A Method for Testing Implicit Learning

in Individuals with an Autism Spectrum Disorder

by

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Abstract

A METHOD FOR TESTING IMPLICIT LEARNING IN INDIVIDUALS WITH AN AUTISM SPECTRUM DISORDER

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This paper presents a mechanism for testing implicit learning ability in subjects with an autism spectrum disorder (ASD). Individuals with an ASD experience deficits in reciprocal social interaction and communication while displaying odd behavior and stereotyped mannerisms. The onset of the disorder usually occurs very early in development, before the emergence of evidence that effortful conscious processes are occurring within the individual. Implicit acquisition of information seems to play an important role in the typical development of social and communication skills. Since individuals with autism have associated deficits in these areas, a problem with the unconscious acquisition of information from the environment is suggested. However, it is not clear if the associated problem in unconscious acquisition is global, or if it is limited to information within a social context. This experimental paradigm is designed to measure implicit learning ability of both social and nonsocial information. Results demonstrate typical implicit learning ability on the nonsocial SRT task by the ASD group, and atypical performance on the social SRT task. There is additional evidence for a familial factor in RT while completing both SRT tasks. This study may yield important information regarding the endophenotype of autism.

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Table of Contents

List of Tables....viii

List of Figures....ix

Introduction....1

Operational Definitions of Consciousness and the Unconscious....4

Experimental Methods for Assessing Implicit Learning....6

Modifications to the SRT Task in Previous Studies of Implicit Learning....9

The Role of Attention in Implicit Learning Studies....10

Attention and Autism Spectrum Disorders....12

The Autism Endophenotype and Attention....15

Empirical Evidence for the Robustness of Unconscious Processes....17

Evolutionary Model: Why Are Unconscious Processes Robust?....25

Autism Diagnosis and Associated Deficits....29

Autism and Unconscious Acquisition....30

Autism Treatment: Explicit Instruction for Implicitly Acquired Skills....35

Deficits of Autism Spectrum Disorders: Implicit Learning or Social?....39

An Implicit Learning Task for Individuals with Autism....40

Normative and Pilot Data Collection....43

Hypothesis....46

Method....48

Participants....48

Assessment of ASD Participants....48

Apparatus....51
Stimuli....51
Procedure....53
Statistical Analyses....54
Results....55
Blocks One through Five: Sequence Learning....56
Sequence Learning Interference - Block Five vs. Block Six....61
The Effect of Interference: Block Five vs. Block Seven....62
Errors and Perseverative Errors....63
Familial Analyses....73
Discussion....76
Evidence for Unconscious Acquisition of Information in the ASD Group....77
Performance Deficits for the ASD Group on the Social Task....78
Is Reaction Time Familial?....86
Suggestions for Follow-up....86
Appendix....90
Social Task Model A Photographs....90
Social Task Model B Photographs....90
Nonsocial Task Geometric Forms....91
DSM-IV Criteria for Autism....92
References....94

List of Tables

Table 1: Normative Data for Facial Expression Pictures Used in the Social Sequence Reaction Time Task.....44

Table 2: Descriptive Data for Subjects Included in the Analyses for the Social and Nonsocial Sequence Reaction Time Implicit Learning Tasks.....50

Table 3: Within Group Differences in the Mean RT of Block Six and the Average of the Mean from Block Five and Seven for Both the Social and the Nonsocial Sequence Reaction Time Task.....66

List of Figures

Figure 1: Line graph of pilot subjects performance on the nonsocial and social implicit learning sequence-reaction time task....47

Figure 2A: Learning curves for the nonsocial sequence reaction time task....58

Figure 2B: Learning curves for the social sequence reaction time task....59

Figure 3A: Scatterplot of the interference scores on the nonsocial sequence reaction time task....64

Figure 3B: Scatterplot of the interference scores on the social sequence reaction time task....65

Figure 4A: Mean error rate and 95% confidence intervals, as a function of block and group for the nonsocial sequence reaction time task....67

Figure 4B: Mean error rate and 95% confidence intervals, as a function of block and group for the social sequence reaction time task....68

Figure 5A: Mean perseverative errors and 95% confidence intervals as a function of group and block for the nonsocial sequence reaction time task....71

Figure 5B: Mean perseverative errors and 95% confidence intervals as a function of group and block for the social sequence reaction time task....72

Introduction

Throughout the course of life we acquire information that is necessary for survival and development through complex processes known collectively as learning. If a lay person were asked to think about learning, he or she might conjure up an image of a young student with a nose buried in a dense text book, burning the midnight oil. This image is accurate when used to describe someone who is engaged in an effortful conscious process to acquire information. Beginning very early in life, long before we are able to exercise such conscious control to incorporate knowledge about a given topic by opening a book and rigorously studying, we are acquiring information about our environment and developing skills related to communication, social functioning, appropriate behavior, and a legion of others that are linked to typical development. From the first day of life our senses are collecting information about the complex patterns of statistical differences that are inherently present in our environment and we are indeed learning. We, and other organisms, acquire this information from our environment via sensory input and it is necessary for the development of the individual, as well as for the success of the species.

In the past several decades there has been extensive exploration of the cognitive capabilities of the unconscious by both researchers and theorists alike. Research has focused on distinguishing the robust unconscious processes from the frangible conscious processes, and theorists have focused on developing a viable explanation for this contradistinction. The result is a large literature that demonstrates the implicit system is less subjected to population variance and environmental insults than the explicit

counterpart. This body of literature has been summarized elsewhere (Reber A.S. Allen. & Reber P.J., 1999) and highlights will be reviewed later when relevant. Several theoretical analyses have suggested that evolution is responsible for the dissociation between the two systems. These viewpoints will also be discussed in some detail because the inherent message these theories is extremely relevant to the focus of this paper, which is to explore implicit learning in a sample of individuals with autism.

Autism is a severe pervasive developmental disorder with an onset that occurs very early in a child's development, usually before the age of three years and often there are severe cognitive deficits associated with the disorder (Folstein & Rutter, 1977). According to the Diagnostic and Statistical Manual for Mental Disorders, Third Edition (American Psychiatric Association, 1980), approximately 70 percent of autistic individuals have an IQ less than 70, and 40 percent have an IQ less than 50. If autism follows suit with other disorders that have associated deficits in explicit functioning (e.g., Parkinson's, Alzheimer's, and Huntington's disease, amnesia, etc.), it would be reasonable to expect evidence of normal implicit functioning in these individuals. However, children with this disorder experience deficits related to communication, reciprocal social interaction, and play skills. The mere existence of these deficits that occur so early in development, some time before a typically developing child shows any true evidence of making a conscious effort to learn, at least suggests a possible breach in the system that controls unconscious acquisition. There have been no studies conducted to date that explore implicit learning in autistic subjects, probably for the lack of an appropriate paradigm that can be used with the variable level of functioning associated

with this disorder.

However, it is important to note that young typically developing children do show signs of cognitive functions as they are developing symbolic play (i.e., using a placeholder object to represent another object). This behavior also occurs around the same time that they begin to acquire language, and researchers believe these developmental milestones occur together because they are subserved by the same cognitive achievements (see McDonough, Stahmer, Schreibman, & Thompson, 1997). That is to say that using a block to represent a cup during play is a similar behavior to using a word to stand for an action or event. Therefore, it seems likely that very young children are engaging in cognitive processes. Whether or not the processes are taking place in the conscious or unconscious in unknown. However, for simplicity and the purposes of this paper, effortful conscious processes are operationally defined as explicit attempts to acquire information, rather than acquiring knowledge through observation.

The ultimate goal of this project is to test a novel mechanism for measuring implicit learning ability in individuals with autism, while taking into consideration the social nature of the deficits associated with the disorder. Toward this end, a review of the literature that examines the cognitive unconscious will be presented. To begin, it is necessary to provide a description of what is meant by consciousness and the unconscious in the context of this paper and others that explore implicit learning. Then common research methods for distinguishing between implicit and explicit processes will be provided along with a short review of the literature that supports the robustness of the implicit system. The reader may then be left seeking an explanation of the profound

resiliency of processes that operate in the unconscious. Thus, it will be valuable to discuss the concepts of evolutionary biology that led to the development of an evolutionary-based theory to explain the differences between explicit and implicit cognition. Moving forward, a detailed description of the diagnostic criteria of autism will be presented with review of the autism spectrum disorders while paying particular attention to symptoms that seem to indicate problems with the unconscious acquisition of information. These problems will be illustrated by comparing and contrasting typical development with what happens (or does not happen) in the development of autistic children. After the background in implicit learning and autism is established for the reader, a method to test implicit functioning in individuals who are diagnosed with an autism spectrum disorder will be introduced and tested in a sample of individuals with an autism spectrum disorder.

Operational Definitions of Consciousness and the Unconscious

To assist the reader with the interpretation of the elements in this paper, it is necessary to be clear about the meaning of terms "consciousness" and "unconsciousness" as they are applied here. Consciousness, as James (1890) discusses is a cluster of cognitive functions that enables us to be aware of the self. As a relatively late arrival on the evolutionary scene, consciousness was preceded by perceptual and cognitive functions that operated implicitly (Reber, 1992). We possess consciousness as a higher order of being, where organisms from a lower order of species do not possess this cognitive capability. We have the ability for reflection and control over our actions, and the ability to monitor and modify cognitive functions. Protozoa do not display such behavioral

evidence and given their simplistic nervous system it is fair to assume the absence of conscious cognitive control. Consciousness goes well beyond the awareness of an external world that is not oneself, to include the awareness of and the capacity to play a causal role in the inner workings of oneself (Reber, 1992).

It is important to distinguish the complex processes that we are referring to when we mention consciousness from the more simplistic definitions such as wakefulness, which is displayed by early vertebrates with a sleep-wake cycle (Baars, 1988). These more primitive forms of life may exhibit "conscious wakefulness," but it is not clear that they have "consciousness." Following the same train of thought, when we refer to the unconscious, we are not merely referring to sleep, or the absence of consciousness, as it was just defined. In fact, if an organism possesses consciousness, both cognitive processes can be occurring at the same time. The "unconscious" refers to a system in which sophisticated cognitive processes occur without awareness and motivated effort. Unconscious processes transpire in humans, and in lower classes of organisms where evolution has not provided for the development of a sophisticated consciousness.

Exemplifying the dissociation of these two systems has developed into a distinct area of research with multiple methods for measuring implicit ability and comparing it to explicit performance. For the most part, the research is conducted to compare implicit learning and memory, with the analogous explicit functions. This paper will focus on the studies of implicit learning, but will also mention the studies of implicit memory when interesting parallels can be drawn. In the next section, two of the popular paradigms for tapping into the unconscious process of learning are introduced.

Experimental Methods for Assessing Implicit Learning

When reviewing the implicit learning literature one will find there are several different methods used to measure implicit learning (see Reber A.S. Allen. & Reber P.J., 1999), which can be problematic to this, or any body of research. The lack of a common method of measurement adds variability to data that are already muddled with the variability of the subjects' general performance, both within and between subject groups. Variability complicates data analyses and the use of multiple assessment methods makes meta-analyses nearly impossible. Studies that report different or contradictory findings with a given population have their impact reduced because the researchers employed different techniques to measure the ability of the implicit system, thus making a proper comparison impossible. Of these multiple methods used to obtain a measure of one's implicit learning ability, there are two that are more commonly and consistently seen in the literature, the artificial grammar learning (AGL) task, and the sequence reaction time (SRT) task.

Arthur Reber coined the term "implicit learning" (Reber, 1967) to refer to the unconscious process of acquiring information from the environment. He developed the AGL paradigm to measure an individual's ability to unconsciously acquire a set of rules about the correct presentation of letter strings. The task was developed to demonstrate the possibility that individuals first learn grammar in natural language acquisition by detecting statistical differences in the spoken language of others in the surrounding environment. This theoretical viewpoint was in contrast to the Chomskian view that we are all prewired with the ability to produce grammar spontaneously (Reber, 1967). In an

AGL experiment, a subject first participates in the learning phase where he or she is shown a series of letter strings that vary in length and is told only to try to memorize the strings. The letter strings are constructed by navigating through a flow chart that presents the rules pertaining to what is a grammatical construction and what is not. There are combinations of letters that cannot "grammatically" appear next to each other, and other individual letters that cannot appear after a particular grammatical pair. After the learning stage, subjects are told that the strings actually followed a set of rules but are given no additional information.

For the second phase of the experiment, the subject sees novel strings and is asked whether or not the strings are following the rules exhibited during the learning phase. If a string follows the rules then it is classified as grammatical, otherwise it is nongrammatical. Once the number of strings correctly identified (as either grammatical or nongrammatical) significantly exceeds the percentage that the subject could obtain if he or she were merely guessing, it was considered fair to assume implicit learning had occurred. In the AGL task, it is important to recognize that the subjects seem to acquire information that pertains to the rules of construction for the strings because the strings displayed in the experimental phase are novel constructions (i.e., never seen before). Therefore, it is most likely the unconsciously acquired knowledge of the rule system that yields the number of correct answers.

The second method to be discussed is used more frequently than the AGL task, and especially with clinical populations. Nissen and Bullemer (1987) introduced the SRT task in a study that examined implicit learning in patients with Alzheimer's disease. In

this original version of the SRT task, a subject sees a series of lighted asterisks displayed on a computer monitor in one of four positions and is asked to execute the keystroke that corresponds to the location of each lighted asterisk. Each asterisk remains on the screen until the subject presses the correct button and the reaction time (RT) is measured to the nearest millisecond (msec). Nissen and Bullemer programmed in a 500 msec delay after the subject's response and before the next asterisk appears. The placement of a delay between the response and the next stimulus is more recently referred to as the response-stimulus interval (RSI). Studies that focus on manipulating this interval and examine its effects on learning have produced some interesting results which will be discussed later. The asterisks were presented in a 10-item sequence, and the sequence appeared ten times in one block. The task included four blocks of the sequential presentation, and a fifth block presented in random order. Since subjects were not told about the repeating sequence, implicit learning was assumed to occur if a subject's reaction time (RT) decreased across the first four blocks and increased from block four to block five.

The SRT task is used frequently throughout the implicit learning literature, and its features can vary from experiment to experiment. The liability associated with such variability within a task is described above. However, the flexibility in the task affords some advantages, such as the task can be easily modified to fit the administration to particular subgroups or examine a particular feature of learning. This enables the experimenter to examine the many different properties of implicit sequence learning and how they may be applied to different clinical populations. In this study we will modify the SRT task for use in the autism population and the task will be geared toward

identifying differences in implicit learning when the stimuli are of a social, or a nonsocial nature.

Modifications to the SRT Task in Previous Studies of Implicit Learning

Researchers have modified the SRT task by altering the key features of the task including the stimuli, type and structural characteristics of the sequence (Cohen, Ivry, & Keels, 1990), length of sequence (Howard & Howard, 1989), number of trials per block, and number of blocks per phase of the experiment. The presence and the length of the RSI can also have a dramatic effect on the results. Stadler (1993) varied the duration and placement of the RSI and found that sequence learning is more efficient if the RSI is longer (by about 1500 msec) at the end of the sequence than it is during the sequence. With the RSI in this position, the beginning and end of the sequence is subtly identified to the subject, but the improvement in learning is dramatic. When either the duration or the position of the RSI was randomized, the beginning and end of the sequence were masked and learning was interrupted. The random presentation of the RSI throughout the sequence made it more difficult for the participant to learn the sequence, possibly because the amount of statistical variation that is present in the stimulus array interfered with the participants' ability to organize their knowledge of the sequence.

Another way to manipulate performance on implicit tasks is to introduce stimuli that require greater attention on the part of the subject. Attentional capacity undoubtedly plays an important role in implicit learning and some researchers have manipulated various features of the SRT paradigm to get a better grasp on understanding that role. Nissen and Bullemer (1987) found they could impair or prevent implicit learning in

subjects by introducing a secondary task to run concurrently with their version of the SRT paradigm. Subjects were asked to respond to the stimulus presented on the screen and to keep track of an auditory stimulus that was sounded at intervals throughout the task. The control subjects demonstrated impaired implicit learning ability, and performed similarly to some of the Alzheimer's disease patients who failed to learn on the standard SRT task. The secondary task appeared to have diverted the attentional resources and the result was impaired performance on the primary task, suggesting that perhaps a lack of attentional resources associated with some clinical disorders may impair performance on such tasks. However, these results suggest very little about the loss of ability to acquire information unconsciously from the environment. It is possible that information is still being acquired but it may take longer for subjects who operate under these conditions to show evidence of learning.

More recently researchers are suggesting that the dual task environment is not really a "dual" task at all, but just a more difficult task than one that deals with only one source of stimuli (Heuer & Schmidtke, 1996; Rah, Reber, & Hsiao, 2000). The multistimuli environment creates a situation that resembles the real world more closely, as we are most often detecting changes in the stimulus array, that are from different modalities.

The Role of Attention in Implicit Learning Studies

At this point it is necessary to take a slight digression and discuss the issue of attention as it pertains to implicit learning. Attention is a key feature of implicit learning tasks as subjects may be required to sit and attend to a simple task for approximately 15

minutes, or perhaps up to an hour or more for a task with greater complexity. Attentional deficits that are associated with the autism have been explored in recent years (Goldstein, Johnson, & Minshew, 2001), and are of some concern here because it may present some difficulty finding subjects that are able to complete an implicit learning task. This research will be addressed in the next section.

