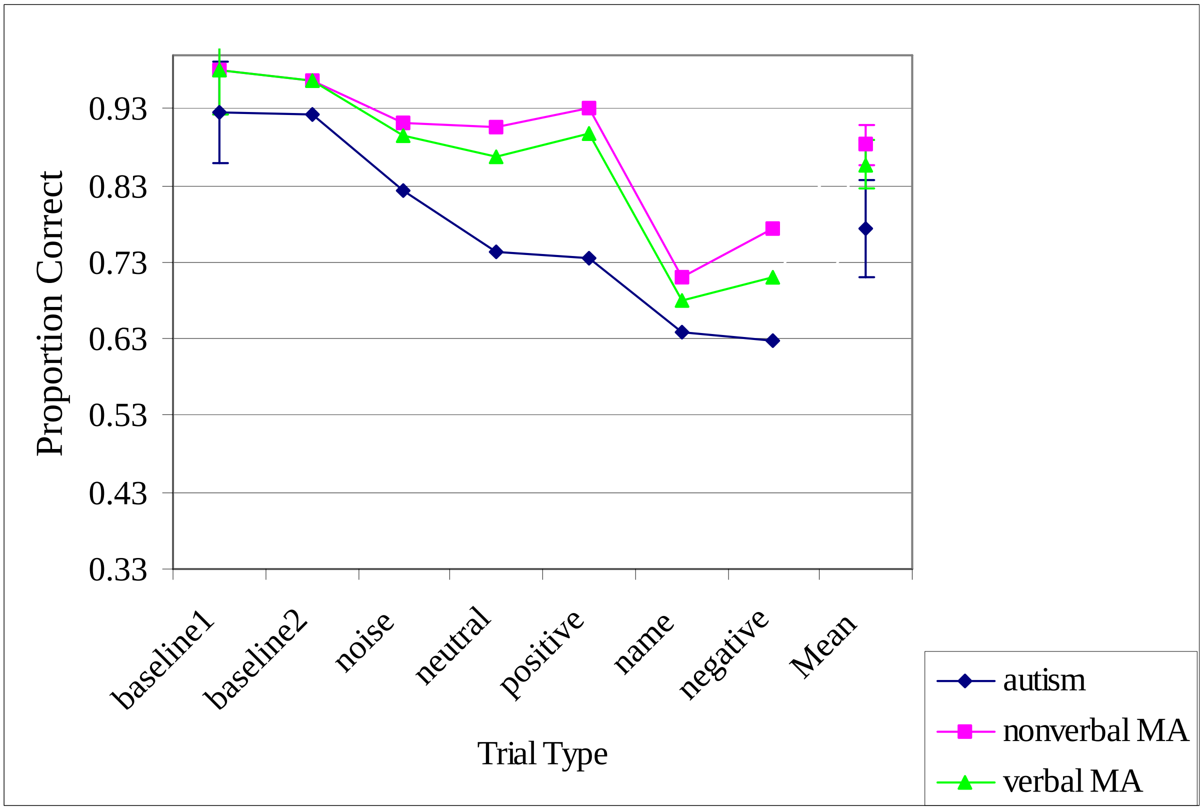


Figure 3. Interaction of group by trial type as measured by proportion correct in dichotic listening task with the autism group (n=23) and control groups matched on verbal ability and nonverbal MA. Error bars on the baseline1 denote within-subject 95% Confidence Intervals (Loftus & Masson, 1994), error bars on the Mean are between-subject 95% CI.

The same Repeated-Measures ANOVA of the dichotic listening task proportion correct was performed with chronological age matched group as control. There was a main effect of group: F(1, 13)=20.81, MSE=.056, p=.000. The mean proportion correct for the CA control group was .91, and for the autism group .76. There also was the main effect of trial type: F(6, 78)=33.21, MSE=.011, p=.000. There was also a significant interaction between variables: F(6, 78)=3.45, MSE=.025, p=.004 (see Figure 4).

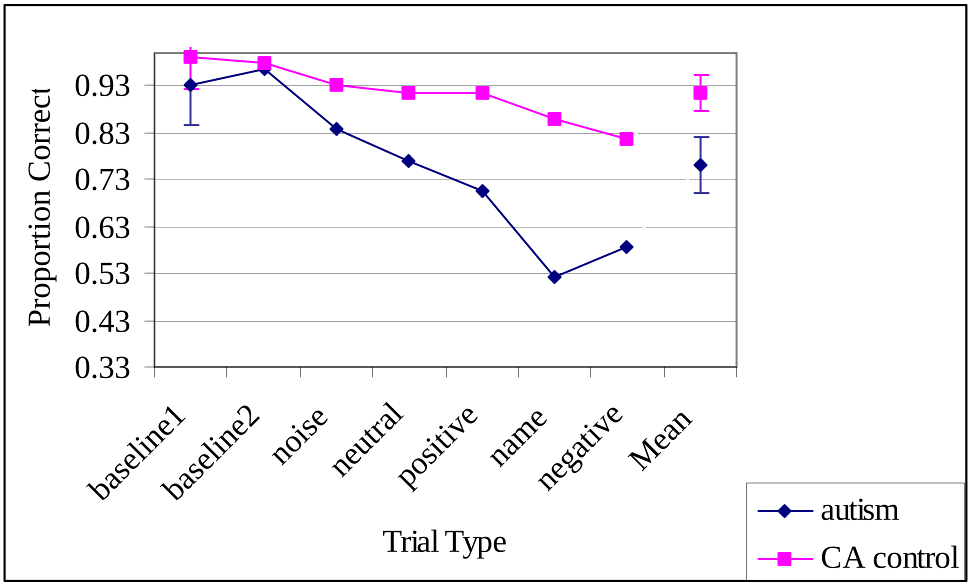



Figure 4. Interaction of group by trial type as measured by proportion correct in dichotic listening task with the autism group (n=14) and the chronological age matched control group. Error bars on the baseline1 denote within-subject 95% Confidence Intervals (Loftus & Masson, 1994), error bars on the Mean are between-subject 95% CI.

Newman-Keuls comparisons of differences between ordered means for trial types were performed (see Appendix C). The nonverbal MA and verbal MA control groups were similar on the pattern of significance. For both control groups names and negative information were significantly different from other conditions. For the autism group, unlike control groups, neutral or positive stimuli trial types were significantly different from baseline1, baseline 2, and noise condition. Chronological age matched control group did not produce significant differences, while the autism subset in that analysis showed that positive stimuli trial types were significantly different from both baseline conditions, and neutral stimuli were different from baseline 2 condition.

An ANOVA with group and trial types by presentation position was performed using the three control groups separately. The analyses revealed the following: for all three analyses there were main effects of group ($p=.002$ with nonverbal MA control, $p=.002$ with verbal MA control, $p=.000$ with CA control), there were main effects of presentation position ($p=.000$ with all control groups), there were no significant interactions with nonverbal MA control, $F(12, 264)=1.19$, $MSE=.075$, $p=.287$, with verbal MA control, $F(12, 264)=1.08$, $MSE=.062$, $p=.379$, or with CA control, F(12, 156)=1.65, MSE=.075, p=.083.  Performance of MA control groups and autism group by presentation position is shown on Figure 5.  Performance of CA control and autism groups by presentation position a shown on Figure 6.

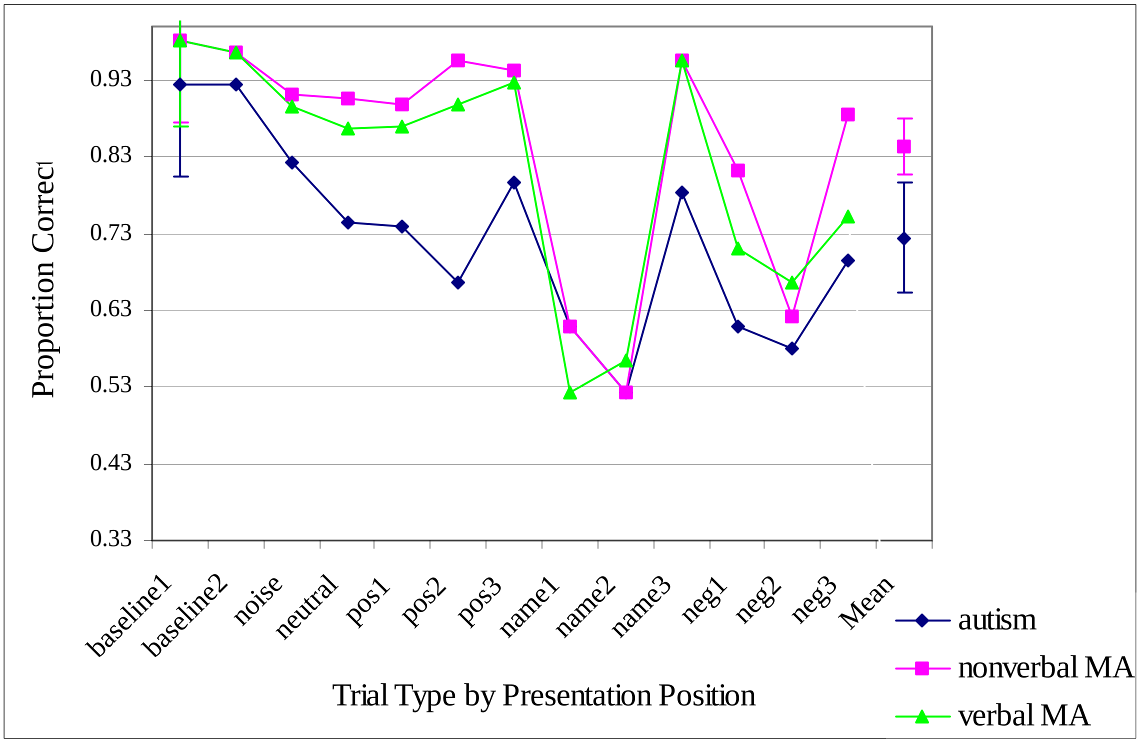



Figure 5. Interaction of group by presentation position as measured by proportion correct in dichotic listening task with autism group (n=23) and control groups matched on verbal ability and nonverbal MA. Error bars on the baseline1 denote within-subject 95% Confidence Intervals (Loftus & Masson, 1994), error bars on the Mean are between-subject 95% CI.