When using the SRT task, the attentional requirement can be manipulated in several different ways. Within a sequence, there are different types of structures that can be created that require more or less attention (J. Cohen et al., 1990). Therefore the design of the sequence in a particular experiment must be carefully considered and related to the target population. By manipulating the number of repeating elements within the sequence, three types of structures can be created: (A) Ambiguous structures, which have no repeating combinations of two stimuli (e.g., ACDBCABD); (B) unique structures, which contain repeating combinations of stimuli that allow one to predict future elements in the sequence (e.g., ADCBADCB); and (C) hybrid structures, which combine the features of the ambiguous and unique structures. In their dual task environment, Nissen and Bullemer (1987) used an ambiguous sequence, which requires the most attentional capacity, and subjects demonstrated learning deficits. However, subjects have demonstrated learning in the dual task environment when the unique or the hybrid sequence structures are used (A. Cohen et al., 1990). Thus the mere addition of a secondary task does not alone impair learning, and the different types of internal sequence structure require different amounts of attentional capacity.

The length of the sequence is another manipulated feature of the SRT paradigm

that is seen in the literature on attention and implicit processes. Longer sequences require more attentional resources than shorter ones, and subjects demonstrate stronger learning effects with shorter sequences (Howard & Howard, 1989). Pascual-Leone et al. (1993) conducted a study of implicit learning on patients with Parkinson's disease and found a similar effect of a longer sequence, but concluded the diminished learning effect was due to a greater demand on working memory as a result of the longer sequence. However, shorter sequence length does not always ensure more efficient learning. In some studies the two types of manipulation (structure and sequence) have been combined and it was found that shorter sequences with a more difficult structure were harder to learn than longer sequences that had less complicated structures (Stadler & Neely, 1997). Research studies like these illustrate the impact of the variations in stimuli and the associated effects on learning. Both features of the sequence and the presence of a secondary task will effect learning in a way that may be mimicking what is occurring in the real-world environment.

Attention and Autism Spectrum Disorders

Attentional impairment has been implicated as a core deficit of autism and has been studied extensively for the past several decades. Both the SRT and the AGL task require the attention of the subject for a reasonable amount of time (e.g., approximately 15 to 60 minutes). As this paper is presenting a method for measuring implicit learning ability in individuals with autism, the associated attentional deficits require some consideration here. When subjected to neurocognitive testing, individuals with an autism spectrum disorder (autism, Asperger's, or pervasive developmental disorder, not

otherwise specified) may display atypical performance that suggests a deficit in executive functions (Noterdaeme, Amorosa, Mildenberger, Sitter, & Minow, 2001) and reduced attentional engagement during visual tasks (van der Geest, Kemner, Camfferman, Verbaten, & van Engeland, 2001). However, the attentional deficits associated with autism do not appear to be global. Children with autism have also demonstrated a level of attention comparable with a normal control group on a continuous performance test of sustained attention (Garretson, Fein, & Waterhouse, 1990).

Deficits in attention are commonly associated with neuroanatomical abnormalities. However, the contradictory results from these studies suggest that at least some of the autism related attentional difficulties are not necessarily linked to neuroanatomical differences and that perhaps problems with attention lie with controllable behavioral anomalies associated with the disorder. For example, it may be difficult for an autistic subject to attend to a task for an extended period of time if he engages in repetitive motor behavior, like finger-flicking or odd posturing. Higher functioning subjects may have similar difficulties completing a task if they feel compelled to discuss the facts of their narrowly focused interest with the examiner. These overt behaviors will give the appearance of reduced attentional capacity, when in fact the same subject can sit and attend for hours to the paraphernalia of their narrow interest (e.g., train time tables) or a video game.

A suitable model of attention that can be globally applied to autism has yet to be developed, which may possibly be attributable to the lack of a consensus on defining the construct itself. Commonly seen definitions for attention include encoding sequences of

information into short-term memory, sustaining concentration, resisting distraction and shifting focus of attention (J. Cohen, 1957). More recently, a four-factor model has been empirically derived to include the following components in one definition of attention: (a) focus on target in the presence of a distraction, (b) sustained vigilance, (c) shift-focus ability, and (d) the ability to receive and interpret information (Mirsky, Anthony, Duncan, Ahearn, & Kellam, 1991).

Based on this model, a comprehensive study was designed to tease out the attentional deficits seen in a large sample of individuals with high-functioning autism (n = 103) when compared to chronological age and sex matched controls (Goldstein, Johnson, & Minshew, 2001). Several tasks were employed to specifically measure attentional capacity in each of the four factors described in the model. It has been established that individuals with autism commonly display psychomotor deficits (Bauman, 1992; Minshew, Goldstein, & Siegal, 1997), and the researchers recognized this deficit as a confound when interpreting the performance of the autistic subjects on tasks that required psychomotor dexterity. The results demonstrated that the performance deficits in the autism group were associated with the tasks that require shift-focus flexibility or that utilize psychomotor speed. Since the autism-related motor deficits alone may have produced the performance deficits in these tasks, the authors found no unequivocal evidence of an attention deficit associated with autism. There was no significant difference between the two groups on tasks that required accuracy of response or sustained vigilance. Therefore, individuals with high-functioning autism should not have a problem attending to tasks of implicit learning. On SRT tasks where RT is

recorded, it is fair to assume that these subjects might be slower than control subjects. However, the overall speed during the SRT task is not the measure of implicit learning. Rather, one measure of implicit learning is the reduction of RT during the learning phase and the increase of RT during the transfer block. Given these results one might expect individuals with autism to learn information implicitly about as well as the control group, but only slower.

The Autism Endophenotype and Attention

An endophenotype can be defined as a cluster of traits or measurable characteristics that are not observable in a routine physical exam, or through a standard psychiatric assessment. As an example, abnormal EEG readings in response to stimuli may be considered part of an endophenotype for a particular psychiatric disorder like schizophrenia. Multiple aspects of attention can offer information about endophenotypes in autism spectrum disorders. Event-related potentials (ERP) reflect brain electrical activity that is associated with a discreet event such as a visual or auditory stimulus, and is frequently applied in tasks measuring attention for the purposes of assessing the associated neural activation. Researchers have utilized this method of measurement to try and explain some of the attentional deficits associated with autism. Dunn (1997) presents a fairly comprehensive review of studies where the autistic group routinely performed the task as well as the normal controls, but there were differences noted in the ERP readings. Some of the atypical readings have been attributed to inefficient processing of information, which in turn was related to difficulties with sustained and selective attention. Belmonte (2000) examined attention in autism through visual evoked

potentials. Subjects were shown visual stimuli that flashed rapidly and alternated between the right and left visual hemisphere. The autism group showed high variability in steady-state responses and no modulation of background EEG, where controls showed increased steady-state responses and decreased background EEG in each corresponding hemisphere. According to the author, these findings suggest the lack of hemispherically independent modulation in autism, which may reflect the abnormal sensory gating.

The diagnosis of Asperger's Disorder in contrast to high-functioning autism is difficult to distinguish, theoretically. Information that can highlight the differences between the two classifications would be of great benefit. Some researchers are beginning to look for endophenotypic differences between the two diagnoses. Rinehart, Bradshaw, Moss, Brereton and Tonge, 2001, tested high-functioning autistic individuals on a hierarchical test of processing. Individuals with high-functioning autism displayed deficits in shifting attention from local to global processing, but those subjects with Asperger's disorder did not show evidence for the same abnormality nor did the normal control subjects. Their finding presents an interesting split of the abilities that are associated with each diagnostic classification because many clinicians, researchers, and parents consider the two disorders to be the same. If the difference between high-functioning autism and Asperger's Disorder is real, the presence of abnormal shifting of attention may be an autism endophenotype and an endophenotype of Asperger's Disorder. Such subtleties, if they are real, may present important information to be considered when attempting to enhance differential diagnostic criteria of autism spectrum disorders.

Attention and neurocognitive abnormalities are complicated constructs and

attempting to gain a better understanding of how they work and influence the lives of individuals is an equally complicated task. The task becomes even more complex when one attempts to use the assessments that were designed for use in a normal population with subjects who are clinically impaired, and autism is an especially difficult condition to study. The collective knowledge base regarding the neuropathology of autism and the associated cognitive capabilities is quite incomplete, mainly because most of the subjects who have the disorder are too low functioning to participate in tasks that adequately measure things like attention, memory, and learning. Neuroimaging techniques would be most informative in this regard. However, a limited number of subjects within this population are capable of following the requirements for imaging, such as remaining motionless, and following task instructions. Most neuroimaging studies of autism have used high-functioning subjects who may not have the same neuroanatomical disturbances as low-functioning subjects.

The results from neurocognitive and neuroimaging studies such as these suggest subclinical features that help to define at least some of the endophenotypic characteristics of ASDs. It is clear that more work needs to be done in this area including the development of ways to tease out more subclinical features associated with this spectrum of disorders. Methods of diagnosing autism can be quite variable and there are inconsistencies in the diagnostic classification. Therefore, further exploration of the endophenotypic characteristics of autism might help to add clarity to the very cloudy differential diagnostic criteria.

Empirical Evidence for the Robustness of Unconscious Processes

Since Reber's (1967) first exploration of the cognitive unconscious, the literature on implicit learning continues to grow, and most dramatically in the past 15 years. The ability to acquire information in the absence of effortful conscious processes has been tested in a number of different conditions where explicit learning tends to vary. In these same conditions, performance on implicit tasks remains fairly stable when compared to the results of explicit testing. For example, it is fair to assume that as age increases so does the amount of explicitly acquired knowledge. In most cases, older people simply have had more time to put effort into acquiring knowledge than younger people. Therefore, very young children will not perform as well as older subjects on some tests of explicit learning.

Nonetheless, cognitive processes that take place without conscious effort are somehow different. Before infants begin to show evidence of such effortful conscious processes, they show evidence for implicit learning ability. Infants have demonstrated unconscious acquisition of information by attending more to the novel strings of nonsense syllables that were different from those strings presented in the learning phase of an experiment (Saffran, Aslin, & Newport, 1996). Young children have performed about as well as adults on implicit learning tasks, when the adults were better at tasks of explicit functioning (Meulmans & Van der Lindan, 1998). These studies, and others like them provide consistent evidence for much less age-dependant variability associated with unconscious processes, than is more commonly associated with explicit functioning.

Implicit processes are not totally without variability in the population. Using a nonverbal sequence, Cherry and Stadler (1995) compared implicit learning ability of

younger adults with older adults (retirees) that were separated into two groups according to level of cognitive ability. Based on level of education, occupational history, and verbal ability, each subject was placed in either the higher or lower cognitive ability group. The young group and the higher ability old group performed comparably on the implicit learning task, but the lower ability old group did not perform as well as the other two groups. These results suggest that implicit learning ability, although intact, may vary somewhat with age and/or general cognitive ability, but there was still much less variation than was seen in explicit learning ability.

Performance on explicit tasks correlate strongly with IQ, which is quite variable in the general population. Implicit learning performance does not correlate with IQ and is assumed to be less variable across individuals (Reber, Walkenfeld, & Hernstadt, 1991). Mayberry, Taylor, and O'Brien (1995) examined the relationship between implicit learning and factors like age and IQ, and found implicit learning to improve slightly with age across two groups (young children and adolescents), but supported previous findings that it is uncorrelated with IQ.

Although groups of elderly subjects have sometimes demonstrated slightly abated performance on the implicit tasks (Cherry & Stadler, 1995; J. H. Howard & D.V. Howard, 1997a) there is to date, no direct evidence that implicit learning task performance fluctuates with as much variability on tasks measuring explicit learning. The previously discussed studies examine factors that affect explicit learning performance in nonclinical populations, and we find implicit learning for the most part, to remain stable within the population.

Also in the past several decades, those researchers who study either unconscious processes or clinical disorders have tested the robust properties of implicit systems when faced with insults that have had a diminishing effect on conscious processes. Perhaps some of the most important evidence for preserved implicit functioning stems from studies involving amnesic patients (Greve & Bauer, 1990; Musen & Squire, 1993; Nichelli, Bahmanian-Behbahani, Gentilini, & Vecchi, 1988; P. J. Reber & Squire, 1994; Sala, Spinnler, & Venneri, 1997; Wilson, Green, et al., 1996). While amnesic patients display numerous difficulties with explicit functioning, there is relatively little difference in their performance on implicit tasks when compared with normal controls. Several studies demonstrate that psychiatric patients, like amnesic patients, show normal performance on implicit tasks but perform significantly worse on tasks of explicit learning when compared to a group of normal controls (Abrams & Reber, 1989; Schmand, Kop, Kuipers, & Bosveld, 1992). Rathus, Reber, Manza, and Kushner (1994) examined performance on implicit and explicit tasks with varying affective states and found an association between test anxiety and explicit learning performance, but that test anxiety had no noticeable effect on implicit learning ability.

Implicit learning, as well as memory, has also been studied in patients with neurodegenerative disorders such as Alzheimer's and Parkinson's disease (AD and PD, respectively). The results from such studies have been similar to those from studies of patients with amnesia, psychiatric disorders, and several other disorders that are not covered in this review (e.g., Korsakoff's syndrome and prosopagnosia). Results from a number of studies are consistent with their findings of stable implicit learning

performance of AD and PD patients while deficits in explicit functions are to be expected (Deweer, Pillon, Michon, & Dubois, 1993; Deweer et al., 1994; Grosse and Wilson, 1991; Knopman & Nissen, 1987; Starkstein et al., 1997).

However, there are also some studies that present slightly contradictory results that deserve some attention here as well. These studies found slightly diminished implicit learning, or a failure to learn implicitly in AD and PD patients (Knopman & Nissen, 1987; Ronacci, Troisi, Carlesimo, Nocentini, & Caltagirone, 1996). It is important to remember when evaluating this literature that when performance on implicit learning tasks is affected it does not necessarily imply the implicit learning mechanism is malfunctioning. For example, very aged and/or neurologically impaired populations may perform these tasks much more slowly than younger, healthier adults, too slow to demonstrate learning in the SRT task because their sensorimotor functions may be disturbed. In other words, when the older, impaired subjects are called on to make a simple timed response they may just be too slow for the task to reflect what is being learned, but these subjects are still capable of learning as well as the younger, healthier counterparts. Additional factors that may affect performance on implicit learning tasks are attention (as discussed earlier), motivation and short-term memory.

Although learning as a cognitive function is given the most attention in this paper, parallel results that add further support to the integrity of unconscious processes can also be seen in studies of implicit memory. Most explicit memory tasks require individuals to recall past events or stimuli. Implicit memory tasks usually start with priming, where the subject is exposed to the test material. During the test phase the subjects are never asked

to simply recall the material, but only to perform a given task as quickly and as well as they can. While performing the implicit memory task, subjects should be unconsciously drawing on information they acquired during the priming stage of the experiment. Implicit memory is measured by how well they perform during the test phase of the experiment.

In nonclinical populations of children ranging from three to 10 years of age, there is evidence of fairly consistent levels of implicit memory, whereas explicit memory functioning increases dramatically with age (Hayes & Hennessy, 1996; Russo, Nichelli, Gibertoni, & Cornia, 1995). In these studies implicit memory is relatively enduring across time. Three-year old children have also demonstrated significant implicit memory effects across a three-month delay (Drummey & Newcombe, 1995). These studies provide some additional evidence for the reduced population variability associated with processes that operate in the unconscious as they are compared to conscious functions.

As with studies of implicit learning, neurodegenerative disorders such as AD, PD, and Huntington's disease (HD) present interesting clinical populations for the study of implicit memory. As demonstrated by the results from studies of implicit learning, there is also evidence for preserved implicit memory systems in patients with these disorders (Heindel, Salmon, Shults, Walicke, & Butters, 1989; Ferraro, Balota, & Connor, 1993). Bylsma, Rebok, and Brandt (1991) studied implicit memory in patients with Huntington's disease. They compared the patients' performance to healthy control subjects on tests of explicit and implicit memory. The patients performed significantly worse than the control group on the explicit task by having more false positive responses. On the

implicit task, there was no significant difference between the patients and the controls, and the same result was found at a six-month follow-up assessment.

As in the implicit learning literature, studies with amnesic patients provide dramatic evidence in support of the stability of the processes that operate in the unconscious by demonstrating preserved implicit memory functioning. A number of studies with this population demonstrate preserved implicit memory and deteriorated explicit memory (Cave & Squire, 1992; Cermack, Talbot, Chandler, & Wolbrast, 1985; Graf, Squire, & Mandler, 1984). Amnesic patients tend to show long lasting priming effects and are usually able to perform as well as control groups on tests of implicit memory. As expected, amnesic patients perform significantly worse than control subjects on tests of explicit memory. Thus, these studies provide strong empirical evidence for the resiliency of the implicit system.

There are some research findings that indicate an overlap between autism and amnesia. These findings have prompted researchers to explore autism as a type of amnesic disorder. Neuroanatomical similarities between medial temporal lobe amnesia and autism have been found (DeLong, 1992), and subjects with autism have performed like amnesic patients on tests of immediate free recall (Boucher, 1981). Medial temporal lobe amnesia is associated with combined damage to the amygdala and hippocampus, and there are animal models that point to an impaired hippocampus and amygdaloid complex associated with autism (Bachevalier, 1994).