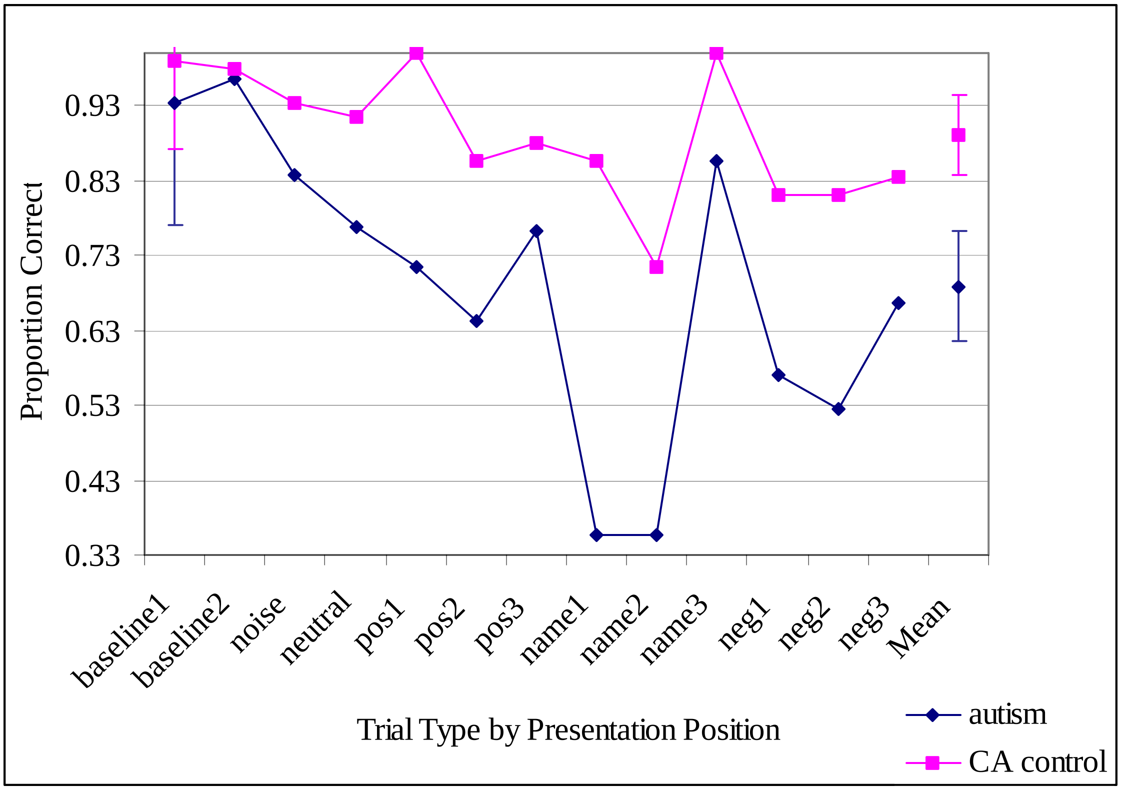



Figure 6. Interaction of group by presentation position as measured by proportion correct in dichotic listening task with autism group (n=14) and CA control group. Error bars on the baseline1 denote within-subject 95% Confidence Intervals (Loftus & Masson, 1994), error bars on the Mean are between-subject 95% CI.

Discontinuous tracking task. As with previous task, pair-wise analyses were performed with group as a within-subject variable (see Appendix E for more conservative analyses). GLM Repeated-Measures factorial ANOVA of reaction times was performed with group and trial types as factors. Outliers of more than 10 seconds were removed. While the analyses of trial type by group with nonverbal MA control (n=38) and CA control (n=26) groups produced no effects, the analysis with verbal MA control group produced the main effect of group, F(1, 20)=7.22, MSE=6150732, p=.014 (children with autism were faster that control group, M=2938 versus M=3715), and marginally significant interaction, F(6, 120)=1.94, MSE=432061, p=.080 (n=42). The analyses of trial type separated by presentation position produced similar pattern: no significant results with nonverbal MA control (n=36), main effect of group with verbal MA control, F(1, 17)=4.54, MSE=10248600, p=.048 (n=36), and a significant interaction with the CA control group, F(12, 144)=1.99, MSE= 527301, p=.029 (n=26). This interaction is seen on Figure7.  The means for the nonsignificant interactions with the other control groups can be seen in Appendix D.

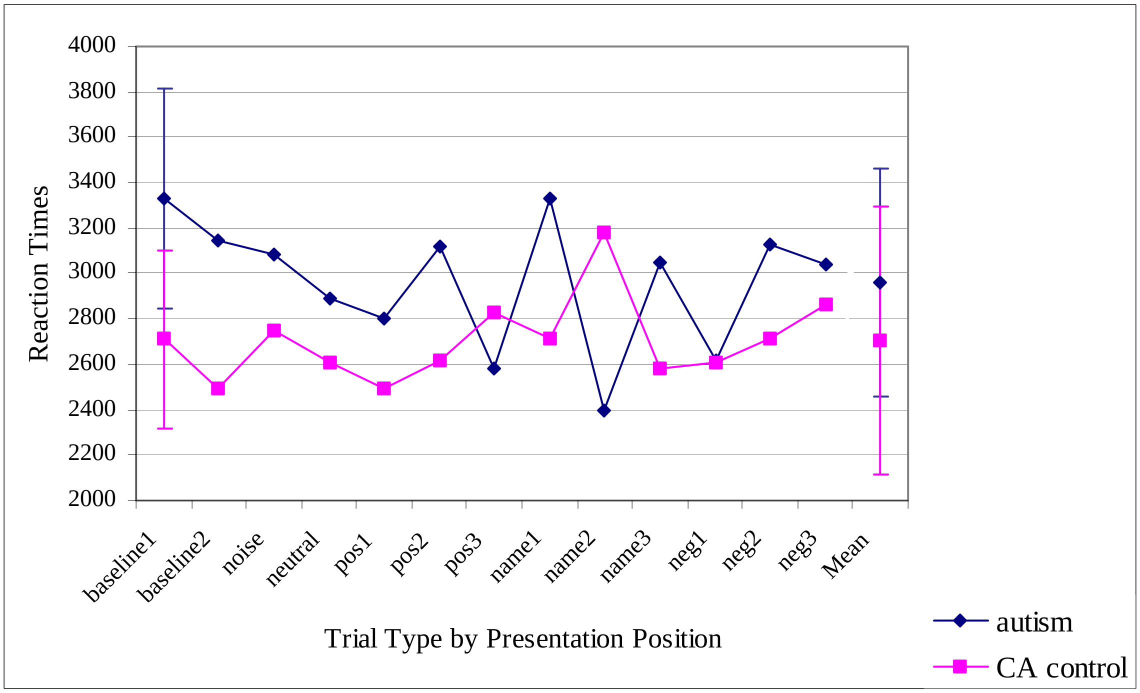



Figure 7.  Interaction of trial type separated by presentation position as measured by reaction time in discontinuous tracking task with CA control group.  Error bars on the baseline1 denote within-subject 95% Confidence Intervals (Loftus & Masson, 1994), error bars on the Mean are between-subject 95% CI.

## Discussion

This study featured the presentation of two selective attention tasks to children with autism and three control groups: a group matched on nonverbal MA, a group matched on verbal MA, and a group matched to a subset of autism sample on chronological age. Reaction time data was analyzed for both tasks and proportion correct was analyzed for the task that allowed performance errors. Finding relevant to autism group will be reviewed first with reaction time analyses followed by proportion correct analyses, then within-subject findings will be discussed.

Dichotic listening task, Reaction Time analyses. As attention is distracted away from the primary task in certain conditions, the mean median RT to the primary task should slow in those conditions. Based on previous literature (Dawson et al., 1998; Leekam et al., 2002), we expected to find differences in our groups in the amount of orienting to distracting social stimuli elicited from our participants. Dawson et al. (1998) specifically showed differences in orienting to personal names between autism and control groups. We predicted that while names would cause the most distraction for the control groups, other pertinent information (i.e., labels of favorite toys and activities) would present the biggest challenge for autistic children. This prompted us to expect an interaction in RT between group and trial types reflecting social aspects of distracting stimuli. Alternatively, other considerations led us to expect that perhaps the orienting to any significant stimulus could be reduced in autistic children (Oades et al., 1988), leading to less distraction than in normal children. Conversely, if autistic children acted like adults with low memory span (Conway et al., 2001), they should be more distractible than normal and therefore orient to significant stimuli in the irrelevant channel more often, slowing RTs to the primary task in those conditions.

We did not find evidence of these interactions (see Figures 2 and 3). Children with autism were distracted by their personal names and by negatively charged stimuli just as control groups were. These findings prompt a conclusion that while children with autism might have difficulty using social information to complete a task or in a joint-attention situation (Dawson et al., 1998; Leekam et al., 2000), they do show covert orienting to social stimuli, such as their personal name. This finding leads us to agree with Iarocci and Burack (2004) who stressed the importance of differentiation between overt and covert orienting and to extend it to distinction between endogenous control of attention as in Dawson et al. (1998) and exogenous control of attention as in this study. It is possible that if subjects were instructed to overtly orient to detected stimuli in irrelevant channel, we could see differences due to deficits in overt shifting of attention. One could argue that covert orienting does not require disengaging of attention from the primary task and shifting of the focus of attention to the irrelevant channel to the degree that covert orienting can be separate from attention shifting. Our study does not offer much insight to Theory of Mind and those who regard social deficit as a core disturbance in autism since it does not involve any social interactions, yet we can suggest that social stimuli, such as name, do elicit exogenous orienting in children with autism. It is also possible that orienting towards speakers is somehow easier for children with autism than orienting towards a person as in Dawson et al. (1998), since there is prior evidence that testing by a computer might lead to different results than testing by a person (Pascualvaca, 1998) in participants with autism.

The reaction time results of our study showed no significant difference in selective attention between autistic group and control groups when matched on verbal or nonverbal MAs. The autism group was significantly slower across conditions than the nonverbal MA matched control subjects and chronological age matched subjects on the primary task that required the use of receptive language but not on the primary task that required only motor responses. They did not differ on the speed of performance from the verbal MA-matched group. All groups seemed to be the most distracted by presentations of personal names and negatively charged words in the irrelevant channel in the dichotic listening task and by presentation of names in the discontinuous tracking task.

When the autistic group is matched to controls on their verbal ability, the difference in reaction times between groups vanishes. Interestingly, the difference in verbal ability between groups can be seen only in the processing times of stimuli in the primary task, as seen in baseline RT differences, and not in the processing of irrelevant information. While some semantic processing of the irrelevant channel does take place (or else we would not have found a main effect of trial type), it is not extensive enough to bring about differences in distraction. If lower verbal ability results in slower processing of verbal stimuli, then having to process two words presented simultaneously instead of one should result in slower processing of both. In this case we would have seen an interaction between the autism and nonverbal MA-matched control group, with the lower verbal ability subjects being significantly slower than higher verbal ability subjects on those trials that show orienting towards irrelevant channel and consequently processing of that channel. (Although the two groups did not significantly differ on verbal ability, the difference was enough to make the group main effect in RT disappear when autism was matched with a control group on verbal MA). Presentation of verbal stimuli in the distracting channel does not seem to slow subjects down further in addition to the baseline differences that reflect discrepancy in verbal abilities.