As previously illustrated, patients with amnesia are expected to show impaired explicit memory, but function about as well as normal controls on tests of implicit

memory. Autistic individuals were tested for a similar dissociation in performance on explicit and implicit tasks because of associated neuroanatomical abnormalities that are similar to those seen in amnesic patients (Renner, Grofer-Klinger, & Klinger, 2000). Children with high-functioning autism and age-matched controls participated in one implicit (perceptual identification) and two explicit memory tasks (recognition and free recall).

The results of this study showed no dissociation between implicit and explicit memory for the autistic group, and they performed as well as the normal control group on both tasks. These results are contrary to the theory that autism is a type of amnesic disorder. However, the autistic group did show an atypical pattern of recall. Where most nonautistic subjects recalled more items from the beginning and end of a list, the autism group recalled more from the end of the list only. This study also provides some evidence for atypical organizational strategies during encoding or retrieval of items from memory among autistic individuals.

The studies discussed in this section are only samples of a rich source of literature that supports the relative stability of unconscious cognitive processes. It seems clear that conscious processes do not share these properties to the same degree. Explicit functioning is subject to the effects of biological insult and environmental injury, and the results are greater variability in the general population, and may sometimes be devastating to the individuals functioning and overall well being. When presented with these same insults and injuries, the functioning of the implicit learning and memory seems to remain intact, despite these same insults and injuries. Theorists have determined possible

reasons for the stability of unconscious processes that are rooted within the principles of evolutionary biology.

Evolutionary Model: Why Are Unconscious Processes Robust?

Several theories have been developed to help explain the dissociation between the implicit and explicit systems, suggesting that unconscious processes are more stable because the unconscious is evolutionarily older than the conscious; where explicit processes operate. There are three well developed evolutionary analyses that help to explain the robustness of the unconscious processes. Rozin (1976) presented an evolutionary theory in a Darwinian context and coined the term "cognitive unconscious," to refer to implicit processes. He argued for the presence of primitive modules where each is linked to specific cognitive functions. Through evolution, the once encapsulated modular units become more accessible to one another. As a result, more sophisticated executive functions become possible and consciousness emerges. In 1987, Sherry and Shacter presented a similar theory also emphasizing the modular approach, but rather than viewing each module as limited to the specific function that developed through evolution, in their theory these modules might also assume various other functions.

The third perspective was developed by Reber (1992) who agreed with the emphasis on function and the adaptive value of structure expressed in the previous two theories, but believes there is a lack of empirical evidence to support the presence (or absence, for that matter) of a modular system. His view is based both on classical heuristics of evolutionary biology and also a more contemporary viewpoint of the evolution of consciousness. Both make an important contribution toward the

development of Reber's arguments for an evolutionary model to support the robustness of unconscious processes, and will be discussed here briefly.

The classical view consists of four laws of development proposed by von Baer in 1828 (translated by Gould, 1977) and provide the basis for the unfolding of Reber's argument. The laws were part of von Baer's critique of the recapitulationists model that ontogeny mirrored phylogeny. Von Baer held the position that this model was not true and that embryos of a higher species could not possibly pass through the adult forms of a lower species. The laws are now captured succinctly through the generalization that differentiation proceeds from the general to the particular. This generalization has become essentially universal in evolutionary biology, and the four laws are rarely stated as they predate Darwin's theory of evolution.

The more contemporary viewpoint also provides similar support for Reber's argument and the present study. Schank and Wimsatt (1987) attempted to formalize von Baer's laws, and many other principles of evolutionary biology, by engendering the developmental lock model. The complexities of their theory can be illustrated through the use of a metaphorical bicycle lock, the type with several separate dials to adjust to a specific number of the combination so the lock can be opened. Metaphorically speaking, opening the lock is akin to the creation of a viable organism and/or a viable species (the theory can be applied to phylogenesis or ontogenesis equally well). To achieve success with the bicycle lock, moving from left to right, each dial needs to be in the correct position before the next dial can make its contribution toward a successful outcome. Following this same logic, each phylogenetic (or ontogenetic) stage of development is

dependent upon the success of the previous developmental stage. In other words, each stage of development should be successful before other stages can develop. This theory should not be interpreted to mean that earlier evolutionary stages of development provide a foundation for future stages (the position of the first dial on a bicycle lock has no influence over the position of the second dial) but successful evolutionary development is dependant upon the successful development of each stage (the lock cannot open unless each dial is in a correct position).

To illustrate Reber's argument for the use of the evolutionary model, it is better to think in terms of a hierarchical pyramid. The base of the pyramid is the strongest part of the pyramid and it is also the first part of the structure that is built. The unconscious appears to be more stable than consciousness and therefore, it is more like the base of the pyramid. Consciousness is subject to variability in the population and can be markedly affected by environmental insults. Therefore, consciousness is akin to a section of the pyramid that must have been built after the structure's base, and has more of its surface exposed to the elements. The exposed surface is naturally subjected to environmental insults. Since the unconscious was "built" before consciousness, in evolutionary terms it must be considered to be older than consciousness.

According to the principles discussed above, that which is older, evolutionarily speaking, tends to be more stable. The newer construct on the evolutionary continuum of a species, in this case consciousness, has not developed the stability of the older construct, or unconsciousness. Thus, the newer construct is subject to population variance and can be markedly affected by environmental insults. In evolutionary terms, if history

dictates the future, it would seem that the less stable constructs would continue to evolve to be more stable, but we have no real way of knowing that this progression will occur. Hence, given this conceptualization of the evolutionary position of the unconscious, Reber puts forward the following five properties that we should expect implicit cognitive systems to display presently without making any predictions for the future evolution of consciousness:

1. Robustness in the face of various disorders and dysfunctions.
2. Age-independence: The systems should display fewer effects of age and developmental level than explicit cognitive functions.
3. Lower population variance: Implicit functions should show little variation as compared to explicit functions.
4. IQ-independence: Measures of implicit functioning should be uncorrelated with standard measures of explicit functioning.
5. Commonality: The underlying processes of implicit acquisition and memorial representation should show across-species commonality.

Reber (1992) presents an in depth review of the results from independent studies where these properties are well supported. In the decade since Reber published this evolutionary perspective of implicit processes, the research results have continued to support the robust nature of unconscious learning and memory. Much of this work utilizes clinical populations that have impaired explicit functioning. The populations in these studies have disorders that develop in adulthood or much later in life, and the associated symptoms suggest no deficit in unconscious processing of information.

Autism is a disorder that affects children before the age of three, mostly before evidence of effortful conscious processes emerge. Children with this disorder display symptoms that seem to be linked with difficulties acquiring information from their environment. Although autism research has come a long way in the past several decades, more work needs to be done to further the scientific knowledge base regarding the perplexing disorder.

Autism Diagnosis and Associated Deficits

Autism is a severe pervasive developmental disorder that typically affects children before the age of three. Kanner (1943) was the first to identify autism as a cluster of symptoms displayed by a group of children that did not show any obvious evidence of an organic disorder. The symptoms included a preference for social isolation, a lack of typically developing language, and a need for "sameness." He borrowed the term from Bleuler, who used it to describe the social withdrawal commonly associated with schizophrenia. Autism was not officially considered a disorder in the U.S. until 1980, when the Diagnostic and Statistical Manual, third edition (DSM III) included autism in the section for psychiatric disorders of infancy and childhood, under the subheading, "Pervasive Developmental Disorders." Since then, the diagnostic criteria have become less restrictive and better developed in subsequent versions of the DSM. It was a decade before autism became a popular focus for various kinds of research.

Although the accepted criteria for diagnosing the disorder require an onset before the age of three, some children show obvious deficits right from birth. Others will show typical development before abnormality begins, which can be in the form of a failure to

progress, or a regression where there is a definite loss of acquired skills. Approximately 40% of parents report typical development until an insidious regression occurs in language, social interaction and reciprocity, and a loss of typical play skills (Tuchman, Rapin, & Shinnar, 1991).

The first signs of the disorder can appear in any of the associated behavioral domains, but a common scenario is one where children fail to respond to the sound of the parent's voice, or even their own name being called. This symptom can be accompanied with the loss of a few acquired words or a total lack of language development. Frequently, parents or a health care provider will question whether or not the child might have a hearing problem because a failure to respond and a lack of language are the most logical indication of such. This concern is quickly dismissed once the hearing is formally checked. Prior to the formal assessment, a parent may perform an informal hearing assessment by conducting the well-known "cookie" test. Here, out of the child's field of vision, a parent asks the child if he wants a cookie (or a favorite snack food), and when this offering gets their child's attention it almost immediately dispels the parent's concern for a hearing loss.

Autism and Unconscious Acquisition. For the first few years of life, typically developing children are continuously acquiring information and developing a staggering assortment of new skills without consciously making the effort to do so. They are readily acquiring information about their physical, social, cultural, familial, and linguistic environments virtually without awareness of the process. The acquisition of this information may be an important aid for the development of skills such as

communication and language. Within the first year or two of life, infants manage to parlay simple vocal exercises into their first single words without being formally taught how to do so, thus marking the development of natural language.

Some children with autism do not ever develop functional language (Lord & Paul, 1997), but for those who do there can be many associated anomalies (Wilkinson, 1998). Some children do not get beyond the use of single words or simple three-word phrases, used mainly to satisfy a want or a need. If children with autism do develop speech it is typically delayed, and the delay can be as long as several years after the acceptable age range associated with typical development. If language develops beyond a simplistic level, there may be problems with the way speech is used appropriately and communicatively. Some children may be able to say any combination of words or sentences but their speech is almost all echoed or repeated from other people in their lives or from television or movies (this symptom is commonly referred to as immediate or delayed echolalia). When they are able to produce their own speech, another problem that hampers the communicative nature of the speech is a possible lack of appropriate tonality, rate, and prosody (Tager-Flusberg, 1995). Without the proper tone, the listener may have extreme difficulty inferring the meaning of what is said.

Typically developing children seem to acquire this knowledge of how to communicate their feelings and other information through the subtle nuances of verbal communication. The acquisition of these skills comes without effort on their part or the aid of a formal educator, but merely through observation of others communicating in their environment. Children with autism who experience these communication deficits seem

to have failed to acquire these skills. However, it is possible that the children have acquired the skills, but the difficulty lies in processing the information. Currently, there is no published research to support either claim.

For individuals with autism, regardless of their language ability, nonverbal communication may also be atypical or the ability may be absent completely (Wetherby & Prutting, 1984). They may not display the appropriate facial expression, or simply have no expression when communicating emotive content. The lack of appropriate facial expression can make things very difficult for parents and others to determine how the child is feeling in a given situation. This symptom may also seriously impair normal social interaction with peers (Lord, 1993). Gesturing is another difficulty associated with both verbal and nonverbal children who have this disorder. Frequently throughout the day, people typically use gestures to communicate or to enhance verbal communication. Without the appropriate use of this mode of communication there are serious impairments (Lord, Rutter, & LeCouteur 1994).

Another group of skills that infants begin to develop early in life pertains to nonverbal communication. Arm and hand movement changes that communicate wants or needs have been examined in infants as early as nine to 15 weeks (Legerstee, Corter, & Kienapple, 1990). The movements were thought to be communicative because they were differential, and coordinated with eye gaze and affective states. Another study marks the differentiation of instrumental and conventional gesturing between the age of nine to 15 months (Messinger & Fogel, 1998). Once again, these features of typical development are emerging before any evidence of effortful conscious cognition.

Individuals with autism will also display some type of repetitive motor behaviors and/or odd restricted interests. It is a widely accepted notion that the various deficits and behavioral abnormalities associated with autism will undoubtedly impair the social functioning of the affected individual (Lord et al., 1994), and repetitive behaviors and restricted interests are no exception. This component of autism is most like obsessive-compulsive disorder where it seems as though the individuals feel pressure to complete some act or a sequence of acts, because they are noticeably distressed when they are prevented from satisfying this compulsive desire. Some individuals may display stereotyped hand and finger movements, or other complex whole body mannerisms. These behaviors are usually done uncontrollably and make the individuals appear extremely odd, thereby markedly affecting social interaction. If the individuals have restricted interests, social interaction also becomes problematic because they may either spend all of their time researching or acting on one particular interest to the exclusion of social interaction or will talk incessantly about one particular topic so that the listener soon becomes disinterested.

Where typically developing children are learning to speak fluently and use nonverbal communication to become functioning, active members in their environment, children with autism are failing to do so. There are certain behaviors that typically developing children (or even infants, for that matter) do almost reflexively, like reciprocal social smiling or motivated eye contact, and children with autism do not seem to display these behaviors with the same frequency or flexibility, if displayed at all (Lord, 1993). These very basic skills are the cornerstones of effective nonverbal communication. On a more

sophisticated level, there are deficits in other important nonverbal behaviors that modulate social interaction. The lack of ability to display and interpret appropriate instrumental and conventional gestures also hampers one's ability to interact socially. Instead of a seamless interaction, there are often awkward pauses and stilted reactions that obviously mark these individuals as very odd.

The autism spectrum of disorders is extremely heterogenous with varying levels of severity within and among associated behaviors, which can lead to confusion about various diagnostic classifications. According to the Diagnostic and Statistical Manual, Fourth Edition, (APA, 1994) milder forms of the disorder that fall short of meeting full criteria for autism in any of the three areas of affectedness might be classified as Pervasive Developmental Disorder - Not Otherwise Specified. Those who fail to meet criteria for autism and have very well developed language skills along with a high level of restricted interests might meet criteria for Asperger's Disorder. These individuals may often go undiagnosed but are often labeled odd or eccentric throughout their lives, perhaps excelling in a particular profession while displaying very poor social skills.

The diagnostic classification of autism also has varying levels of severity associated with it. Extremely affected individuals may never develop speech at all (Lord & Paul, 1997), or not beyond the use of single words or simple phrases. Other higher-functioning individuals (that some term high-functioning autism) may display advanced language skills, but with little emotional intonation. These individuals may better resemble those with Asperger's Disorder, rather than what is commonly thought of as autism. Individuals with even moderate forms of the disorder have difficulty modulating simple

social interactions because of the difficulty interpreting nonverbal gesturing and displaying facial expressions, a skill easily acquired probably unconsciously by very young children early on in life.

Autism Treatment: Explicit Instruction for Implicitly Acquired Skills. Popular methods of treatment for children with autism include behavioral therapies like the Lovaas method (Lovaas & Taubman, 1981), or applied behavioral analysis. In these therapeutic methods inappropriate behaviors are targeted and through discreet trials, the appropriate behaviors are learned. Usually the therapy begins with attempting to distinguish behaviors that could be physically harmful to the child (head banging, or overtly aggressive acts). As these behaviors are overcome, the focus of therapy shifts to the more subtle behaviors that facilitate appropriate social interaction. In essence, this therapeutic intervention is attempting to teach people with autism the skills that typically developing children seem to learn mostly without explicit instruction. Just as the infant may be learning to speak by detecting changes in the stimulus array, children and adults learn the nuances of social interaction at varying levels of sophistication. Typically developing people learn to interact with others appropriately by determining what someone is thinking or feeling by detecting changes in their gestures, body language, vocal tonality and facial expression. All of these skills are typically acquired without much, if any, involvement of explicit instruction. The ability to read nonverbal communication helps people to determine whether or not someone else thinks their behaviors are odd, or if a topic of conversation is too remote, disinteresting, or has just gone on too long. Most autistic children do not acquire these skills as they are

developing, and therefore, need to be engaged in effortful conscious processes to acquire them.

It is rare that the processing of these learned skills ever leaves the explicit realm to become implicit. Social information like interpreting gestures, vocal tones, or others' facial expression is rarely processed seamlessly by a person with autism even after years of therapy, and therefore interactions with others are still awkward. Since there seems to be deficits in the unconscious acquisition and processing of information that modulates appropriate social interaction, is it the implicit learning mechanism that is malfunctioning in autistic individuals, or does the disorder prevent this type information from being absorbed and/or used appropriately throughout the course of their life?

Personal communication with individuals who are characterized as having high-functioning autism or Asperger's Disorder suggests that the difficulty at least for some, lies in the processing of different modalities of information in the stimulus array. One individual explains that he could not look at someone's face and listen to what they were saying. "If you want me to listen to you, I can't look at you," was a statement he used frequently. Another adult with Asperger's Disorder, who was not diagnosed until his mid-twenties, recalls tremendous difficulty relating to his peers throughout his lifetime. He always felt different from them because his hobbies and interests were considered odd by his peers, and he reports that he frequently felt frustrated as he tried to interact with others. "I had to teach myself how to read people. Before, I could never tell if what I was saying was making the other person happy or angry." His wife corroborated his description of his own development, as she stated that he would be very blunt with her

about her appearance, almost to the point of making her cry. "And he would have no idea what he was doing," she stated. Self-reports that demonstrate this level of insight are rare but extremely valuable as the communication deficits associated with autism prevent researchers and clinicians from truly understanding what is occurring in this disorder.

It is hard to know just how much of typical social development is acquired implicitly. There is certainly a lack of research that explores this issue. Lieberman (2000) proposes that implicit learning processes are the cognitive substrate of social intuition. He draws from theories and research findings that support the unconscious acquisition of information in humans, and develops a theory to explain human intuition. As people are making judgements about how to act in social situations they are often reacting to an ambiguous feeling they have. Lieberman believes that these impulses are actually coming from information that we have acquired implicitly from previous social interactions. That we are not merely acting on a hunch as often as we believe, but drawing upon acquired knowledge through a sophisticated cognitive process that takes place in the unconscious. Theories like this suggest that much of how we act in social situations is based on implicitly learned information.

As individuals with autism or a spectrum disorder might have difficulties processing information from more than one source (i.e., making eye contact while listening to the person), this same difficulty might lie in the inability to link the expression on one's face with the tone in their voice. When a person is implicitly learning the meaning of either the facial expression or the vocal expression, both pieces of information complement each other's meaning. That is to say they are concurrent changes in the stimulus array,

both offering congruent information. If the absorption of one piece (or both pieces for that matter) is impaired, the true meaning becomes very difficult to decipher.

Researchers have begun to explore the difficulties that people with autism have with interpreting facial information to try to explain some of the social deficits associated with this disorder. Schultz et al. (2000) examined face recognition ability as compared to object recognition in autistic individuals. They used functional magnetic resonance imaging to map areas of brain activation when 14 high-functioning autistic subjects identified both faces and inanimate objects. They compared these data to that collected from age-matched normal controls and found that the autistic subjects were using the same area in the brain, the inferior temporal gyrus, to identify faces as the normal controls were using to identify objects. When identifying faces, the normal control groups showed activation in the fusiform gyrus, and the autistic subjects showed little or no activation in this area when identifying faces. Despite the processing differences, the subjects with autism showed no deficit in identifying faces as compared to controls.

When processing social information in faces, however, people with autism show relatively selective impairments. There are autism-related deficits in recognizing subtle social information that is presented in faces (such as flirtatiousness), but no deficits in recognizing more basic emotions like anger and happiness (Baron-Cohen, Wheelwright, and Joliliffe, 1997). In an attempt to explore such difficulties, Pelphrey et al. (2002) used an infrared corneal reflection technique to examine the scan path of autistic subjects as they looked at a face to determine the emotional content. They found that autistic subjects spent more time looking at nonfeature areas of the face than at the core feature

areas, such as eyes, nose and mouth areas. Neurobiological studies suggest that an amygdala dysfunction in autism may be responsible for the difficulties associated with social information presented in faces (Baron-Cohen et al., 2000).

Deficits of Autism Spectrum Disorders: Implicit Learning or Social? There are numerous deficits associated with autism that effect the individual's functioning in many areas. Some individuals are only mildly impaired where others are unreachable, and most therapies cannot fully alleviate their symptoms. Although the symptoms of autism are spread across three behavioral domains (communication, sociality, and restricted and repetitive behavior) they all seem to impair (to varying degrees) the social functioning of the individual (Lord, 1993). Or perhaps, to reintroduce the chicken or the egg scenario, it is the impaired social functioning that prevents the typical behavior (in the three behavioral domains) from developing. To illustrate, one common symptom of autism is a lack of reciprocal conversation. That is, if an individual has speech, then he or she may use language to communicate but only for wants and needs, and not to participate in some kind of friendly exchange of information. Is it the lack of typical language development that prevents reciprocal conversational exchanges, or is it the lack of a desire to participate in the reciprocal exchange that prevents language from developing typically? To put it another way, does the social impairment foster abnormal behavior or does the abnormal behavior cultivate the social impairment?

As described earlier, it seems that most children with autism fail to learn many skills that typically developing children seem to learn implicitly. For example, the normal development of communication skills, both verbal and nonverbal, seems to take place

unconsciously via implicit processing of stimuli. As previously illustrated, many children with autism experience communication deficits to some degree. Therefore, it is reasonable to assume there is a defect in the neurological mechanism involved in unconscious acquisition of information. The question is, is this a global deficit or one related to only social information. There have been no published studies to date that examine implicit learning in autism. The next section provides a description the method specifically designed to measure implicit learning in autism while attempting to determine if the problems associated with unconscious acquisition are limited to information that is of a social nature.

An Implicit Learning Task for Individuals with Autism

When researchers first turned their interests toward implicit learning, the focus was to differentiate processes that take place in the unconscious from those that take place in consciousness. It was soon apparent that measures of implicit processing remained stable when faced with other factors like age and IQ, which were highly correlated with measures of explicit processing. As findings were largely in support for the stability of implicit processing in normal populations, researchers began to develop methods to test implicit ability in clinical populations where the explicit system seemed to be deteriorating, such as with amnesia, Alzheimer's, Parkinson's, and Huntington's disease. Again the findings were robust in support of the stability of the implicit system. The evolutionary theory was developed to explain the stability of the implicit system as a much older construct, developing long before consciousness where the explicit systems operate. The unconscious is considered to be the more stable construct, as it seems to be

less affected by neurological insults that markedly affect or even impair the explicit system. However, implicit learning researchers have yet to turn toward clinical disorders like autism where there seems to be deficits associated with implicit acquisition of information.

Autism presents an intriguing area of research for those who study implicit learning, and with the appropriately designed implicit learning task, the results may compliment what is already known about this disorder. As with most tests of cognitive functions, the application of standard tests and methods to a sample of autistic children is inappropriate or at the very least, extremely difficult. Implicit learning cannot be adequately measured if the ability to understand the instructions of the task is impaired. Although the instructions of the artificial grammar task are relatively simple for most research participants, they may be too complex for even high functioning individuals with autism. The SRT task is simpler and seems more appropriate for use in this population.

If the results of the standard SRT task (used by Nissen & Bullemer, 1987) provide evidence for implicit learning ability in autistic subjects, the results would indicate the preserved ability to unconsciously acquire information. This result, in and of itself, would not provide any information about why these individuals do not seem to learn implicitly the nuances of communication and social interaction as they are developing. It is possible that social information is somehow "blocked" from unconscious processing and/or acquisition because of the numerous autism-related social deficits, which if true, might also explain why these related skills need to be explicitly taught to children with autism. To test this hypothesis, in the current study an implicit learning task has been

designed to test implicit learning through social information. If subjects with autism fail to learn on this implicit learning task, but succeed on a task that includes only nonsocial elements, the results would support the possible block to unconscious acquisition of social information.

Through modifications of the standard SRT task, the following experiment was designed to test whether or not individuals with autism have a generally impaired implicit learning mechanism, or if the impairments are limited to implicit learning of social information. Two tasks were constructed to test this hypothesis. One SRT task uses stimuli that are socially relevant, or pictures of a person's face displaying easily identifiable facial expressions (happy, sad, afraid, angry). Normative data were collected on the pictures to ensure the accuracy of depicting the appropriate emotion. The second SRT task uses stimuli that are not socially relevant, or geometric forms (star, circle, square, triangle). Since the shapes are accepted forms in industrialized nations, and the subjects tested in this study are all from an industrialized nation, normative data were not collected. In both tasks, the stimuli appear one at a time in the center of the screen and the subject is asked to respond by pressing the corresponding button on a response box and RT is recorded.

In both of these tasks, the content and presentation of the stimuli are different from the conventional SRT task. In the standard administration, the stimuli are asterisks and are meant to be irrelevant to learning. In the present modification, the stimuli are relevant to the outcome as the effects of social vs. nonsocial stimuli are the focus of the present study. Also, the sequence in the SRT task typically is conveyed to the participant through

the location of the same (benign) stimuli. In this study, the sequence will be conveyed in each task through different stimuli that are presented in one location, the center of the screen. These modifications in and of themselves, are not expected to have an effect on learning as Willingham (1999) demonstrated that implicit sequence learning transfers appropriately while varying position of stimuli, the objects presented as stimuli, and the position of response buttons. However, since this particular version of the SRT task has never been used before, both tasks were administered to 20 pilot subjects (who were later included as part of the normal control subject group) to ensure learning could be demonstrated by typical individuals, prior to testing any subjects with autism.

Normative and Pilot Data Collection

Normative data were collected for the facial expression images only. All images were printed on paper and distributed to a sample of 30 individuals. The only instruction on the sheet was to look at each picture and decide which basic emotion was displayed, then write the emotion on the line under each picture. The subjects who completed this task were not told that each picture fell into one of the four categories used in this experiment (fear, anger, happy, sad). If they had been told in advance, each picture would most likely be classified correctly even if it only loosely resembled the emotion. Keeping these subjects blind to the four basic emotions yields an unbiased account of which emotion is represented by each image.

The normative data were in support for the use of each picture. All eight pictures (four from Model A, and four from Model B) from the social task were included. Since the subjects were not told to choose either happy, sad, afraid or angry to identify each

emotion, but only to write down which basic emotion they thought was displayed by each picture, the responses were somewhat variable within each emotion. Responses were classified in three ways, an exact match (angry = angry), a "like" match (gleeful = happy), and "not a match" (surprised = afraid). An a priori cutoff of greater than 10% of responses classified as "not a match" then the picture would not be included in the experiment. No picture met that criteria and all were classified with 90% of responses or greater as exact or like matches. The full normative data for the stimuli used in this experiment are presented in Table 1.

Table 1

Normative Data for Facial Expression Pictures Used in the Social Sequence Reaction Time Task (N = 30).

Picture	Model	% Exact Match	% "Like" Match	% Failed to Match
Happy	A	93	7	0
Happy	B	73	27	0
Angry	A	87	13	0
Angry	B	87	13	0
Sad	A	93	7	0
Sad	B	93	7	0
Afraid	A	87	13	0
Afraid	B	70	26	4

Note. Values are rounded to the nearest whole number. Model A is used in the learning phase and transfer (interference) block; Model B is used to return to sequential presentation, after the transfer block.

After normative data for the faces were established, pilot data were collected to ensure that implicit sequence learning occurs under these conditions. Twenty pilot

subjects (12 undergraduate psychology students, and eight adults from the community) were run on each task. Mean of median RTs were calculated from each of the seven blocks for each subject. Historically the variability in RT data, from both individual and between subjects, has been problematic for analysis of these tasks. It is generally accepted by implicit learning researchers that the most representative way to capture a subject's performance is not to simply take the mean RT from each block, but to take the median RT from each of the ten trials in one block and then compute a mean for that block. The median is much less sensitive to atypical delays in responding to one or two stimuli as well as to very quick responses by merely guessing correctly. Both of these situations can skew the mean for a block and misrepresent the true functioning of the subject.

The means of medians from each block were then plotted on a line graph to illustrate the general learning curve. If RTs decreased (subjects got faster) across blocks one through five, and then increased (subjects got slower) in block six, and then decreased again in block seven, implicit learning was assumed to have occurred. However, the occurrence of implicit learning was statistically tested by averaging the mean (of median) RT in block seven with that of block five, and a t test was used to determine if this mean RT was different from the mean RT from block six. The t tests were run for both the social and nonsocial tasks.

For both the social and nonsocial paradigms used in this experiment, graphical representation of the pilot RT data was in support of implicit sequence learning. Appropriate learning curves that suggest implicit learning were obtained for the social

and nonsocial tasks (see Figure 1). Evidence for learning was obtained in both the nonsocial task, $t(19) = 3.57$, $p < .05$, and the social task, $t(19) = 2.87$, $p < .05$. Therefore, using different stimuli to convey knowledge about the sequence, and presenting all stimuli one at a time in one location does not seem to interfere with learning on the SRT task. Thus, the modified SRT task is appropriate for use in the present study.

Hypothesis

If autism is like other neurological disorders (PD, AD, HD, and amnesia) where unconscious acquisition of information occurs normally despite the cognitive impairments, there should be little effect on the implicit processing of information in these subjects. However, there is reasonable evidence from the deficits associated with the disorder that children with autism do not implicitly learn the nuances of social communication like typically developing children.

As the evolutionary theory suggests, and as seen in other neurological disorders, the autism group is expected to perform as well as subjects without autism on the nonsocial task. However, the social content in the facial expression task may present a problem for the subjects with autism for implicit learning of the sequence. The subjects without the disorder are expected to have no difficulty learning the sequence implicitly, and should perform like they did on the nonsocial task. Should these predictions prove true, it will provide evidence for an intact implicit learning mechanism in individuals with autism, and suggest that the social deficits associated with autism interfere with implicit learning when socially relevant stimuli are involved.

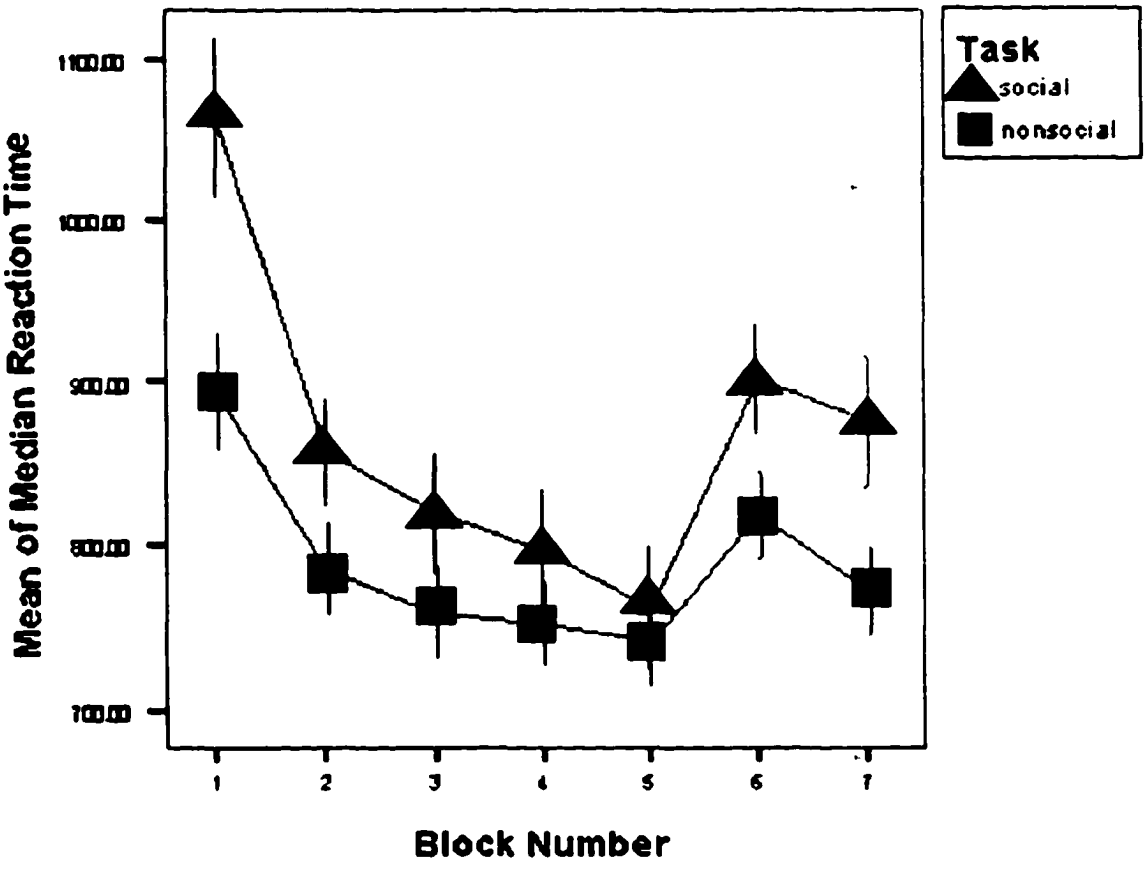


Figure 1. Line graph of pilot subjects performance on the nonsocial and social implicit learning sequence-reaction time task. Learning curve provides evidence for implicit learning of the sequence using the nonsocial stimuli, geometric forms (square, circle, star, triangle) and the social stimuli, facial expressions (Happy, Angry, Sad, Afraid).

Method

Participants

Three groups participated in the present study: the autism spectrum disorder group (ASD) which included subjects with a diagnosis of autism, pervasive developmental disorder (PDD), or Asperger's Disorder; the relative group (unaffected parents and siblings of individuals with an ASD), and a control group (unaffected and unrelated to those with an ASD). ASD participants were recruited from social skills training groups at the Cody Center, Stony Brook University, New York; the Groden Center, Rhode Island; University of Medicine and Dentistry in New Jersey, and other family support groups in the New York area. The control subjects were recruited from a population of undergraduate students enrolled in the psychology program at Brooklyn College, and people from the community.

Assessment of ASD Participants. Subjects with autism were assessed with the Autism Diagnostic Interview-Revised (ADI-R; Lord et al., 1994), which uses a DSM-IV based algorithm to diagnose autism according to deficits across three behavioral domains (reciprocal social interaction, communication, and restricted and repetitive behaviors). The DSM-IV criteria are presented in the Appendix. Subjects identified as having Asperger's Disorder were assessed using the Gilliam Asperger's Disorder Scale (GADS; Gilliam, 2001), which is an informant-based interview consisting of 32 questions that assess the subject's difficulties in social interaction, the presence of restricted patterns of behaviors, odd cognitive patterns, and deficits in pragmatic language skills. After the scale is completed, an Asperger's Disorder Quotient is generated by summing the ratings

for each item, and the total score is used to assign one of three levels of classification: High/Probable ($\geq$ 80); Borderline (70 - 79); and Low/Not Probable ($\leq$ 69). The GADS demonstrates strong internal consistency, interrater reliability, test-retest reliability, and validity for the diagnosis of Asperger's disorder (see Gilliam, 2001).