Children with autism did not show disproportionate slowing of reaction times during a dichotic presentation as compared to the baseline conditions. As such, they had no difficulty with spatial localization of auditory attention, and in that sense our task might be more similar to the easy condition of Teder-Salejarvi et al. (2005) than their difficult condition, especially since our dichotic stimuli differed on physical features and the sound source were located much wider than six degrees used in their study.

It might be relevant to note in this context that noise trial type did not seem to slow the autism group as much as it did the other groups (although this difference did not lead to a significant interaction). While this finding is not significant and we do not want to overstress it, one might speculate whether this trend was caused by heightened pitch sensitivity, as suggested by Gomot et al. (2002) or whether autistic subjects failed to recognize the representational meaning of the sounds (i.e. sound of train, bug buzzing, etc), as Oades et al. (1988) might suggest.

<u>Dichotic listening task, Proportion Correct analyses</u>. The proportion correct measure offered a few interesting insights. The verbal MA matched group, as well as other control groups, showed significantly lower error rates than the autism group. In fact, the verbal MA matched group resembles the nonverbal MA matched group on this measure more than it does the group with autism. This suggests that performance on this selective attention task requires more than receptive language knowledge (although the importance of verbal ability is stressed by the significant interaction in comparison of CA matched group and autism group, which were also significantly different in PPVT-III

measure), especially in the light of the fact that all groups showed near ceiling performance during baseline data collection stages, indicating that the primary task alone was well within receptive language abilities of our groups. There are several possible explanations for this main effect. The errors could happen at the stage of encoding, processing, or decision making. The reason for this main effect needs further exploration.

The interactions of group by trial type were not statistically significant for either nonverbal MA matched control or verbal MA matched control as compared to the autism group with the same pattern seen in reaction time data observed for all groups: subjects tend to make the most errors when a name or a negatively charged word is in the distracting channel. Yet post-hoc comparisons revealed that the autism group made more errors on all verbal distractors, including neutral words and positively charged words. These results support electrophysiological findings (Boddaert et al., 2004; Ceponiene et al., 2003; Dawson et al., 1988) that suggest deficits in autistic participants in processing of verbal stimuli.

The interaction of group by trial type for chronologically matched control and autism groups was significant. While the baseline receptive language difference offers a quick explanation, other mechanisms seem likely to be involved. In autistic children orienting to the irrelevant channel apparently interferes with the decision about the stimulus in the primary task to a larger degree than in typically developing chronologically matched children. If the error rate measure reflects the degree of processing capacity involvement in the task, we can say that irrelevant stimuli require more processing capacity in the autism group than in the control group. It is plausible that this capacity is taken up by a more effortful inhibition of irrelevant stimuli. As such, the control group had enough capacity to orient to irrelevant information and still make the correct decision in the primary task, while children with autism did not. It is possible that in typical controls orienting to irrelevant channel happens after the decision about the stimulus in the primary task is made, during the time the response action is being planned, which would indicate a more effective allocation of attention than that of children with autism who appear to have simultaneous activation of relevant and irrelevant stimuli. In this context we can say that these findings support Belmonte and

Yurgelun-Todd (2003) in that filtering might be more effortful in autism, yet later stages of filtering claimed by Belmonte and Yurgelun-Todd did not reflect in our RT measure. Research of possible compensatory mechanisms is an important direction in future research in autism that might provide new information to discussion on whether autistic cognitive processing differs qualitatively or quantitatively from that of control groups.

Significant interaction of trial type by group for chronologically matched control and autism groups, along with the absence of significant interaction for analyses that instead involved the younger, MA-matched control groups, might suggest that autistic children resemble younger, typically developing children. This would provide support for those researchers who subscribe to the view that cognitive processes in autism show developmental delay rather than being qualitatively different. However, the group main effect between autism group and verbally matched control group on the proportion correct measure prevents us from making this conclusion generally.

Discontinuous tracking task. This task showed the effect of chronological maturation on the primary task performance: autism group was faster than the younger control groups (significantly than verbal MA group and nonsignificantly faster than nonverbal MA group). The significance of interaction in the analysis using CA control group is not straightforward for interpretation. Children with autism seemed to slightly slow down during the first presentation of name in the irrelevant channel, a tendency which is also visible and significant using analyses with group as a between-subject factor (see Appendix E), yet it was offset by faster reaction time for the second presentation of name. Control group, instead, did not show orienting until the second presentation of name. While it is possible that in this pattern of results the control group demonstrates a superior inhibition to children with autism and, for that matter, to younger typical children, and/or it is also possible that children with autism make an extra effort to stay on task acknowledging the distracting properties of name, this pattern appears to be somewhat irregular. It is possible that this result is due to smaller sample, and further investigation is needed to draw conclusions from it.

To summarize our findings for a group of children with autism as compared to control participants, selective attention does appear affected in a dichotic listening paradigm as seen in error rate analyses, if not in reaction times. A question of why we saw differences in proportion correct but not in RTs remains to be researched. The time of response execution is obviously taken up by different processes in children with autism and the control groups. Post-hoc comparisons provide some support towards a conclusion made by Belmonte and Yurgelun-Todd (2003) that the autism group is subject to a “processing bottleneck”: all stimuli receive much the same degree of sensory evaluation and the irrelevant stimuli must be actively discarded. This is not to say that the control groups did not make mistakes when they were exposed to pertinent stimuli in the irrelevant channel or that autistic children were not successful in inhibiting the irrelevant channel sometimes.

As to the contributions to the theory of typical selective attention, this research supports some form of attenuated filter. Early selection theory would predict only noise to have an effect on the primary task performance because it carries changes in physical properties of the sound, which is the type of information that is processed first in the stream of auditory processing. Other types of distracting information are supposed to have no effect on the primary task because they are discarded before any semantic processing according to this theory. Our study presented a different pattern of results. Some semantic processing of the irrelevant channel does take place but not to the extent that it reflects differences in receptive language abilities. One could argue that a personal name is an item of immediate recognition of sorts that requires no semantic processing, similar to suggestion of Mack and Rock (1998) that names “pop out” in the perceptual field, however it is difficult to extend this suggestion to negatively charged words. In any case, both names and negatively charged words do require attentional capacity for processing as they slowed subjects down in the primary task and caused them to make more errors. It appears that in some situations only the first few presentation of name draws subjects’ attention enough to slow them down. This finding is similar to that of Harris and Pashler (2004). A similarity between our discontinuous tracking task and the disparity judgment task used by Harris and Pashler is that both tasks appear to tax processing capacity only minimally, so that the surprise factor of personal name presentation in the irrelevant channel is exhausted during the initial presentation processing.

Norman's theory of pertinence (1968) is supported in that pertinent items in the distracting channel do, in fact, prompt subjects to orient to them. However, contrary to what one might predict, subjects' favorite stimuli (words related to favorite activities) did not seem to cause any more distraction as neutral irrelevant words. From the evolutionary perspective it makes sense to orient the most to stimuli that might signal danger or unpleasant experiences. A personal name carries a certain degree of learning history that indicates incoming information, specifically about negative stimuli our findings might suggest. Based on our results, it seems to make sense to talk more about punishment history than reinforcement history when discussing behavior modification. While it is difficult to draw immediate clinical applications of these findings to the behavior modification therapy of children with pervasive developmental disorders, it is something that needs to be discussed and investigated further.

There were several limitations to this study. The effect of medications that some subjects with autism take cannot be completely ruled out, although in this case whatever the effects on performance in a selective attention task these medications could have had, they did not result in significant interactions in the main analyses of selective attention measures. This limitation is common for research literature in this area as many children with ASD take medications of some kind if not to decrease the severity of autistic symptoms of repetitive behaviors, then to minimize diseases that frequently cooccur with autism, such as sleep disorders, food allergies, metabolic abnormalities, etc. While these medications are not typically thought to effect attention directly, it is important to mention them in describing samples for potential future analyses. As to the medications that are sought to influence attention more directly, it is generally assumed that it is better to allow subjects on their typical dosage instead of withholding medication on the date of the experiment, as it might cause atypical performance due to withdrawal.

Additionally, the degree to which attention is implicated in the ASD can vary substantially from child to child. While some of children with autism have educational diagnoses of ADD or ADHD, others do not have attentional deficits addressed directly, as they are sometimes masked by more severe problems, such as self-injurious behavior. While baseline measures account for individual differences in specific tasks, a more general measure of attention might be a good idea. Also, the measure of autism symptomology used in this study could be improved, if not by choosing a more diagnostically predictive measure, then by collecting the data differently (i.e., using interview format and not questionnaire format), as it became obvious during the analysis of this measure that some parents did not follow intstructions closely. On a similar note, in this study we had to rely on parents' understanding of pleasant and unpleasant stimuli for their children. It might seem that this approach introduces biases, such as differences in exposure to certain stimuli (e.g., while spiders are seen by children quite frequently, ghosts are definitely not). Yet, the pattern of orienting to different types of stimuli was replicated by several groups, and this can be taken as indicator that parents generally are accurate in predicting pleasant and unpleasant stimuli for their children, or at the very minimum parents of autistic children are as accurate at predicting those things as parents of typically developing children.

A limitation that might be addressed by future research is better defined control groups. Control groups in this study overlapped in a subset of subjects, and hence could not be compared to each other directly. Also, the comparison between CA matched control group and autism group was done on a smaller sample. As a result, it is not possible to conclude whether the significance of interaction in the analyses of proportion correct with CA group is due to significant difference in that sample on the verbal ability scores, whether older typical group was just more successful in inhibiting response competition than younger typical group, or whether younger children with autism were more severely disabled than older children with autism, since that smaller sample was younger that the larger sample with autism. Further investigation is needed to answer these questions.