ASD participants were recruited if their intellectual and linguistic functioning was at a level enabling adequate responsiveness to the task requirements based on the ability to follow the instructions. Of the 29 participants in the ASD group (25 males and four females, age nine to 50 years, $\underline{M}$ = 18.97, $\underline{SD}$ = 8.88), 19 met ADI-R criteria for autism, six met GADS criteria for a likely diagnosis of Asperger's Disorder, two met GADS criteria for a borderline dx of Asperger's Disorder, and two were eliminated after testing because their diagnosis of autism could not be confirmed (no available informant to complete an interview). The relative group consisted of 30 parents (19 mothers, 11 fathers; age from 19 to 62, $\underline{M}$ = 44.70, $\underline{SD}$ = 5.94) and 10 unaffected siblings (seven females, three males; age seven to 22 years, $\underline{M}$ = 14.20, $\underline{SD}$ = 9.45).

The normal control group consisted of 27 participants, 12 were recruited from a psychology undergraduate program at Brooklyn College, eight were research assistants employed by Mount Sinai School of Medicine, and seven were volunteers from the community. The age range in this group was from age 19 to 79 ($\underline{M}$ = 27.89, $\underline{SD}$ = 16.25). All normal control subjects were screened for a first-degree relative with an ASD and none were found to have an affected relative.

Subjects from all three groups were excluded after testing from all analyses if they did not complete all blocks from both the social and nonsocial SRT task, or if the percentage

of errors exceeded 20 percent on either task. This criterion was determined by examining a scatter plot of the percentage of error for each group on both tasks. A line was then drawn across the plot to separate the extreme cases from the rest of the group, and 20 percent seemed to be the appropriate cutoff for all three groups on both tasks. There were 12 subjects from the ASD group that were excluded (one for incomplete data collection, nine for excessive errors on both tasks, one for excessive errors on only the social task); seven subjects from the relative group (five for incomplete data collection, two for excessive errors on both tasks); and four subjects from the control group (two for incomplete data collection, and two for excessive errors on both tasks). The number of subjects per group and the descriptive statistics are presented in Table 2.

Table 2

Descriptive Data for Subjects Included in the Analyses for the Social and Nonsocial Sequence Reaction Time Implicit Learning Tasks

Group	n	Gender (M/F)	Age Range (M/SD)
ASD	17		9 to 50 (20.53/10.15)
ADI-R Autism		10/2	
GADS Likely		4/0	
GADS Borderline		1/0	
Relatives	33		14 to 62 (40.61/13.33)
Parents		11/17	
Siblings		2/3	
Control	23	10/13	19 to 75 (25.57/12.83)

One way ANOVA indicates significant differences in the mean age for each of the three groups, F (2, 72) = 17.84, p < .001, and post hoc analysis using Tamhane's T2 (a conservative pair wise comparison test based on a t test, which is appropriate for use here because there are unequal variances among the three groups) indicates no significant difference in age between the ASD and control groups (p = .437), but the relative group was significantly older than both of the other two groups (p < .001, for both pair wise comparisons). Independent sample t tests were then performed, using a correction for unequal variances between groups, which confirmed the significant difference between the ASD and the relative group, t (40.92) = -5.94, p < .001), and between the relative and the control group, t (48.63) = 4.25, p < .001. The difference between the ASD and the control group was nonsignificant (p = .174). This difference in age of the relative group is suspected to have little effect on the implicit learning results as previous studies show implicit learning to remain stable across different age groups.

Apparatus

The SRT task was designed using SuperLab Pro software (version two; Cedrus Corporation, 1999) and the RB-410, 4-button response box (also from Cedrus Corporation). Subjects were seated in front of a lap top computer (Dell Inspiron 7500, Pentium III, 500MHz, 128 MB SDRAM) with a 15.4" SXGA high-resolution color display screen (1024 x 768 pixels, 8 MB, 125 MHz SGRAM).

Stimuli

Images on both the social and nonsocial task appeared in the center of the screen on a white background. The facial expression pictures used in the social task are

approximately 10.8 cm x 7.62 cm, and the shapes used in the nonsocial task are approximately 3.8 cm by 3.8 cm. Digital images of facial expressions were taken in color with a Fuji MX-1200

digital camera with 1.2 megapixel resolution. Models for facial expression images were two Caucasian females with dark hair and prominent facial features. Both models were instructed to make the exaggerated versions of the all four facial expressions.

In the social task the stimuli for the first five blocks are images of one model (Model A) making all four facial expressions. In order to preclude possible cues from factors other than facial expression, for the learning blocks, only one model is used with no other differences in appearance except the facial expression. Therefore, the only novel characteristics of each image is the change in expression. The transfer block is Model A, but the expressions will be presented in a pseudorandom order. Upon returning to the sequential presentation in block seven, a different model (Model B) is used to display the same four facial expressions presented in the same sequence as before the transfer block. The use of Model B in block seven requires subjects to associate the emotion with the sequence. Pictures used in this experiment are presented in the appendix.

In the nonsocial task, one of four shapes (star, circle, square, triangle) appeared in the center of the screen, each drawn with a solid black line. Both the background and the interior portion of each stimulus are white. Since there is no other component than the shape (unlike in the social task where each expression has the particular model as an accompanying component) there is no change in the stimulus after the transfer block. Everything about the presentation will remain consistent with the exception of the change

from sequential presentation in blocks one through five, to pseudorandom presentation in block six, and then back to sequential presentation in block seven, which presented the same sequence used in blocks one through five.

In both the social and nonsocial task, each stimulus remained on the display until the correct button is pressed. The next stimulus appeared after the subject responded correctly. Subjects were seated in front of the computer with the display positioned for optimal viewing. The response box was placed on the side of the computer to match the subject's dominant hand. An index card was placed in a slot behind the buttons on the response box with the corresponding emotion or shape printed directly above and connected to the appropriate button with an arrow. Subjects were asked to rest four fingers on top of the four buttons. The only instruction to them was to respond as quickly as possible by pressing the button that corresponds to the stimulus on the display. There was a short rest break between each task of the experiment. The order of the tasks, starting with either the social or nonsocial task was alternated with each subject to control for the effects of fatigue on one task only.

Procedure

Both tasks in the experiment follow the same general format. The stimuli are presented with a sequence length of 10 that repeats 10 times per block during the learning phase of the experiment. There are five blocks of sequential presentation of stimuli before one transfer block of pseudorandom presentation, where no one stimulus repeats itself immediately in succession. The numerical version of the sequence for the social task is 4-2-3-4-1-3-2-4-3-1 (where 1 = a picture of a face expressing fear, 2 = angry, 3 =

sad, and 4 = happy). For the nonsocial task, the sequence is 2-1-4-3-1-2-4-1-3-4 (where 1 = the shape of a star, 2 = circle, 3 = square, and 4 = triangle). The sequences presented here are ambiguous, that is, no pair of stimuli repeats within the sequence (A. Cohen et al., 1990). Additionally, there are no second-order conditionals where two events in the sequence predict the third, which can facilitate learning. The pseudorandom block, or transfer block was designed so it is not obviously different from the learning phase of the experiment. There is no repeating sequence and no event immediately repeats itself (1-1), the stimuli are not presented in ascending numerical order (1-2-3-4) or descending numerical order (4-3-2-1) and as in the sequence, there are no repeating second-order conditionals. Additionally, each stimulus will have approximately the same number of occurrences in the transfer block as it will in any one block of the learning phase.

Statistical Analyses

Implicit learning is expressed in two ways in the SRT task: first as the rate of reduced RT over the first five blocks of the repeated sequence and an increase in RT during the pseudorandom presentation, and second as the comparison of mean of the median RT for blocks five (the last block of the repeated sequence before the pseudorandom presentation in block six) and seven (the return of the repeated sequence) with the mean of the median RT for block six.

As in previous studies that utilize the SRT task and in the analysis of the pilot data, the mean of the median (of the 10-item sequence) RT per block was analyzed (Ferraro et al., 1993; Nissen & Bullemer, 1987; Vakil, Kraus, Bor, & Grosswasser, 2002). The amount of errors and perseverative errors (one error immediately following an error) was

also analyzed. The three groups were compared on the two different versions of the SRT task.

All data are analyzed with a mixed factor MANOVA design with repeated measures. In the analysis, Block is entered as a within subjects factor, Group is the between subjects factor, and Task 1 (nonsocial) and Task 2 (social) are entered as repeated measures. This design is applied for all comparisons unless otherwise specified. Since data were collected from subjects with an ASD and their unaffected siblings and parents, a familial aggregation analysis is appropriate to determine if differences in RT and/or patterns of error are greater between families than within each family. In this analysis, the family membership is the between subjects factor, thus including both affected and unaffected individuals from one family in the same group.

Results

A visual inspection of the learning curves that were produced by each group for each task reveals interesting within and between group differences in task performance. Figures 2A and 2B show the plotted means of the medians and 95% confidence intervals for the nonsocial task (top) and the social task (bottom) as a function of block and group. On both tasks, the ASD group is the slowest of the three, the control group is the fastest, and the relatives are in between. All three groups displayed a similar pattern of learning on both tasks as RT decreased steadily across blocks one through five, and demonstrated implicit learning (rather than just getting faster across blocks one through five by motor learning) by an increase in RT from block five to block six (pseudorandom presentation). On the nonsocial task, all three groups get faster in block seven, once the sequence is

reinstated. On the social task, however, in block seven the ASD group seems to get even slower than they were during block six, while the relative and control group get faster. The confidence intervals surrounding the mean for each block indicate greater within group variability for the ASD group than is seen in the other two groups.

Within and between group differences were analyzed for significance on both tasks, first by examining all three groups performance on blocks one through five. Then, blocks five, six, and seven were analyzed separately to examine the effect of the pseudorandom block on implicit learning, and how that effect might be different for each of the three groups included in this study.

Blocks One through Five: Sequence Learning

There is a significant overall (both tasks together) group effect, F (4, 138) = 3.01, p < .05, a significant group effect for the nonsocial task, F (2, 70) = 3.85, p < .05, and the social task, F (2, 70) = 5.46, p < .05. This result suggests differences in speed among the three groups on each task, but does not indicate which groups are significantly different. Examining the Group effect further, simple contrasts were utilized to compare the relative and the control group to the ASD group. The difference between the ASD group and the relative group is not significant on either

task (p = .089 for nonsocial, and p = .112 for social), but there is a significant difference between the ASD and the control group on the nonsocial (p < .05), and the social tasks (p < .05). Tukey's post hoc analysis also revealed a difference between the ASD and the control group on both tasks, (p < .05, for both), and no significant difference between the ASD and the relative group (p = .204 for nonsocial, and p = .249 for social), or the

relative and the control group (p = .359 for nonsocial, and p = .102 for social). According to this analysis the ASD group is significantly slower than the control, but not the relative group, and the relative group is not significantly slower or faster than either group.

The overall Block by Group interaction is significant, F (16, 558) = 1.70, $p < .05$, but when the tasks are analyzed separately the interaction is nonsignificant for both the nonsocial (p = .095) and the social task (p = .159). Therefore the differences in the group performance are only revealed when the data from the two tasks are combined. When the tasks are analyzed separately, which is of interest in this study, no significant differences in the pattern of learning are found. As one can see in Figures 2A and 2B, the pattern of RT per block indicates learning in all three groups on both tasks because the mean RT decreases steadily across the first five blocks. Repeated contrasts on the Block main effect on the nonsocial task indicate significant differences between blocks one and two, F (1, 70) = 27.15, $p < .001$, blocks two and three, F (1, 70) = 17.15, $p < .001$, and blocks three and four, F (1, 70) = 7.83, $p < .05$, but a nonsignificant difference between blocks four and five, suggesting a ceiling effect where subjects have reach peak performance in block four. The ASD group, although following a similar pattern overall, does not have a dramatic decrease in RT from block one to block two, as the other groups do and are probably causing the significant repeated contrast between these two blocks. A paired sample t test shows the nonsignificant difference in RT between these two blocks for the ASD group, p = .892, and indicates the ASD were slower learners than the other two groups on this task.

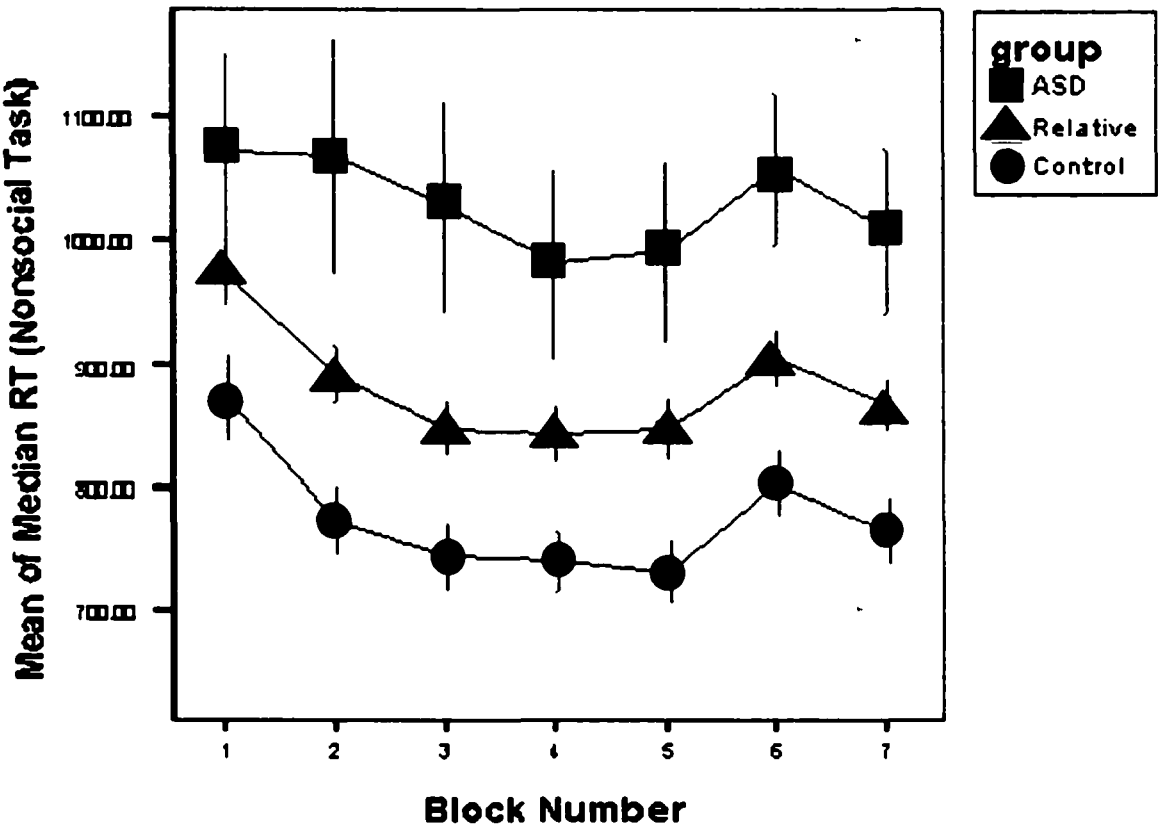


Figure 2A. Learning curves for the nonsocial sequence reaction time task. Means of the median RT are plotted as a function of block and group with 95% confidence intervals. The autism spectrum disorder (ASD) group is the slowest of the three, followed by the first degree relative group (parents and siblings of the subjects in the ASD group), and the unrelated controls are the fastest of the three. Larger confidence intervals around the block scores for the ASD group indicates greater within group variability than is seen in the other two groups.

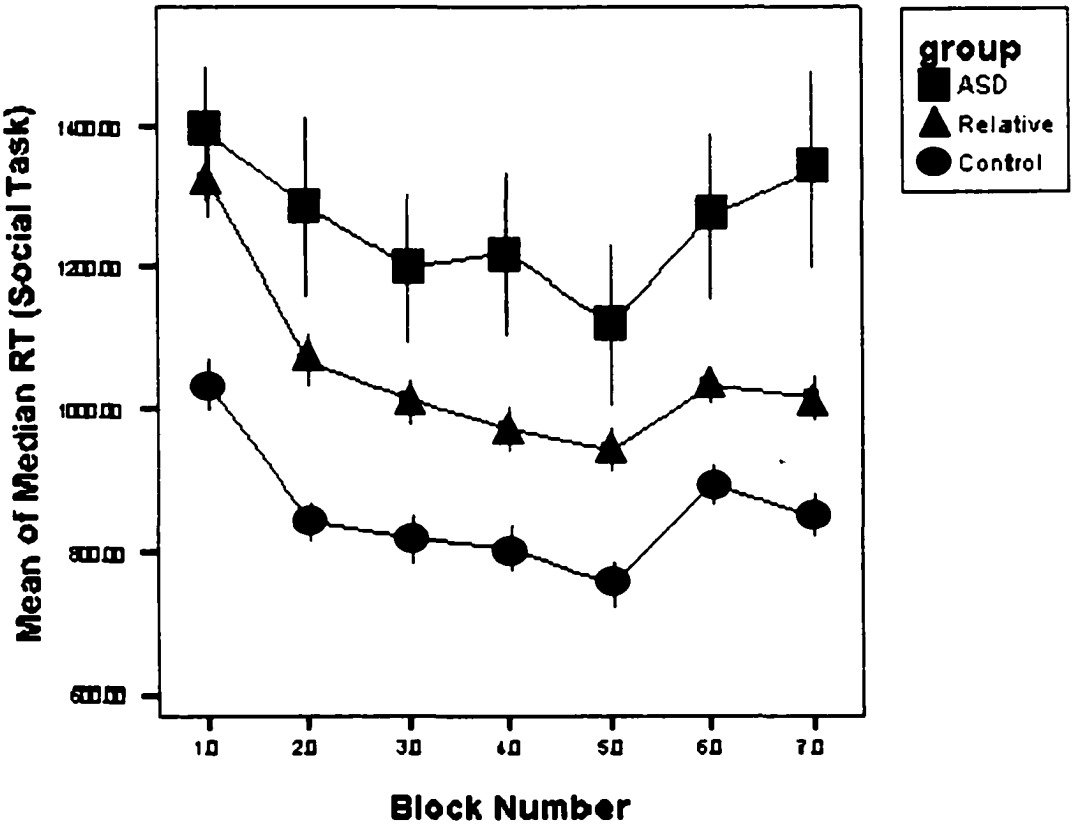


Figure 2B. Learning curves for the social sequence reaction time task. Means of the median RT are plotted as a function of block and group with 95% confidence intervals. The autism spectrum disorder (ASD) group is the slowest of the three, followed by the first degree relative group (parents and siblings of the subjects in the ASD group), and the unrelated controls are the fastest of the three.

On the social task, repeated contrasts on the Block main effect indicate significant differences between blocks one and two, F (1, 70) = 42.40, $p < .001$, blocks two and three, F (1, 70) = 11.68, $p = .001$, a nonsignificant difference between blocks three and four (which was probably driven by the ASD group's increase in RT), and a significant difference between blocks four and five, F (1, 70) = 10.55, $p < .05$. There were no significant repeated contrasts for any two blocks when examining the Block by Group interaction. Thus, suggesting the three groups displayed a similar pattern of RT means across the first five blocks.

To explore possible differences in learning among the three groups, a proportion of learning was created by subtracting the mean of median RT in block five from the mean of median RT from block one, and then dividing by the baseline mean of median RT (from block one). This proportion is computed to indicate the amount of RT reduction across the first five blocks that is proportionate to the baseline RT for each group. Results from the ANOVA indicated no significant differences among the three groups on both the nonsocial task ($p = .086$), and the social task ($p = .216$). However, it is noteworthy that the differences among the three groups nears significance on the nonsocial task. Simple contrasts reveal a significant difference ($p = .035$) in the proportion of learning between the ASD ($M = .064$, $SD = .101$) and the control group ($M = .146$, $SD = .129$) on the nonsocial task. The difference between the ASD and the relative group ($M = .130$, $SD = .119$) is marginally nonsignificant on this task. These differences are consistent with a proportionally less dramatic decrease in RT on the nonsocial task across blocks one through five for the ASD group than is seen with the

other two groups. This could be a suggestion of implicit learning impairments in the ASD group or perhaps just a slower, more careful approach to these kinds of tasks.

Sequence Learning Interference - Block Five vs. Block Six

Blocks five and six were analyzed next to see if all three groups experienced a similar reaction to the change from the sequential presentation (block five) to the pseudorandom presentation (block six). Using only these two blocks, there is a significant overall group effect, F (4, 138) = 2.74, $p < .05$, and there is also a significant group effect on both of the nonsocial, F (2, 70) = 5.28, $p < .01$, and the social task, F (2, 70) = 5.73, $p < .01$. These results reflect the same differences in each group's speed that is seen in the analysis of blocks one through five. Simple contrasts reveal that the ASD group is significantly slower than the control group on the nonsocial ($p < .01$) and the social ($p < .01$) task. They are also significantly slower than the relative group ($p < .05$ for both tasks). Tukey's post hoc analysis indicates no significant difference between the relative and the control group. The Block by Group interaction did not reach significance for either task, and there were no significant Block by Group interactions on the repeated contrasts that were applied to compare block five to block six. These results indicate similarities between the groups as they move from the sequential presentation in block five to the pseudorandom presentation in block six. Therefore, all three groups experienced a similar level of learning interference from the pseudorandom presentation.

An interference score was calculated for each subject by subtracting the mean RT (of the ten medians) in block five from the mean RT (of the ten medians) in block six. The higher the score the stronger the interference. Scatterplots of these scores are presented

for each group in Figure 3A, for the nonsocial and Figure 3B the social task. If a score falls below the zero coordinate, it indicates that the mean RT for block five was actually higher than that of block six, and it appears that the relative group has the most subjects that have a negative interference score. A three (group) by two (task) ANOVA was performed to look for possible between group differences on the interference scores. There was no significant effect for group on either task (p = .865 for the nonsocial, and p = .618 for the social task). Simple contrasts revealed no between group differences for the ASD vs. relative group comparison (p = .760 for nonsocial, and p =381 for social), and for the ASD vs. control group comparison (p = .874 for nonsocial and p = .842 for social). Independent sample t tests revealed no significant differences between the relative and the control group, p = .566 for the nonsocial, and p = .269 for the social. Therefore, on both tasks, all three groups experienced a similar level of interference.

The Effect of Interference: Block Five vs. Block Seven

To investigate the effect of the interference, a mixed factor ANOVA with repeated measures was performed on the data from the three groups on these two blocks. Block five is the last block of sequential presentation before the pseudorandom presentation in block six, and in block seven the sequential presentation is restored. If subjects have implicitly learned the sequence during blocks one through five, RT should decrease in block seven close to where they were in block five. This analysis shows a significant group effect, F (2, 70) = 5.36, $p < .01$ indicating differences in the mean RT of these two blocks from all three groups. The ASD group had the highest mean RT (M = 1114.39), the relatives had the second highest (M = 918.87) and the controls were the fastest of the

three (M = 776.54). Simple contrasts reveal significant differences between the ASD and the relative group ($p < .05$), and between the ASD and the control group ($p < .01$).

The more compelling result is the significant Task by Block by Group interaction, F (2, 70) = 3.85, $p < .05$, suggesting a different pattern of performance on these two blocks among the three groups on both tasks. Examination of the difference between the mean for block five and the mean for block seven for each of the three groups reveals a rather large difference for the ASD group on the social task (mean of block seven - mean of block five = 218.96), and a much smaller difference for the nonsocial task (17.24). The relative group had a small difference on the nonsocial task (19.87) and a moderate difference on the social task (77.05). The control group also had a small difference on the nonsocial task (32.28) and a moderate difference on the social task (97.47).

To further investigate the between group differences in patterns of learning on each task, individual t tests were performed on each task within each group. For this analysis, the mean of block five and block seven is compared with block six for significant differences. A significant difference between these two suggests that subjects have implicitly learned the sequence in blocks one through five, transfer the learning across block six and recover knowledge about the sequence in block seven. The results of this analysis are presented in Table 3.

The relative and the control groups showed significant differences in these scores on both tasks. The ASD group, however, showed a significant difference in these two scores on the nonsocial task only. The difference between the mean of block five and block seven on the social task is nonsignificant for the ASD group, thereby indicating this group

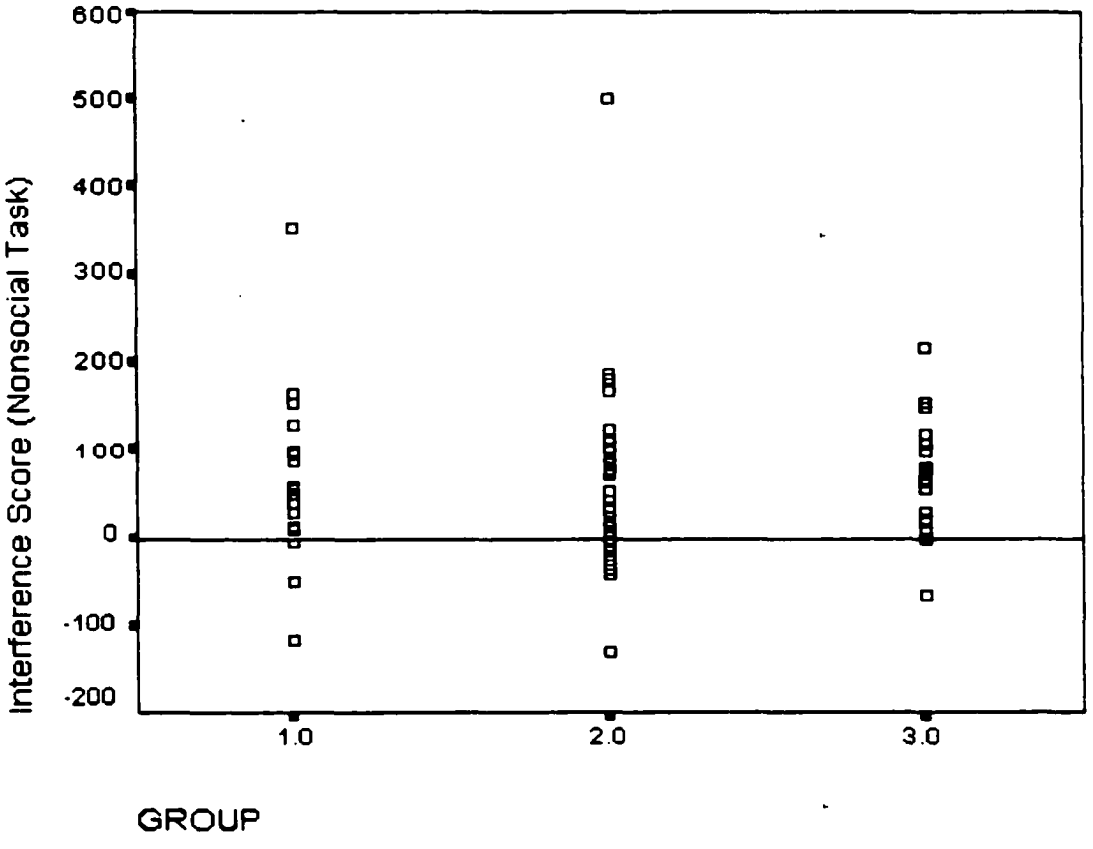


Figure 3A. Scatterplot of the interference scores on the nonsocial sequence reaction time task. Group 1 = Autism spectrum disorder, Group 2 = first degree relatives of the subjects in Group 1, and Group 3 = unrelated control subjects. Interference scores were calculated by subtracting the means of median RT in block five from the means of median RT in block six. Block five is the last sequential presentation of stimuli before a block six, which is pseudorandom presentation of stimuli.

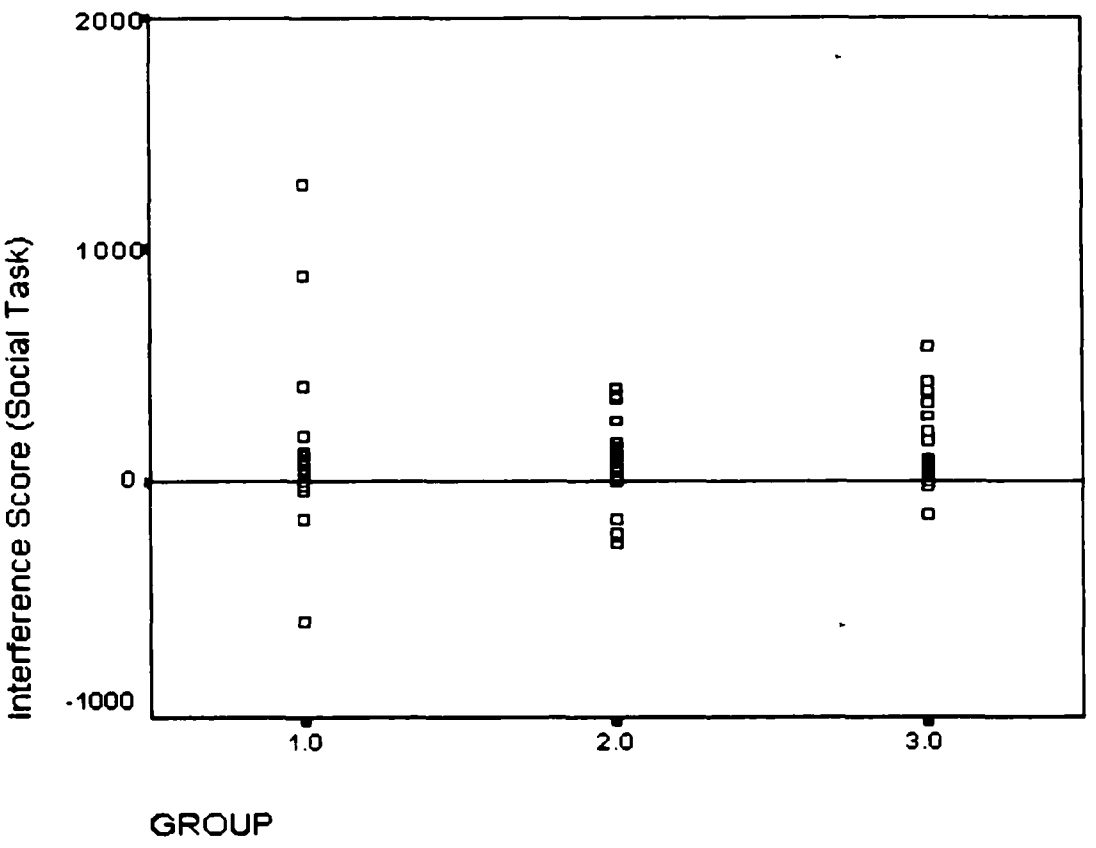


Figure 3B. Scatterplot of the interference scores on the social sequence reaction time task. Group 1 = Autism spectrum disorder, Group 2 = first degree relatives of the subjects in Group 1, and Group 3 = unrelated control subjects. Interference scores were calculated by subtracting the means of median RT in block five from the means of median RT in block six. Block five is the last sequential presentation of stimuli before a block six, which is pseudorandom presentation of stimuli.

Table 3

Within Group Differences in the Mean RT of Block Six and the Average of the Mean from Block Five and Seven for Both the Social and the Nonsocial Sequence Reaction Time Task.

Group	Task	t Score (df)	p value
Autism Spectrum Disorder	Nonsocial	3.72 (16)	.002
	Social	.60 (16)	.557
First Degree Relatives	Nonsocial	3.90 (32)	< .001
	Social	2.26 (32)	.031
Unrelated Controls	Nonsocial	4.54 (22)	<.001
	Social	3.39 (22)	.003

was not able to transfer knowledge about the sequence across the pseudorandom presentation in block six, recover in block seven. Therefore, when compared to the other two groups in this study, the ASD group indicates inefficient implicit learning of the sequence using stimuli of a social nature.

Errors and Perseverative Errors

The mean errors and 95% confidence intervals per block were plotted for each group and are presented in Figure 4A for the nonsocial and Figure 4B for the social task. The pattern of errors that one might expect to see would be a steady decrease in the number of errors across blocks one through five, and an increase in the number of errors on block six (pseudorandom presentation) and a decrease in errors on block seven when the sequence returns. On the nonsocial task, the ASD and the relative groups do not show a typical

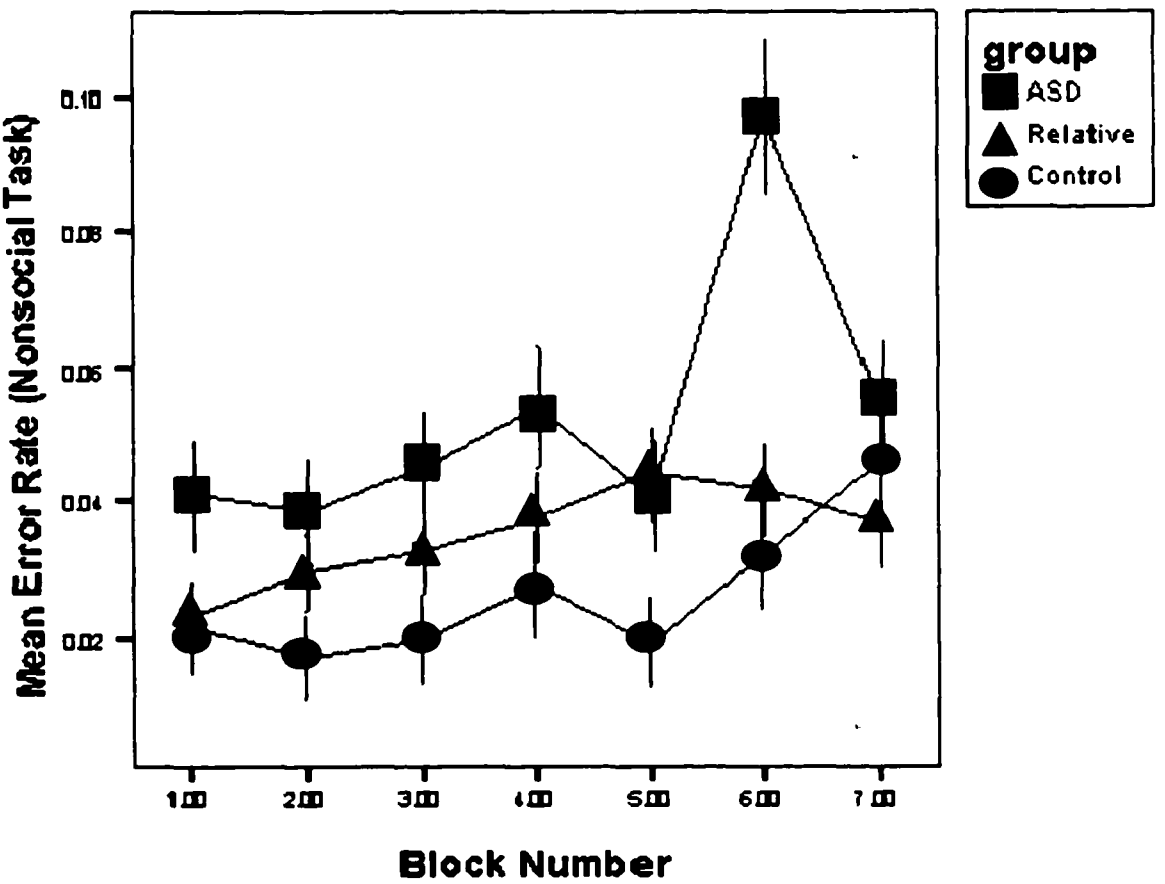


Figure 4A. Mean error rate and 95% confidence intervals, as a function of block and group for the nonsocial sequence reaction time task. The increase in errors over block six (pseudorandom presentation of stimuli) for the control subjects indicates the controls were probably anticipating the next stimulus better than the autism spectrum group, and the relative group.