List 1. a. Targets used in dichotic listening and discontinuous tracking tasks.

| | | | | | |
|---|---|---|---|---|---|
| Airplane | angel | apple | baby | bathtub | bedroom |
| berries | blanket | bottle | building | bunny | butter |
| button | cactus | camel | candle | carrot | chicken |
| circle | closet | coffee | diaper | dinner | dolphin |
| donkey | driver | fairy | flower | football | forest |
| glasses | hammer | honey | insect | island | jacket |
| kitchen | kitten | lady | lemon | letter | lily |
| lion | mailbox | marble | medal | mermaid | mirror |
| money | monkey | mountain | necklace | needle | noodles |
| onion | orange | paintbrush | paper | pencil | penguin |
| penny | pepper | person | picture | pigeon | pillow |
| pitcher | pony | pumpkin | puppy | puzzle | raison |
| ribbon | robin | salad | sandals | scissors | shoulder |
| shovel | shower | singer | smile | snowman | sofa |
| soldier | squirrel | stroller | sunshine | sweater | table |
| teapot | tiger | toilet | toothbrush | towel | toystore |
| tractor | t-shirt | tummy | turkey | turtle | water |
| window | winter | zebra | | | |

b. Distractors used in dichotic listening and discontinuous tracking tasks.

| | | | | | |
|---|---|---|---|---|---|
| ankle | answer | elbow | evening | fishing | garden |
| heaven | laughter | morning | neighbor | number | painting |
| palace | pedal | people | pocket | puddle | teacher |
| whisper | woman | wonder | | | |

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## APPENDIX A

Please, list 10 things, people, or activities that your child finds to be most **pleasant**, and then rank them on the scale from 1-10, with 1 being fairly neutral and 10 being the strongest item in its desirability for your child. For example, “soda” – 7, “candy” – 10, etc.

1.

2.

3.

4.

5.

6.

7.

8.

9.

10.

Comments:

Please, list 10 things, people, or activities that your child finds to be most **unpleasant**, and then rank them on the scale from 1-10, with 1 being fairly neutral and 10 being the strongest item in its undesirability for your child. For example, “bathing” – 7, “spinach” – 10, etc.

1.

2.

3.

4.

5.

6.

7.

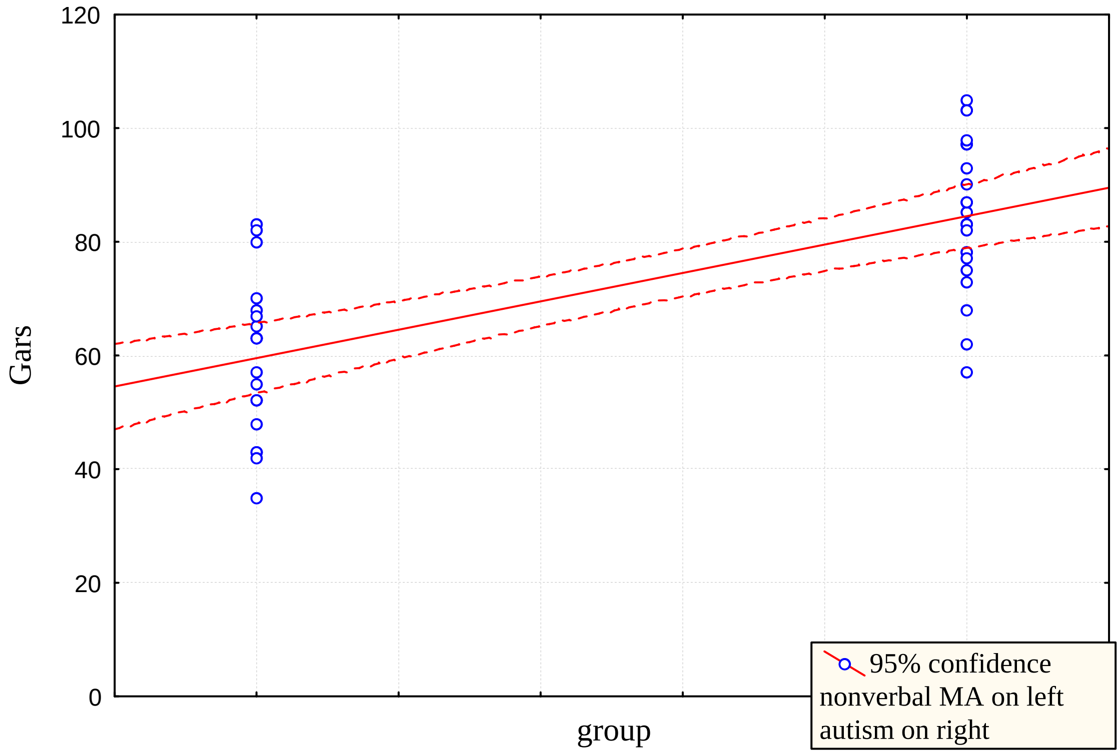
8.

9.

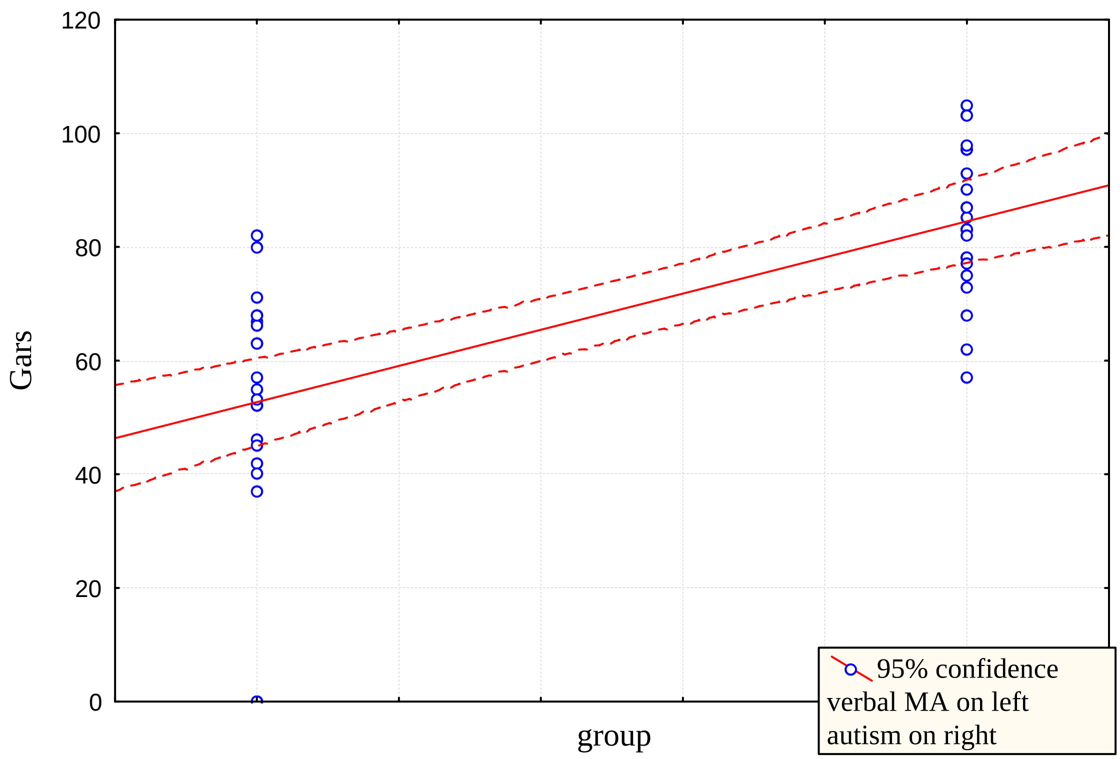
10.

Comments:

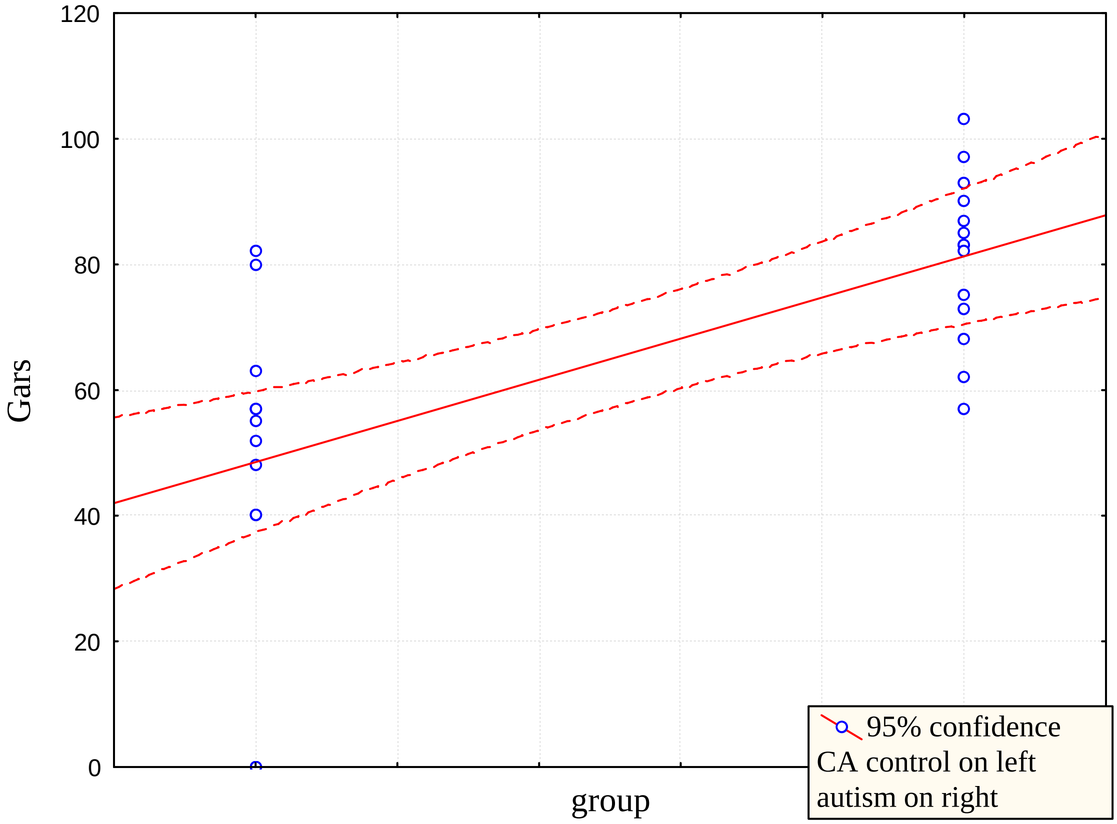
APPENDIX B




A. Scatterplot of GARS scores for autism group and nonverbal MA control group.




B. Scatterplot of GARS scores for autism group and verbal MA control group.




C. Scatterplot of GARS scores for autism group and CA control group.

APPENDIX C

| | Type | bl1 | neu | noise | name | neg | pos | bl2 | bl1 | neu | noise | name | neg | pos |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | bl1 | | | | | | | | | | | | | |
| C | neu | .64 | | | | | | | | | | | | |
| C | noise | .61 | .93 | | | | | | | | | | | |
| C | name | **.00** | **.00** | **.00** | | | | | | | | | | |
| C | neg | **.00** | **.01** | **.01** | .50 | | | | | | | | | |
| C | pos | .52 | .98 | .96 | **.00** | **.01** | | | | | | | | |
| C | bl2 | .75 | .76 | .72 | **.00** | **.00** | .44 | | | | | | | |
| A | bl1 | .59 | .98 | .94 | **.00** | **.00** | .88 | .62 | | | | | | |
| A | neu | **.00** | **.00** | **.00** | .74 | .51 | **.00** | **.00** | **.00** | | | | | |
| A | noise | **.01** | .06 | .13 | .08 | .25 | .15 | **.02** | .15 | .17 | | | | |
| A | name | **.00** | **.00** | **.00** | .10 | **.02** | **.00** | **.00** | **.00** | .08 | **.00** | | | |
| A | neg | **.00** | **.00** | **.00** | .16 | **.01** | **.00** | **.00** | **.00** | .07 | **.00** | .83 | | |
| A | pos | **.00** | **.00** | **.00** | .59 | .66 | **.00** | **.00** | **.00** | .84 | .18 | .08 | .08 | |
| A | bl2 | .69 | .93 | .78 | **.00** | **.01** | .98 | .76 | .96 | **.00** | .12 | **.00** | **.00** | **.00** |