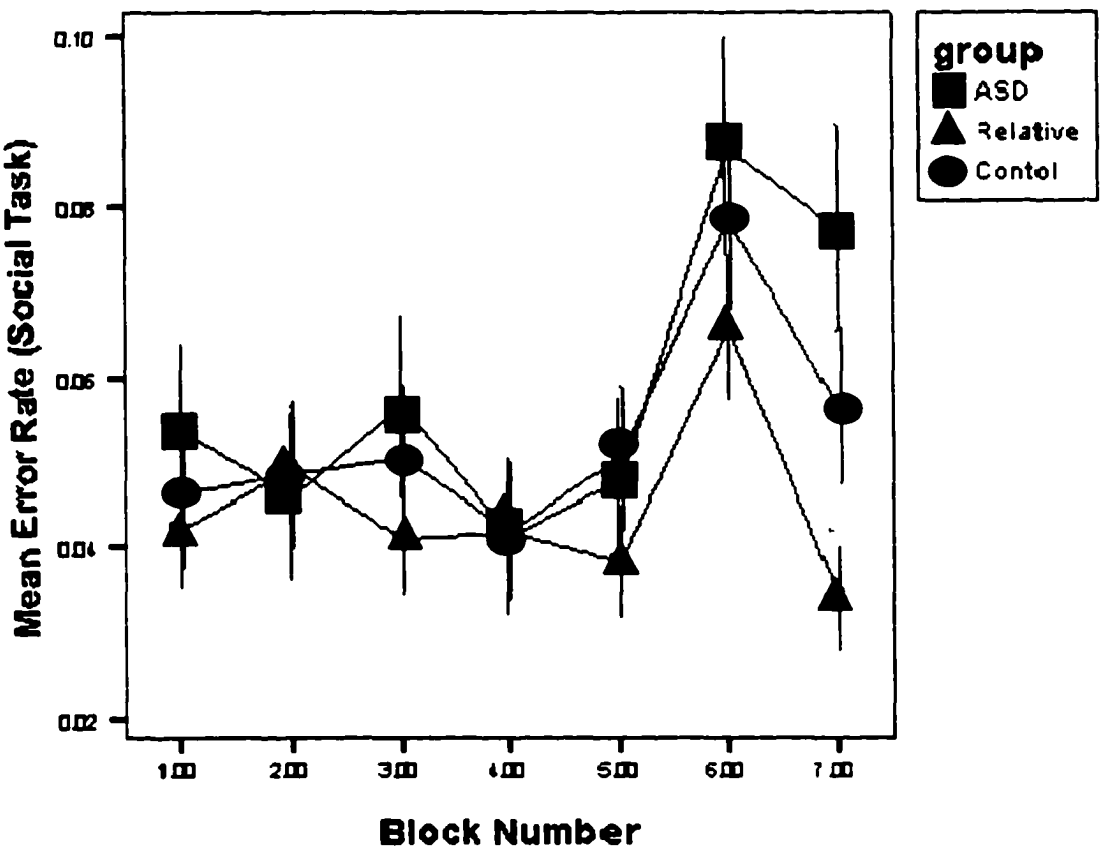


Figure 4B. Mean error rate and 95% confidence intervals, as a function of block and group for the social sequence reaction time task. All three groups perform similarly.

pattern of errors while the control group does. The control group shows a visibly larger increase in the mean error rate for block six than the other two groups. In fact, the mean error rate for the relative group decreases from block five to six. The control group was also completing the task faster than the other two groups, indicating that they might have been anticipating the next stimulus slightly more efficiently than the other two groups, and thus experienced a larger increase in the error rate on block six. On the social task all three groups seem to display a similar pattern of errors, but the ASD group seemed slightly more erratic than the other two.

A MANOVA with repeated measures was conducted to search for differences in the error patterns of the three groups on the two tasks. There is a significant overall (both tasks combined) main effect of Group, F (4, 138) = 3.48, $p < .05$, and a Block by Group effect, F (24, 838) = 1.73, $p < .05$. Univariate analysis of the nonsocial task reveals a significant effect for Group, F (2, 70) = 3.78, $p < .05$, and a significant Block by Group interaction, F (5.66, 198.25) = 2.48, $p < .05$, but both the main effect and interaction are nonsignificant for the social task ($p = .480$ and $p = .409$, respectively).

The percentage of error was generated by dividing the total number of errors by the number of total responses. The percentage was then analyzed for within and between group differences and there is a significant Task by Group interaction, F (2, 70) = 4.60, $p < .05$. Examination of the group means reveals the ASD group had a significantly higher percent of errors on the social task than they did for the nonsocial task, t (16) = 2.60, $p < .05$. The difference on the error percentage between the two tasks was nonsignificant for the relative and the control groups ($p = .096$, and $p = .984$, respectively).

A univariate ANOVA was conducted on the percentage of errors for each task, which yielded a significant between group difference, F (2, 70) = 3.47, p < .05, for the nonsocial task. Simple contrasts reveal significant differences for the ASD group vs. the control group and the ASD vs. the relative group (p < .05 for both), with the ASD group making fewer errors than the other two groups on this task. Tukey's post hoc test reveals no significant difference between the relative and control group (p = .141). On the social task, the univariate ANOVA revealed no significant difference between the group means (p = .440). Therefore, when considering errors, the ASD group actually performed much better on the nonsocial task than the other two groups, making significantly fewer errors where on the social task, they made about as many errors as the other two groups.

The means of perseverative error (i.e., an error followed by another error) and 95% confidence intervals generated by all three groups are presented in Figures 5A and 5B, for the nonsocial and the social task. On the nonsocial task, again, the control group displays an increase in perseverative errors in block six (pseudorandom presentation), where the ASD group shows a large increase only in block seven. The relative group appears to remain steadier than the other groups across all seven blocks. On the social task the ASD group appears to have more perseverative errors than the other two groups with a large spike on block six and a decrease in block seven. The other two groups show a similar pattern across blocks five, six and seven, but the differences are much less pronounced. A repeated measures MANOVA shows a significant main effect for Group, F (4, 138) = 4.07, p < .01, but the Block by Group interaction did not reach significance (p = .190). Univariate tests reveal a significant Group effect only for the social task, F (2, 70) = 4.60,

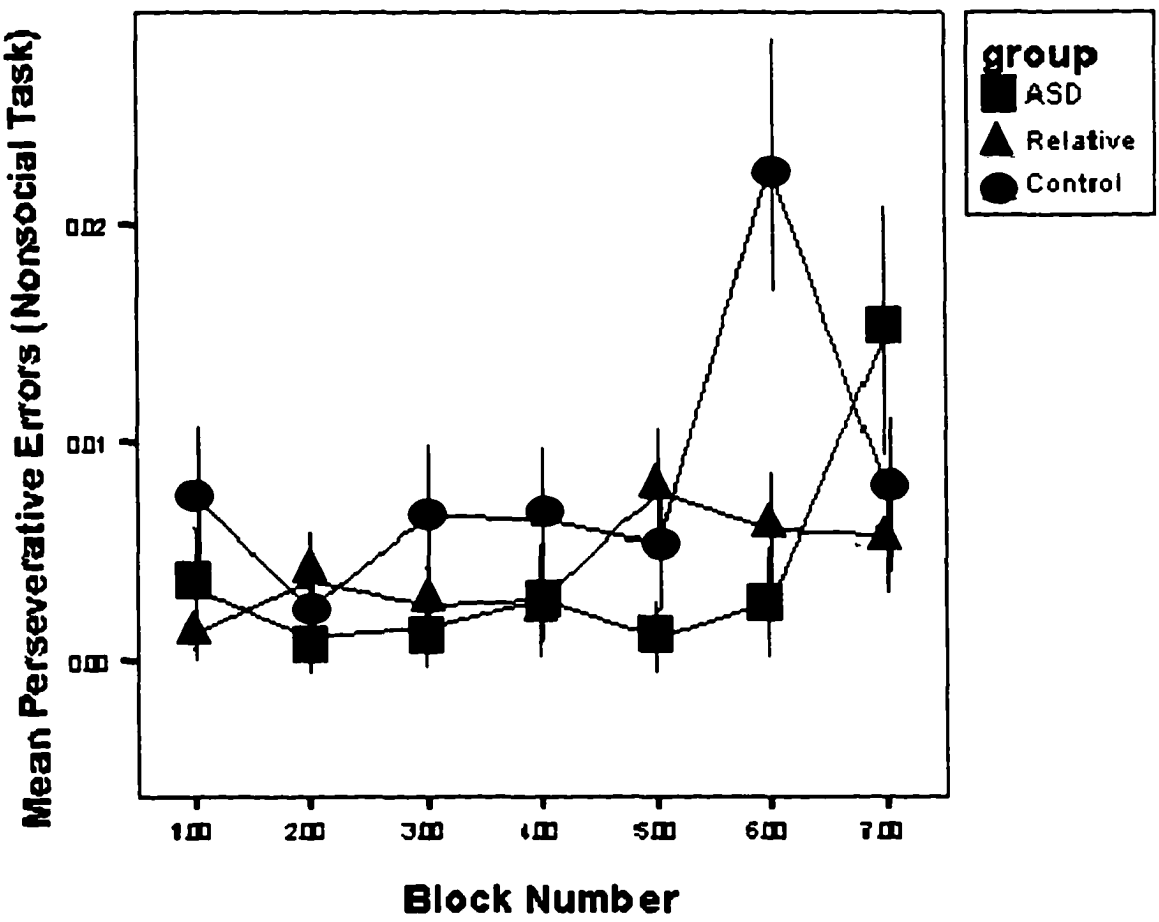


Figure 5A. Mean perseverative errors and 95% confidence intervals as a function of group and block for the nonsocial sequence reaction time task. The autism spectrum disorders (ASD) group displays fewer persverative errors than the relative and the control groups. Confidence intervals reveal considerable overlap between all three groups on the nonsocial task, and overlap for the relatives and controls on the social task.

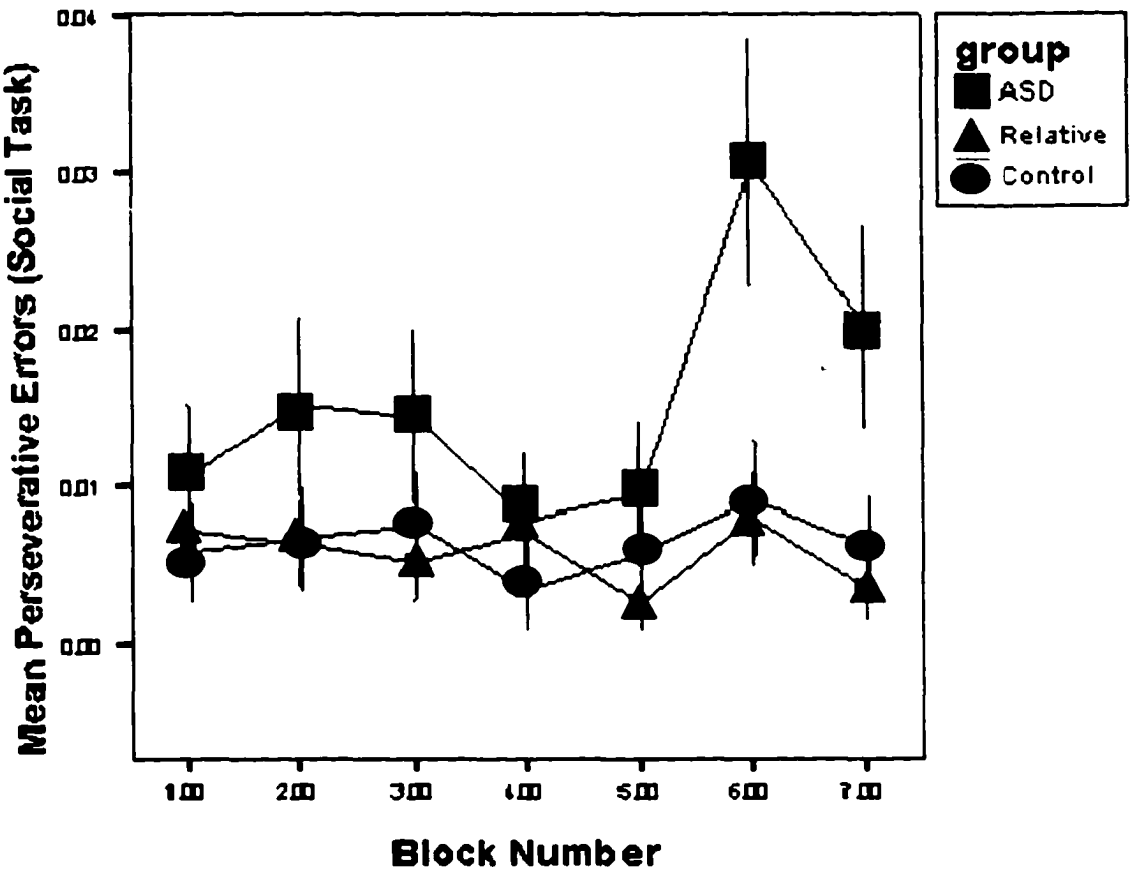


Figure 5B. Mean perseverative errors and 95% confidence intervals as a function of group and block for the social sequence reaction time task. The ASD group displays more perseverative errors than the other two groups. Confidence intervals reveal considerable overlap between all three groups on Blocks one through five.

but for the social task only. There were no significant differences found between the groups on the nonsocial task ($p = .134$).

Familial Analyses

A visual inspection of most of the graphs presented throughout this paper suggests at least a possibility that certain features of sequence learning may run in families. The most obvious familial factor is reaction time itself. The relative group performs these tasks slower than the controls, but not quite as slow as their ASD relatives. In the analysis of blocks one through five, the difference between the relative and the control group was not significant. However, in Figures 2A and 2B, one can see that between the relative and the control group there is no overlap of confidence intervals that surround the mean RT, and visually, there seems to be a considerable difference between these two groups. Therefore, two separate analyses were conducted to examine pair wise, between group comparisons (i.e., ASD vs. relative, and relative vs. control).

The mixed factor ANOVA with repeated measures for the ASD vs. relative comparison confirmed the nonsignificant result for each task ($p = .137$ for nonsocial, and $p = .172$ for social). The same method was used to analyze the relative vs. control comparison, which yielded significant results for the nonsocial task, $F(1, 54) = 5.04$, $p < .05$, and for the social task, $F(1, 54) = 9.39$, $p < .05$. These results suggest that the relatives perform these tasks more like the ASD group, and less like the control subjects. One possible reason for the difference in performance between the relative and control groups is that the relatives are significantly older than the control group, $t(48.63) = 4.25$,

$p < .001$, and the ASD group as well, $t\ (40.92) = -5.94$, $p < .001$. Older individuals have demonstrated slower RT than younger individuals on SRT tasks (D.V. Howard & J.H. Howard Jr., 1989; J.H. Howard Jr. & D.V. Howard, 1997). To explore the possibility that the significantly higher age is having an effect on the overall RT, and thereby causing the relative group to perform more slowly than the controls, this group was divided into two groups, one with ages falling below the median age (40), and the second with ages above. In the younger group, there were five males, and 10 females, mean age = 29.47, SD = 10.00, and SE = ± 2.58. In the older group there were eight males, and 10 females, mean age = 49.89, SD = 7.17, and SE = ± 1.69. The data from these two groups were analyzed and yielded a nonsignificant group effect, $p = .458$ for the nonsocial, and $p = .271$ for the social task. Therefore, age is probably not the reason for the slower RT in the relative group.

To further explore the possibility that age could be a contributing factor to the between group differences in RT, the data from all seven blocks in each task were analyzed for all three groups using age as a covariate. Although there is a significant age effect on the nonsocial task, $F\ (1, 69) = 4.14$, $p < .046$, there was no significant age effect for the social task, $p = .058$. Additionally the main effect for group was still significant for the nonsocial task, $F\ (2, 69) = 5.69$, $p < .01$, and for the social task, $F\ (2, 69) = 7.03$, $p < .01$. Thus, as with the relative group, age variability does not seem to account for the between group differences on either task in this study.

To determine whether or not RT to these stimuli tends to vary more between families than it does within, the data from the ASD group and the relative group were combined

and submitted to a mixed factor (family membership for the between group factor, and the 14 means of median RT from each of the seven blocks on each task) MANOVA, with repeated measures (nonsocial, and social tasks), and age was entered in as a covariate. Individuals with an ASD were excluded from this analysis if there were no additional family members who were tested. Therefore, there were fourteen families included in this analysis with an average of 2.93 members per family (all families had two to four members).