A. Approximate probabilities for Newman-Keuls comparisons, for nonverbal MA matched control (C) and autism (A) groups in dichotic listening task as measured by proportion correct. Probabilities <.05 are highlighted.

| | Type | bl1 | neu | noise | name | neg | pos | bl2 | bl1 | neu | noise | name | neg | pos |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | bl1 | | | | | | | | | | | | | |
| C | neu | **.03** | | | | | | | | | | | | |
| C | noise | .19 | .43 | | | | | | | | | | | |
| C | name | **.00** | **.00** | **.00** | | | | | | | | | | |
| C | neg | **.00** | **.00** | **.00** | .43 | | | | | | | | | |
| C | pos | .16 | .67 | .96 | **.00** | **.00** | | | | | | | | |
| C | bl2 | .69 | .07 | .31 | **.00** | **.00** | .24 | | | | | | | |
| A | bl1 | .28 | .51 | .86 | **.00** | **.00** | .74 | .26 | | | | | | |
| A | neu | **.00** | **.00** | **.00** | .33 | .64 | **.00** | **.00** | **.00** | | | | | |
| A | noise | **.00** | .24 | .12 | **.00** | **.01** | .18 | **.00** | .06 | **.03** | | | | |
| A | name | **.00** | **.00** | **.00** | .24 | .12 | **.00** | **.00** | **.00** | **.03** | **.00** | | | |
| A | neg | **.00** | **.00** | **.00** | .32 | .11 | **.00** | **.00** | **.00** | **.02** | **.00** | .79 | | |
| A | pos | **.00** | **.00** | **.00** | .32 | .51 | **.00** | **.00** | **.00** | .81 | **.04** | **.04** | **.03** | |
| A | bl2 | .39 | .42 | .74 | **.00** | **.00** | .50 | .46 | .96 | **.00** | .05 | **.00** | **.00** | **.00** |

B. Approximate probabilities for Newman-Keuls comparisons, for verbal MA matched control (C) and autism (A) groups in dichotic listening task as measured by proportion correct. Probabilities <.05 are highlighted.

| | Type | bl1 | neu | noise | name | neg | pos | bl2 | bl1 | neu | noise | name | neg | pos |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | bl1 | | | | | | | | | | | | | |
| C | neu | .81 | | | | | | | | | | | | |
| C | noise | .77 | .96 | | | | | | | | | | | |
| C | name | .34 | .60 | .72 | | | | | | | | | | |
| C | neg | .12 | .48 | .47 | .78 | | | | | | | | | |
| C | pos | .85 | .97 | .99 | .35 | .38 | | | | | | | | |
| C | bl2 | .86 | .81 | .70 | .39 | .16 | .87 | | | | | | | |
| A | bl1 | .87 | .78 | 1.00 | **.59** | **.39** | .94 | .85 | | | | | | |
| A | neu | **.02** | **.14** | **.12** | .45 | .41 | **.12** | **.02** | **.10** | | | | | |
| A | noise | **.21** | .56 | .60 | **.73** | **.75** | .41 | **.25** | .50 | **.49** | | | | |
| A | name | **.00** | **.00** | **.00** | .00 | .00 | **.00** | **.00** | **.00** | **.00** | **.00** | | | |
| A | neg | **.00** | **.00** | **.00** | .00 | .00 | **.00** | **.00** | **.00** | **.01** | **.00** | .29 | | |
| A | pos | **.00** | **.01** | **.01** | .09 | .15 | **.01** | **.00** | **.01** | .30 | **.13** | **.01** | **.05** | |
| A | bl2 | .92 | .83 | .57 | **.45** | **.21** | .90 | .82 | .84 | **.04** | .32 | **.00** | **.00** | **.00** |

C. Approximate probabilities for Newman-Keuls comparisons, for CA matched control (C) and autism (A) groups in dichotic listening task as measured by proportion correct. Probabilities <.05 are highlighted.

APPENDIX D

Mean RT for control and autism groups in discontinuous tracking task by presentation position in msec.

| Group | Trial Type | Mean RT | St. Error | N |
|---|---|---|---|---|
| nonverbal control | Baseline1 | 3078 | 246 | 18 |
| nonverbal control | Neutral | 2973 | 202 | 18 |
| nonverbal control | Noise | 3021 | 221 | 18 |
| nonverbal control | Name1 | 3417 | 427 | 18 |
| nonverbal control | Name2 | 2833 | 215 | 18 |
| nonverbal control | Name3 | 2994 | 266 | 18 |
| nonverbal control | Negative1 | 3031 | 307 | 18 |
| nonverbal control | Negative2 | 3009 | 273 | 18 |
| nonverbal control | Negative3 | 3091 | 297 | 18 |
| nonverbal control | Positive1 | 2928 | 217 | 18 |
| nonverbal control | Positive2 | 3053 | 254 | 18 |
| nonverbal control | Positive3 | 3331 | 319 | 18 |
| nonverbal control | Baseline2 | 2806 | 208 | 18 |
| verbal control | Baseline1 | 3267 | 238 | 18 |
| verbal control | Neutral | 3342 | 243 | 18 |
| verbal control | Noise | 3508 | 272 | 18 |
| verbal control | Name1 | 4050 | 516 | 18 |
| verbal control | Name2 | 3711 | 437 | 18 |
| verbal control | Name3 | 3300 | 417 | 18 |
| verbal control | Negative1 | 3355 | 306 | 18 |
| verbal control | Negative2 | 3439 | 291 | 18 |
| verbal control | Negative3 | 3561 | 321 | 18 |
| verbal control | Positive1 | 3178 | 240 | 18 |
| verbal control | Positive2 | 3450 | 315 | 18 |
| verbal control | Positive3 | 3739 | 360 | 18 |
| verbal control | Baseline2 | 3171 | 237 | 18 |
| Autism | Baseline1 | 3096 | 230 | 23 |
| Autism | Neutral | 2838 | 192 | 23 |
| Autism | Noise | 3006 | 225 | 23 |
| Autism | Name1 | 3113 | 315 | 23 |
| Autism | Name2 | 2452 | 175 | 23 |
| Autism | Name3 | 2730 | 233 | 23 |
| Autism | Negative1 | 2719 | 236 | 23 |
| Autism | Negative2 | 2764 | 240 | 23 |
| Autism | Negative3 | 2856 | 275 | 23 |
| Autism | Positive1 | 2761 | 223 | 23 |
| Autism | Positive2 | 2972 | 229 | 23 |
| Autism | Positive3 | 2730 | 278 | 23 |
| Autism | Baseline2 | 2982 | 233 | 23 |

APPENDIX E

Dichotic listening task. Medians were used for all the reaction times analyses. Only correct trials were used. GLM Repeated-Measures factorial ANOVA of the dichotic listening task reaction times was performed with autism and nonverbal MA matched group first with group between-subject variable and trial types as within-subject variable. The group with autism was significantly slower than the control group: $F(1, 41)=6.07$, $MSE=2237103$, $p=.018$. The median RT for receptive identification of a word with an auditory distractor present for the group with autism was 2314 msec and for the control group 1889 msec. There was a significant difference in RT for trials with different types of auditory distractors: $F(6, 246)=6.04$, $MSE=557051$, $p=.000$. While noise, neutral words, words associated with positive things in the distracting channel generated similar RTs, trials with personal names and words associated with negative things generated RTs slower by about 300 msec (see Table 1E for mean median values). There was no interaction between group and trial type variables: $F(6, 246)=.64$, $p=.694$.

Table 1E. Mean Median RT across nonverbal MA control and autism groups in dichotic listening task by trial type in msec.

| Trial Type | Mean Median | St. Error |
|---|---|---|
| Baseline1 | 1842 | 126 |
| Baseline2 | 1802 | 127 |
| Noise | 1939 | 77 |
| Neutral | 2116 | 94 |
| Positive | 2069 | 91 |
| Name | 2394 | 230 |
| Negative | 2547 | 149 |

The same type of repeated-measures ANOVA of the dichotic listening task RT was performed with group and trial types as factors but using the verbal MA control group. There was no main effect of group this time: $F(1, 41)=.01$, $MSE=7178264$, $p=.905$. Median RT for receptive identification of a word with an auditory distractor present for the group with autism was 2314 msec and for the control group 2340 msec. Again there was a significant difference in RT for trials with different types of auditory distractors: $F(6, 246)=6.18$, $MSE=669335$, $p=.000$. There was no interaction between group and trial type variables: F(6, 246)=.60, p=.727. Figure 1E shows performance of the autism group and both control groups by trial type.

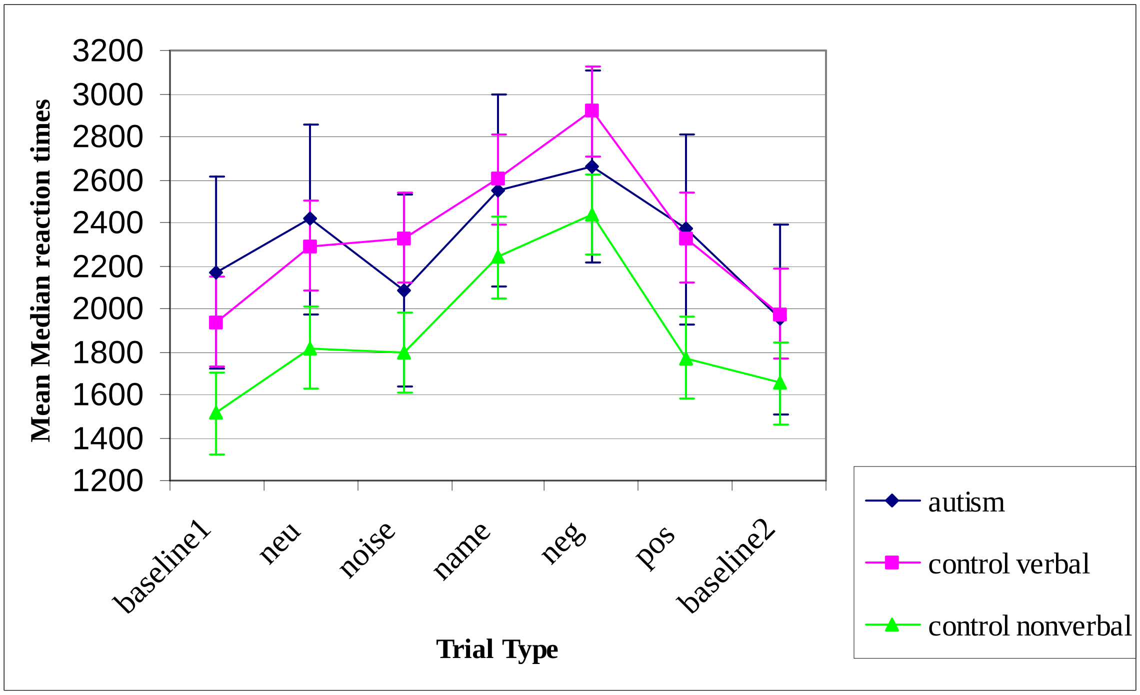



Figure 1E. Interaction of group by trial type as measured by RT in dichotic listening task with autism group (n=23) and control groups matched on verbal ability and nonverbal MA. Error bars denote within subject 95% Confidence Intervals (Loftus & Masson, 1994).

Newman-Keuls comparisons of differences between ordered means for trial types and both groups were performed (see Table 2E). The nonverbal MA matched control and autism groups were identical on the pattern of significance. For both groups names and negative information trial types were significantly different from the baseline1 condition and negative information was different from the baseline2 condition. No pairs of the same trial types were different between groups. Verbal MA matched control group showed p<.05 only between the negative stimuli trial type and the baseline conditions.

Table 2E. Approximate probabilities for Newman-Keuls comparisons, for nonverbal MA matched control (C) and autism (A) groups in dichotic listening task as measured by reaction times. Probabilities <.05 are highlighted.

| | Type | bl1 | neu | noise | name | neg | pos | bl2 | bl1 | neu | noise | name | neg | pos |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | bl1 | | | | | | | | | | | | | |
| C | neu | .67 | | | | | | | | | | | | |
| C | noise | .60 | .92 | | | | | | | | | | | |
| C | name | **.04** | .35 | .37 | | | | | | | | | | |
| C | neg | **.00** | .12 | .11 | .82 | | | | | | | | | |
| C | pos | .49 | .98 | .92 | .38 | .10 | | | | | | | | |
| C | bl2 | .54 | .89 | .81 | .17 | **.03** | .60 | | | | | | | |
| A | Bl1 | .83 | .57 | .64 | .80 | .87 | .69 | .48 | | | | | | |
| A | neu | **.03** | .84 | .31 | .79 | .94 | .30 | .14 | .70 | | | | | |
| A | noise | .36 | .59 | .92 | .84 | .79 | .78 | .61 | .70 | .59 | | | | |
| A | name | **.01** | .15 | .15 | .96 | .67 | .14 | **.05** | .55 | .82 | .38 | | | |
| A | neg | **.00** | .06 | .06 | .63 | .87 | .05 | **.01** | .32 | .70 | .18 | .63 | | |
| A | pos | .05 | .33 | .35 | .63 | .97 | .89 | .18 | .66 | .84 | .59 | .85 | .70 | |
| A | bl2 | .60 | .63 | .84 | .72 | .56 | .91 | .97 | .60 | .32 | .56 | .14 | **.05** | .35 |

The same Repeated-Measures ANOVA of the dichotic listening task RT was performed with group and trial types as factors with CA control group. There was a main effect of group, as in the analysis with nonverbal MA matched control group: F(1, 25)=9.95, MSE=3057649, p=.004. The median RT for receptive identification of a word with an auditory distractor present for the group with autism was 2582 msec and for the control group 1779 msec. Again there was a significant difference in RT for trials with different types of auditory distractors: F(6, 150)=2.74, MSE= 774336, p=.015. There was no interaction between group and trial type variables: F(6, 150)=.66, p=.695. Mean median RTs for both groups can be found in Table 3E.

Table 3E. Mean Median RT for chronological age control and autism groups in dichotic listening task by trial type in msec.

| Group | Trial Type | Mean Median | St. Error |
|---|---|---|---|
| CA control | Baseline1 | 1393 | 249 |
| CA control | Baseline2 | 1419 | 228 |
| CA control | Noise | 1695 | 180 |
| CA control | Neutral | 1730 | 193 |
| CA control | Positive | 1882 | 249 |
| CA control | Name | 2017 | 483 |
| CA control | Negative | 2320 | 266 |
| Autism | Baseline1 | 2542 | 259 |
| Autism | Baseline2 | 2294 | 237 |
| Autism | Noise | 2214 | 187 |
| Autism | Neutral | 2650 | 201 |
| Autism | Positive | 2522 | 258 |
| Autism | Name | 3087 | 501 |
| Autism | Negative | 2767 | 276 |

Factorial ANOVA of the dichotic listening task proportion correct was performed with group as a between-subject variable and trial types as within-subject variable. The nonverbal MA control group was used first. There was a main effect of group: F(1, 44)=10.53, MSE=.091, p=.002. There also was the main effect of trial type: F(6, 264)=26.44, MSE=.021, p=.000 (see Table 4E for means of proportion correct). The interaction between variables did not reach a significance level of .05: F(6, 264)=1.97, p=.071.

Table 4E. Means of proportion correct across nonverbal MA control and autism groups in dichotic listening task by trial type.

| Trial Type | Mean | St. Error |
|---|---|---|
| Baseline1 | .95 | .013 |
| Baseline2 | .95 | .019 |
| Noise | .87 | .018 |
| Neutral | .83 | .023 |
| Positive | .83 | .020 |
| Name | .67 | .047 |
| Negative | .70 | .026 |

The same Repeated-Measures ANOVA of the dichotic listening task proportion correct was performed with verbal MA as the control. There was a main effect of group: F(1, 44)=5.80, MSE=.097, p=.020. There also was the main effect of trial type: F(6, 264)=31.44, MSE=.020, p=.000.  The interaction between variables was not significant: F(6, 264)=1.15, p=.333.  Performance of both control groups and of the autism group by trial type on this dependent variable are shown in Figure 2E.

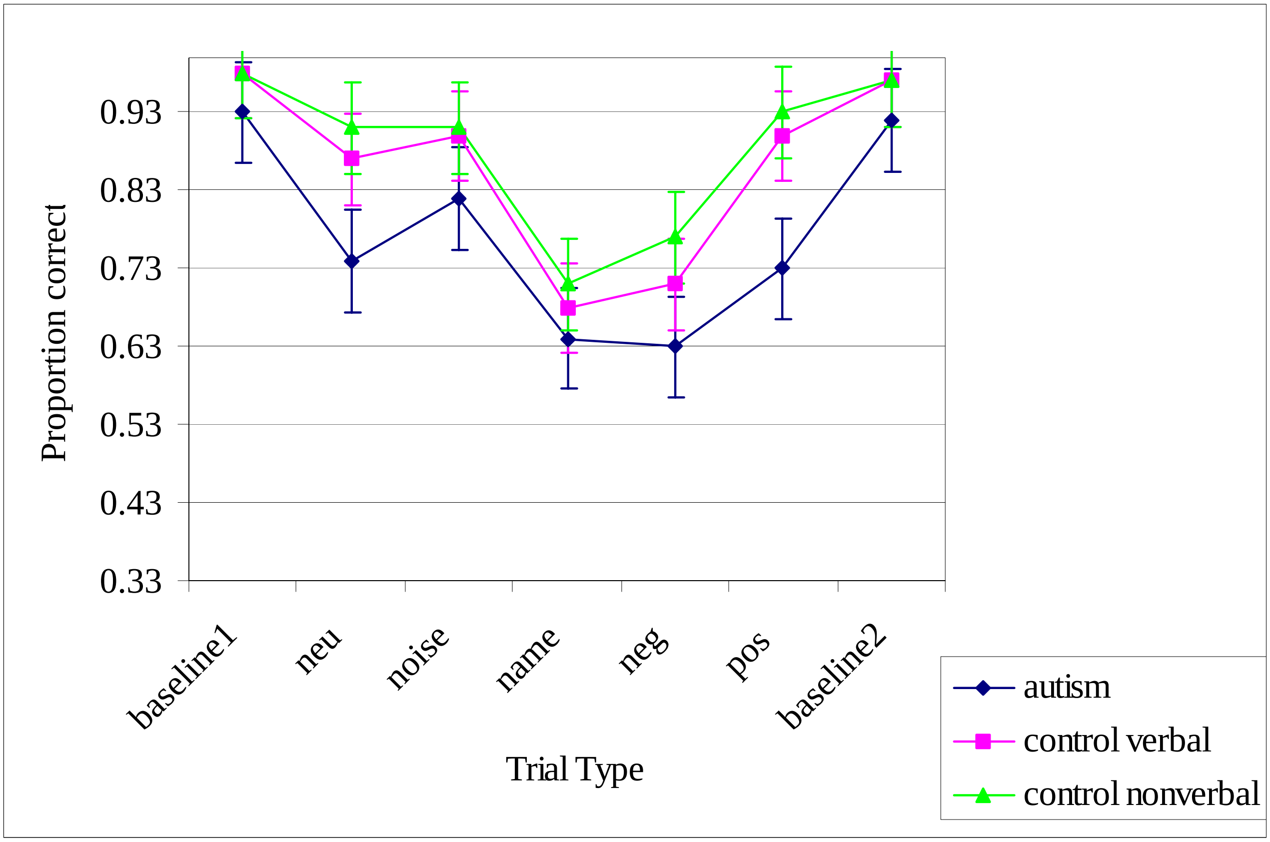



Figure 2E. Interaction of group by trial type as measured by proportion correct in dichotic listening task with the autism group (n=23) and control groups matched on verbal ability and nonverbal MA. Error bars denote within subject 95% Confidence Intervals.

Newman-Keuls comparisons of differences between ordered means for trial types and both control groups were performed (see Table 5E).  The two control groups were identical on the pattern of significance.  For both control groups names and negative information were significantly different from all other conditions.  For the autism group names and negative information were significantly different from baseline1, baseline 2, and noise condition but not from neutral or positive stimuli trial types.

Table 5E. a. Approximate probabilities for Newman-Keuls comparisons, for nonverbal MA matched control (C) and autism (A) groups in dichotic listening task as measured by proportion correct. Probabilities <.05 are highlighted.

| | Type | bl1 | neu | noise | name | neg | pos | bl2 | bl1 | neu | noise | name | neg | pos |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | bl1 | | | | | | | | | | | | | |
| C | neu | .57 | | | | | | | | | | | | |
| C | noise | .56 | .92 | | | | | | | | | | | |
| C | name | **.00** | **.00** | **.00** | | | | | | | | | | |
| C | neg | **.00** | **.00** | **.01** | .45 | | | | | | | | | |
| C | pos | .48 | .97 | .96 | **.00** | **.00** | | | | | | | | |
| C | bl2 | .73 | .72 | .68 | **.00** | **.00** | .41 | | | | | | | |
| A | bl1 | .92 | .98 | .96 | **.00** | **.04** | .89 | .70 | | | | | | |
| A | neu | **.00** | .27 | **.01** | .80 | .57 | **.01** | **.00** | **.00** | | | | | |
| A | noise | **.05** | .11 | .60 | .18 | .32 | .29 | .08 | .12 | .14 | | | | |
| A | name | **.00** | **.00** | **.00** | .42 | .07 | **.00** | **.00** | **.00** | .06 | **.00** | | | |
| A | neg | **.00** | **.00** | **.00** | .25 | .59 | **.00** | **.00** | **.00** | .05 | **.00** | .82 | | |
| A | pos | **.00** | **.01** | **.01** | .64 | .73 | .41 | **.00** | **.00** | .83 | .15 | .06 | .06 | |
| A | bl2 | .80 | .94 | .81 | **.00** | **.03** | .98 | .96 | .96 | **.00** | .09 | **.00** | **.00** | **.00** |

b. Approximate probabilities for Newman-Keuls comparisons, for verbal MA matched control (C) and autism (A) groups in dichotic listening task as measured by proportion correct. Probabilities <.05 are highlighted.

| | Type | bl1 | neu | noise | name | neg | pos | bl2 | bl1 | neu | noise | name | neg | pos |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | bl1 | | | | | | | | | | | | | |
| C | neu | .10 | | | | | | | | | | | | |
| C | noise | .33 | .49 | | | | | | | | | | | |
| C | name | **.00** | **.00** | **.00** | | | | | | | | | | |
| C | neg | **.00** | **.00** | **.00** | .49 | | | | | | | | | |
| C | pos | .28 | .74 | .96 | **.00** | **.00** | | | | | | | | |
| C | bl2 | .73 | .17 | .45 | **.00** | **.00** | .37 | | | | | | | |
| A | bl1 | .82 | .80 | .95 | **.00** | **.00** | .86 | .43 | | | | | | |
| A | neu | **.00** | .38 | **.02** | .63 | .80 | **.02** | **.00** | **.00** | | | | | |
| A | noise | .05 | .41 | .71 | **.05** | .13 | .48 | .09 | .15 | .06 | | | | |
| A | name | **.00** | **.00** | **.00** | .64 | .35 | **.00** | **.00** | **.00** | .09 | **.00** | | | |
| A | neg | **.00** | **.00** | **.00** | .57 | .81 | **.00** | **.00** | **.00** | .07 | **.00** | .82 | | |
| A | pos | **.00** | .05 | **.02** | .57 | .64 | .48 | **.00** | **.00** | .83 | .08 | .10 | .09 | |
| A | bl2 | .68 | .71 | .86 | **.00** | **.00** | .63 | .88 | .96 | **.00** | .13 | **.00** | **.00** | **.00** |

The same Repeated-Measures ANOVA of the dichotic listening task proportion correct was performed with chronological age matched group as control. There was a main effect of group: $F(1, 26)=22.12$, MSE=.053, $p=.000$. There also was the main effect of trial type: F(6, 156)=20.11, MSE=.018, p=.000. There was also a significant interaction between variables: F(6, 156)=4.82, p=.000 (see Figure 3E).

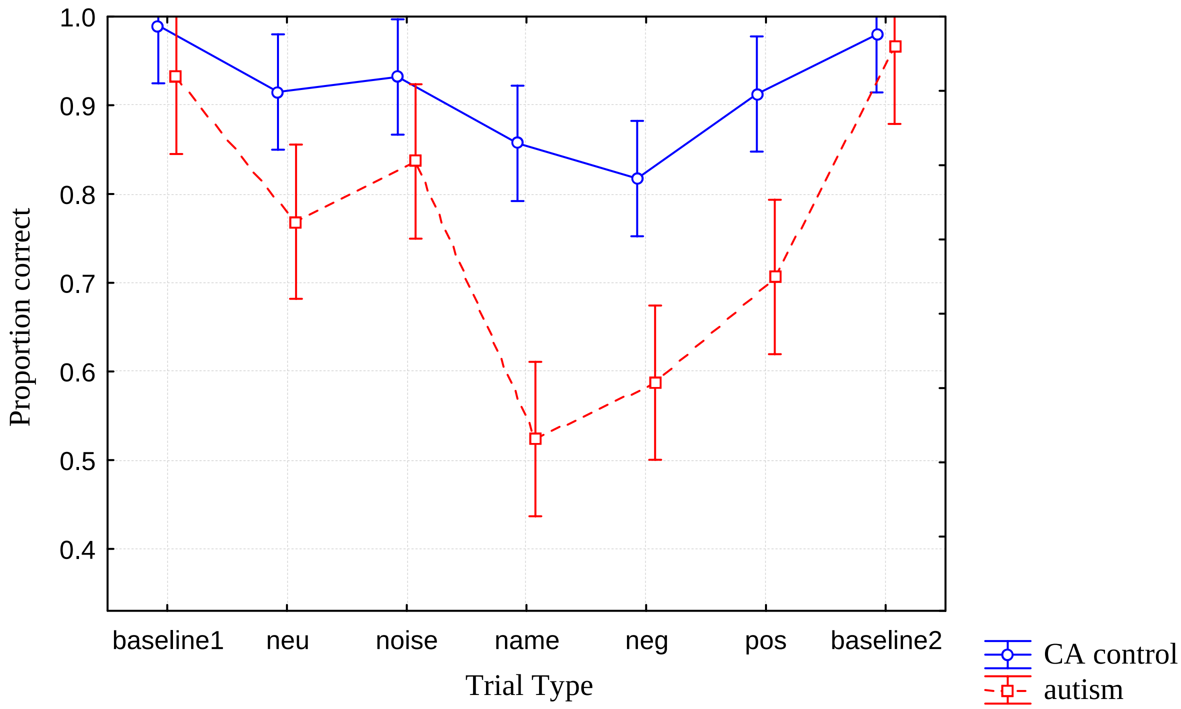



Figure 3E. Interaction of group by trial type as measured by proportion correct in dichotic listening task with the autism group (n=14) and the chronological age matched control group. Error bars denote within subject 95% Confidence Intervals.

An ANOVA with group and trial types by presentation position was performed using the three control groups separately. The analyses revealed the following: for all three analyses there were main effects of group (p=.004 with nonverbal MA control, p=.030 with verbal MA control, p=.000 with CA control), there were main effects of presentation position (p=.000 with all control groups), there were no significant interactions with nonverbal MA control, F(12, 528)=1.29, MSE=.069.96, p=.218, or with verbal MA control, F(12, 528)=.92, MSE=.073, p=.523. The interaction with CA control and autism groups by presentation position was significant: F(12, 312)=2.05, MSE=, p=.020. Performance of MA control groups and autism group by presentation position is shown on Figure 4E. Performance of CA control and autism groups by presentation position a shown on Figure 5E.

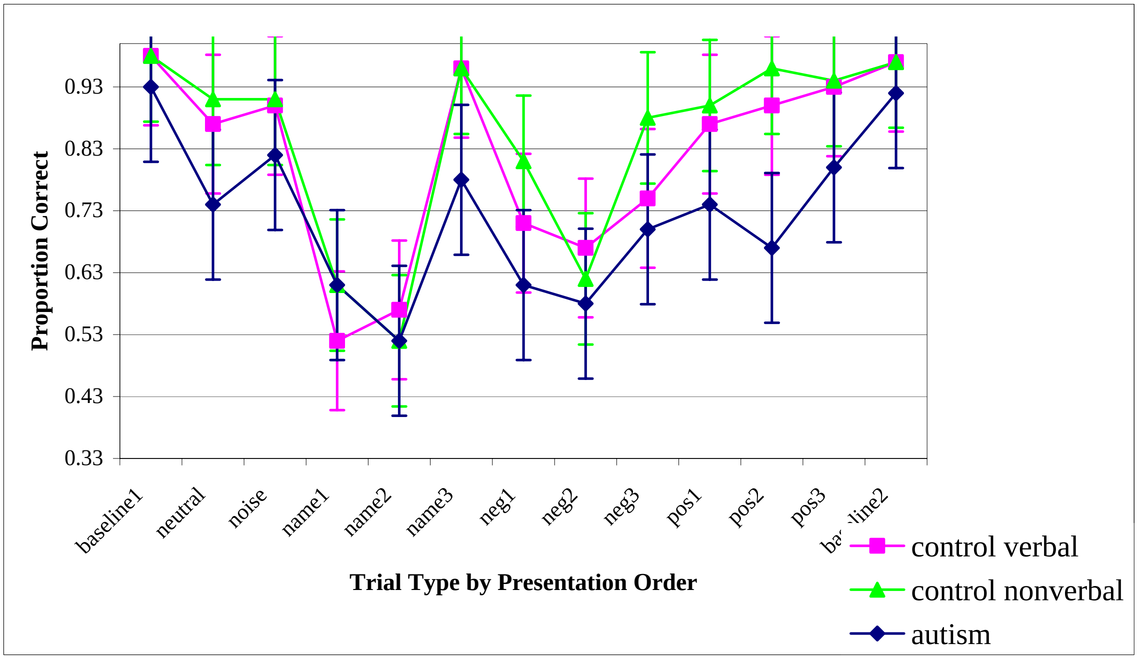



Figure 4E. Interaction of group by presentation position as measured by proportion correct in dichotic listening task with autism group (n=23) and control groups matched on verbal ability and nonverbal MA. Error bars denote within subject 95% Confidence Intervals.

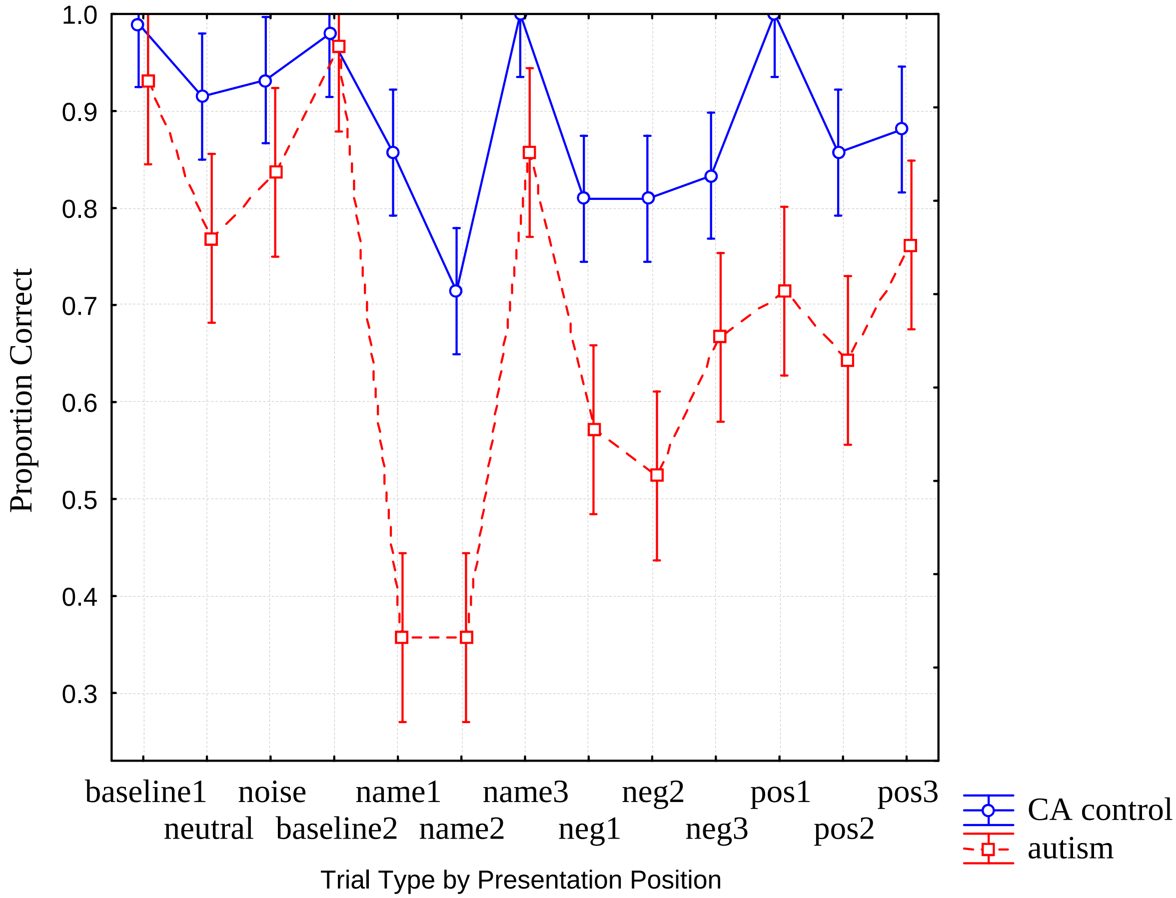



Figure 5E. Interaction of group by presentation position as measured by proportion correct in dichotic listening task with autism group (n=14) and CA control group. Error bars denote within subject 95% Confidence Intervals.

Discontinuous tracking task. GLM Repeated-Measures factorial ANOVA of reaction times was performed with group and trial types as factors. Outliers of more than 10 seconds were removed. While the analysis of trial type by group with nonverbal MA control group produced no effects, the analysis of trial type separated by presentation position produced a significant main effect of presentation position, $F(12, 468)=1.91$, $MSE=459661$, $p=.031$ (see Figure 6E). The analysis of trial type separated by presentation position with verbal MA controls produced a marginal main effect of presentation position, $F(12, 468)=1.57$, $MSE=625666$, $p=.097$ (see Figure 7E), with no significant interaction. The presentation position effects were observed with this type of analyses but not with the analyses presented in the main part of the text in which group was treated as a repeated measure within subjects data.

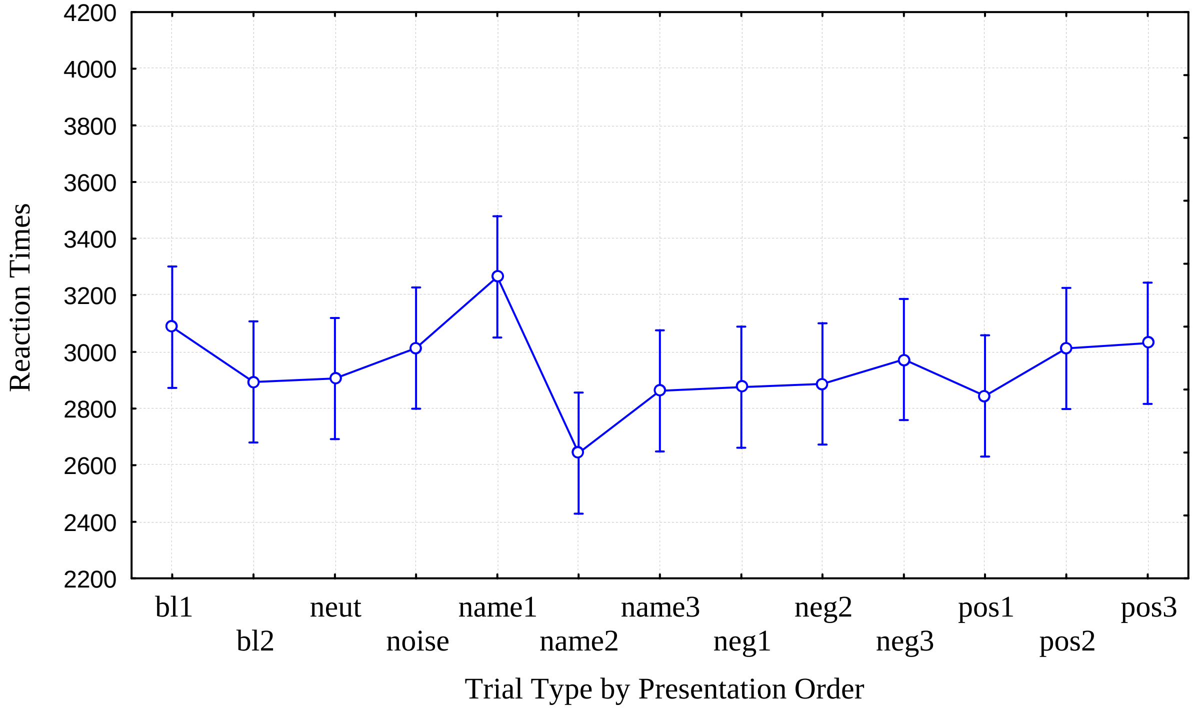



Figure 6E. Main effect of trial type separated by presentation position as measured by reaction time in discontinuous tracking task with nonverbal MA control group. Error bars denote within subject 95% Confidence Intervals.

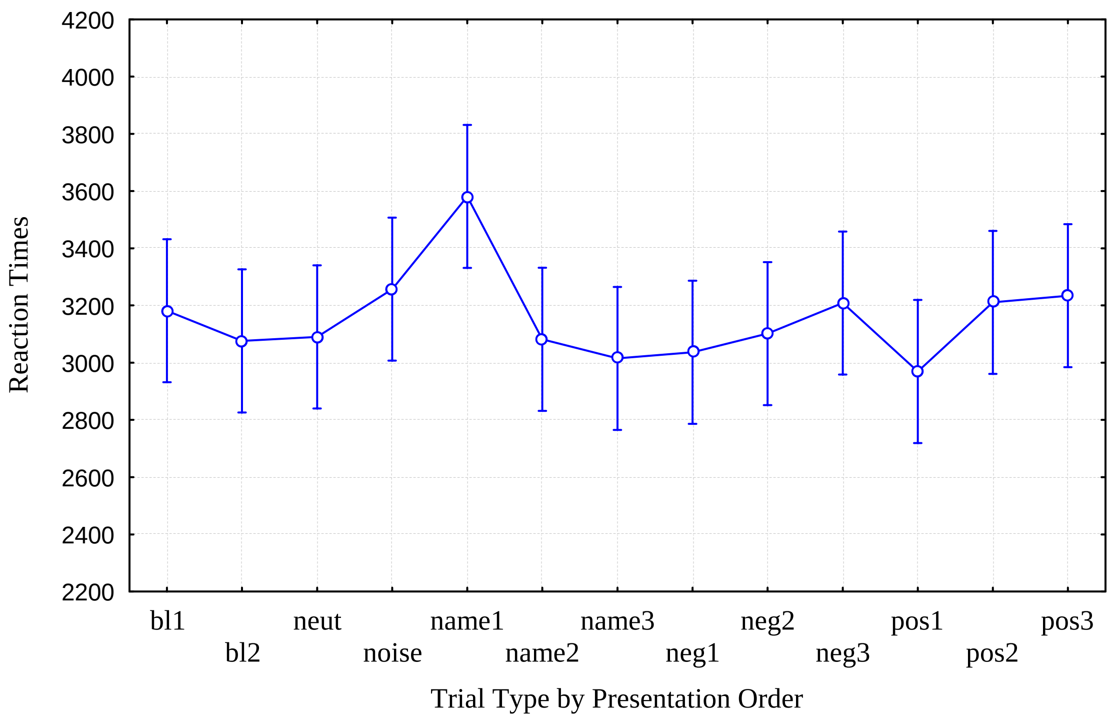



Figure 7E. Main effect of trial type separated by presentation position as measured by reaction time in discontinuous tracking task with verbal MA control group. Error bars denote within subject 95% Confidence Intervals.

VITA

Anna Hismjatullina was born in Tallin, Estonia, a former USSR republic. After the collapse of the Soviet Union, her family immigrated to Tver, Russia, where Anna completed her high school education at the local gymnasium. She moved to the USA in 1995 and attained a Bachelor of Arts in Psychology in 1997 from Columbia College, Columbia, MO. She received Master of Arts in Psychology, Experimental Psychology area, in 2000 from the University of Missouri-Columbia. Anna earned Ph.D. in Psychology, Cognition and Neuroscience area, in 2006 from the University or Missouri-Columbia under the supervision of Dr. Nelson Cowan.

Within cognitive psychology, Anna's interests are in selective attention. In her research she would like to answer the questions what attracts individual's attention and why. Anna also has a longstanding interest in autism and has worked with children with autism since 1996 in programs of early intervention. These two topics are combined in her dissertation project on selective attention in children with autism.

Outside of professional area Anna enjoys reading and traveling. Her family resides in California.