There is a significant effect for family membership on the nonsocial task, F (13, 27) = 2.65, $p < .05$, and for the social task, F (13, 27) = 2.18, $p < .05$. However, from three of these 14 families, there was one subject who was excluded from these analyses due to their error rate. All three subjects were members of the ASD group before exclusion. When these three subjects are included in this familial analysis, the results become more significant for the nonsocial task, F (13, 30) = 3.62, $p = .002$, and for the social task, F (13, 30) = 2.86, $p = .009$. These findings are suggesting that, at least for families with an individual who has autism, reaction times on these tasks tend to vary more between families than they do within one family unit. To determine the measure of agreement within families, an intraclass correlation (ICC) was calculated, applying the correction for unequal family size and moderate effects were found, ICC = .63 for the nonsocial, and ICC = .57 for the social task. Thus, families are performing these tasks similarly to their relatives, and that similarity is not as strong between families, suggesting a familial component to RT tasks.

Similar analyses were also conducted to examine the familial relationship in error and perseverative error patterns. Visual inspection of Figure 4 indicates an overlap in the error rate per block for the ASD and the relative groups on the nonsocial and social tasks. There is a similar overlap for these two groups on the perseverative error rate per block on the nonsocial task. However, both of these factors yielded nonsignificant results on the social and the nonsocial task. For the error patterns on the nonsocial task, $p = .181$, and on the social task, $p = .355$. For the perseverative error pattern on the nonsocial task, $p = .348$, and on the social task, $p = .487$. Therefore, both error and perseverative error patterns are not more similar within families than they are between the families in this analysis.

Discussion

There are three intriguing implications drawn from the results of this study that are covered in this section. The first finding is that subjects with an ASD demonstrate unconscious acquisition of sequence information (using stimuli that is devoid of social implications) about as well as, and in some respects better than, their unaffected relatives, and the unrelated controls. The second finding is the apparent difficulty the ASD group had learning the sequence on the social task when compared to their own performance on the nonsocial task, and compared to the performance of the relative and control group on the social task. The third is the possibility that reaction time performance on these tasks tends to be similar among the members of the same family, but differ among families. These results will be discussed along with the relevant implications in the sections that

follow. After the discussion of findings, new directions for research in this area will be suggested.

Evidence for Unconscious Acquisition of Information in the ASD Group

The results from the nonsocial task in this study suggest that people with an autism spectrum disorder are capable of unconsciously acquiring information from their environment. Albeit slower than the relative and the control groups, the ASD group displayed an almost identical pattern of learning across the seven blocks on this task, thereby suggesting that they were able to use the information about the sequence to increase their speed across blocks one through five, and transfer the knowledge about the sequence across the pseudorandom presentation of stimuli into block seven where the sequence is restored. Since implicit learning ability is demonstrated in this sample of individuals with an ASD, this finding strengthens previous findings supporting the stability of the unconscious and robust implicit learning.

The ASD group also made significantly fewer errors on the nonsocial task than both of the other two groups, suggesting their approach to this task was more careful and methodical than the other two groups. Both the relative and the control group showed no significant difference in the number of errors on either task, suggesting that these subjects approached each task similarly. The ASD group, however, was not able to apply the same careful approach shown on the nonsocial task to the social task, and made about as many errors as the other two groups.

Performance Deficits for the ASD Group on the Social Task

The ASD group was also able to acquire information about the sequence and decrease their RT across blocks one through five when the stimuli had social implications. On this task, block six (pseudorandom presentation) interfered with learning as it did on the nonsocial task, but on block seven the ASD group performs differently than the other two groups. The relative and control groups decreased their reaction time as expected, and the ASD group did not. It appears that this group demonstrated difficulty transferring the knowledge about the sequence to the new face in block seven.

These data provide support for the idea that people with an ASD use unconsciously acquired information that is of a social context, or at least that involves facial expressions, differently than their relatives and unrelated controls. The results suggest that the ASD group does not generalize their knowledge about the sequence that they acquired from the first five blocks using Model A's face, to block seven when the sequence is presented using Model B's face. The difficulty with generalization of skills and knowledge from the learning environment to novel situations has been a key topic of autism research for at least three decades.

The "failure to generalize" was first explored and discussed in the 1970's in the context of applied behavioral therapy (Lovaas, Koegel, & Schreibman, 1979; Rincover & Koegel, 1975; Schreibman & Lovaas, 1973). Using this method of therapy, an individual with autism would go through repeated discreet trials to learn a new behavior. Through a system of rewards the individual would learn to reproduce the behavior in the therapy session, but have difficulty applying the new skill in other situations. This difficulty with

generalization has been attributed, at least by some, to stimulus overselectivity, where the individual with autism will respond to only a limited number of stimuli (or possibly only one) in the environment when displaying the newly learned behavior. To illustrate this concept, consider the following hypothetical example.

Ten children with autism are taught by one teacher to touch their nose when requested. The children then go into another room and are asked by a different teacher to touch their nose and only four do so. These four can generalize the newly learned skill to a new location and new teacher. The first teacher now enters the new room and asks the 10 children to touch their nose and this time six children respond. The additional two children respond now because the first teacher is making the request, and they are responding to her as the stimulus, not only the request. The other four did not respond because they were originally responding not just to that specific teacher's request, but to an irrelevant hand movement she made while teaching them to respond to the request. Therefore, the 10 children are each learning the same response, but are actually responding to different stimuli, some of which are totally irrelevant to the request.

Lovaas et al. (1979) suggests that this difficulty with stimulus overselectivity contributes to their social aloofness in presence of complex, multidimensional stimuli provided by human beings in everyday interactions and situations. Individuals with an ASD may not be responding to the cues that typically developing individuals (implicitly) learn to respond to during a social interaction. Leiberman (2000) suggests that humans are unconsciously acquiring information constantly during social interactions, and the

collected information is unknowingly used to make judgements in future social interactions, but referred to commonly as intuition.

It is possible that subjects with autism were not associating the actual emotions with the stimuli. In other words, these subjects might have just learned which button went with what picture and did what they needed to do to make the picture change to the next one. They might be experiencing stimulus overselectivity and are responding to irrelevant stimuli in the photograph (e.g., a dimple that is formed when Model A smiles, or a wrinkle in the forehead when she frowns). This would explain why they were not able to adapt to the new face in block seven, when both of the other groups could do so. The relatives and the controls associated the sequence to which emotion they were seeing, and not just the physical properties associated with Model A. Therefore, when the face changed in block seven, the relative and the controls quickly adapted to the new face and used what they previously learned about the sequence and the emotion to accelerate their RT in block seven.

Since the 1970's, there have been a number of studies conducted that have focused on skill generalization and autism. The collective results of these studies present mixed findings. There are several that reaffirm the failure to generalize (Dunlap, Koegel, & Egel, 1979; Hadwin, Baron-Cohen, Howlin, & Hill, 1996), and some where there was at least partial evidence of generalization (McGregor, Whiten, & Blackburn, 1998; Muto T., 2001; Young, Krantz, McClannahan, & Poulson, 1994). However, there are quite a number of studies that present evidence that individuals with autism can generalize skills and knowledge to novel situations (Alwell, Hunt, Goetz, & Sailor, 1989; Belchic, &

Harris, 1994; Celiberti & Harris, 1994; Cohen, Sudhalter, Landon-Jiminez, & Keogh, 1994; Koegel, Camarta, Valdez, & Marta, 1997; Massey, & Wheeler, 2001; Sigafoos & Littlewood, 1999). Of particular relevance to the present study, is one that used photographs of familiar people's faces to teach emotional expression to a very low-functioning, nonverbal autistic male (Stafford, 2002). The results of that study demonstrated successful generalization by the subject of his knowledge regarding the emotive content of the facial expression to photographs of unfamiliar faces.

As there are conflicting results from studies of generalization abilities and autism, it is difficult to attribute the results of the present study completely to a failure to generalize. This deficit may be associated with a particular subtype of autism (that is unidentified at the present time) or a particular severity level. Many features of autism that people think of as stereotypically autistic, are true for very low-functioning individuals with the disorder, and not at all seen in higher functioning subjects. Most of the subjects involved in the present study were reasonably high functioning, and may possess skills beyond what is conventionally thought to be associated with autism.

However, if a failure to generalize is causing the increased RT in block seven for the ASD group, this is the first study to demonstrate this deficit as it pertains to unconsciously acquired information. It is important to remember that these subjects are not learning the expression of emotion by Model A's face, but they are learning the sequence of presentation for the emotions. It is knowledge of that sequence that is not generalized in block seven, not the knowledge of the expression of emotion. All of the other studies that explore a failure to generalize are referring to explicitly learned skills

and/or knowledge (e.g., play skills, asking questions, following instructions, imitation, etc.).

In reference to the evolutionary theory discussed in the introduction of this paper, the results of this study may suggest an autism-related deficit in the evolutionarily "old" mechanism associated with unconscious processing of, at least, social information. Since this deficit is related to only social information, this explanation seems unlikely. If there was an insult to the unconscious, it is likely to have global effects and not limited to one area of cognition.

Another possible explanation for the disrupted performance of the ASD group on the social task is their need to explicitly process the information presented in the facial expression to determine the emotion, where the other groups are implicitly processing the same information. If the ASD subjects are processing this information explicitly, and not automatically they may be introducing a lag of a few hundred milliseconds before responding. During the lag imposed by the autistic subjects' processing, explicit processes may dominate, and explicit processing of information during an implicit learning task has been shown to interfere with implicit learning (Destrebecqz & Cleeremans, 2001). There are known differences in the way that people with autism process facial information when compared to control individuals (Schultz et al., 2000). Neuroimaging studies have provided evidence that people with autism show activation in the inferior temporal gyrus when identifying both faces and objects. Control subjects show activation in the fusiform gyrus when identifying a face and the inferior temporal gyrus when identifying an object. People with a particular expertise (e.g., birdwatching)

also show activation in the fusiform gyrus when identifying the object of their expertise (e.g., a bird; Critchley et al., 2001; Schultz et al., 2000). Therefore it is suggested that typically developing individuals develop an expertise for identifying faces and people with autism do not.

The amygdala is believed to play an important role in the acquisition of face expertise, such that it participates in signaling the emotional and social relevance of faces (Grelotti, Gauthier, & Schultz, 2001). Furthermore, in subjects with an ASD, structural abnormalities in the amygdala have been identified (Bauman & Kempner, 1995). Also, neuroimaging studies have shown less activation in the amygdala than normal subjects while perceiving social stimuli, which may explain some of the autism-related differences in processing faces.

Typically developing children have developed a face expertise in early childhood and can individuate a face much more quickly and efficiently than a nonface object. Entry-level processing is used to differentiate the parts of an object (chair vs. car), and subordinate level of processing requires additional effort and time to make more subtle distinctions (corvette vs. camaro). For faces, people typically utilize a subordinate level of processing and categorize faces at the individual level as fast as they categorize them as faces (Tanaka, 2001).

The prevailing view of how emotional content in faces is processed in the amygdala, is that it happens, not just automatically, but without conscious effort and requires no little or no attention (Oeman, 2002). However, additional work shows that the processing of faces does in fact require attention and is processed through top down processes

(Pessoa, Sabine, & Ungerleider, 2002). It is possible, that the structural abnormalities seen in the amygdala of subjects with autism, and with the related attentional deficits associated with the disorder, these abnormalities are explaining the impaired implicit learning on this task. It is important to note that despite these processing differences, people with an ASD generally perform as well as controls on face processing tasks (Celani, Battacchi & Arcidiacono, 1999; Teunisse & de Gelder, 1994), but their performance on these tasks has been impaired when elements of emotion are added to the face (Davies, Bishop, Manstead, & Tantum, 1994).

The error analysis also suggests the ASD group had difficulty with the social task as compared to the nonsocial task. It is reasonable to assume that subjects with an ASD would be relatively good at simple, repetitious tasks. Although they were slower than the other groups in this study, they made significantly fewer errors on the nonsocial task than they did on the social task. The administration of these tasks was counterbalanced so this result cannot be explained by greater fatigue on the social task.

Elevated perseverative errors also yield some notable evidence of increased difficulty for the ASD group on the social task. This group made fewer perseverative errors on the nonsocial task than the relative and control group, but on the social task the situation changes and the ASD group made significantly more errors than the other group. Perseverative errors are particularly interesting here because of the relative simplicity of this task. In the SRT task, as subjects are learning the sequence and getting faster at the task, they are typically beginning to anticipate the next stimulus. It is expected that they will guess incorrectly for a small percentage of the responses. However, once they hit the

wrong button once, the next button press will most likely correctly match the stimulus. If they press a wrong button a second time, it may suggest a difficulty processing the information presented by the stimulus and choosing the correct response. Therefore, if the ASD subjects are approaching SRT tasks more methodically and carefully than the relative and the control group, their method does not help them to make fewer errors on the social task.

It is important to mention here that the designation of the task using facial expressions as stimuli as a 'social' task is somewhat of a misnomer. There is no real 'social' component to this task as completing the task does not involve interaction with another person. Rather, it is meant to imply that the stimuli used is important in social interactions and development. If a person is not efficiently processing the information present in another person's facial expression, the interaction may seem awkward or stilted, and the individual who cannot process the information may seem odd or different. Repeated interactions like this across multiple situations may certainly have an effect on an individual's development.

For some reason the ASD group in this study is showing deficits in implicit learning of information that is of a social nature. As stated in the introduction, individuals with autism display communication (verbal and nonverbal) and reciprocal social interaction deficits (eye gaze, smiling, conversation) that would indicate problems with acquiring certain skills used in social interaction, and these skills are acquired in typical development mostly without conscious effort. These results demonstrate the problem with unconscious acquisition of information is distinct to stimuli that are of a social

nature, and that with nonsocial stimuli individuals with an ASD perform like their unaffected relatives and normal controls, only slower.

Is Reaction Time Familial?

The third interesting finding in this study is the familial nature of reaction time for families with an individual with autism. Data from twin and family studies show strong evidence for a genetic component to the disorder and that there are certain traits of autism that vary together among siblings with the disorder (Bailey et al., 1995; Silverman et al., 2002), and that there are traits that when possessed by the autistic individuals, also show up in a less severe form in the nonautistic relatives (August, Stewart, & Tsai, 1981). The relative group in this study not only performs these tasks more slowly than controls, but members of a family tend to vary in reaction time similarly.

This finding may suggest a neurological underpinning in families with an autistic individual that may possibly be related to attentional deficits associated with autism. RT and attention may be part of the endophenotype of autism with a possible genetic component. Interestingly enough, this finding is not limited to social or the nonsocial task. The deficits in RT are seen in both tasks, further suggesting an underlying neurocognitive component that may be different in families with an individual who has autism.

Suggestions for Follow-up

The findings from this study are certainly intriguing and a warrant further exploration into this area of autism and implicit learning of different contextual information. Since there is evidence for deficits on the SRT task that uses stimuli of a social nature, a study

that has a better designed control task is an intriguing follow up to this work. The present study employed a nonsocial task as the control, which used simple geometric forms. The ASD group demonstrated learning here, but displayed some difficulty on the social task, which used facial expressions as the stimuli. Facial expressions contain a good deal more information to be processed than simple geometric forms. It would be interesting to see if similar results occur with a nonsocial task that uses a more complex stimuli. Additionally, the generalization skill (or lack there of) needs to be addressed. In the present study subjects needed to transfer their knowledge of the sequence to a new face, but still relate just the emotion to the sequence. This process is somewhat more complicated than what is occurring in the present nonsocial task, as the stimuli do not change in block seven, and there is no new presentation of the geometric form in which to transfer the acquired knowledge of the sequence.

A simple illustration of this suggestion can be illustrated through the use of an everyday dinnerware set. In this example, four separate pieces of a matching pattern of dinnerware can be used as the stimuli. Subjects would see a picture of a dinner plate, then a mug, then a soup bowl, and then a pitcher. All four pieces would have the same pattern (e.g., purple grapes on a yellow background). Subjects would need to correctly identify the piece of dinnerware and press the corresponding button to change to the next picture and the dinnerware pieces would be presented in a sequence of ten. The same pattern and pieces would be used during the transfer block, but then the pattern would change (e.g., to a modern design with colored shapes) and the same four pieces of a

different set would be used during the seventh block when the sequence returned. This will require that subjects transfer their knowledge of the sequence to a new stimulus.

Another suggestion for a follow up study would be to carefully delineate the diagnostic categories by having one group of subjects who meet criteria for autism, and another group of subject who meet criteria for Asperger's Disorder. Also, it is necessary to include a separate family member group for each diagnostic category. This might help reduce some of the within group variability seen in the present study and may also yield more information pertaining to the familial component while helping to delineate differences between the two diagnostic categories.

Additionally, the familial component of RT needs to be explored further. This study provided no familial controls, that is, the family members of the normal control subjects were not tested. Therefore no information can be gleaned that pertains to a general familial nature of RT, or is this a feature that is distinct to families with autism. Control families need to be tested in a follow up project to determine if the familial nature of RT is global, or is it distinct to families with an autistic individual.

The present study demonstrates the capability of individuals with autism to unconsciously acquire information from their surrounding environment. Therefore, once again the evolutionarily older construct of the unconscious demonstrated stability where there is a dramatic insult to conscious functioning. Despite this ability, individuals with autism experience extreme social deficits that are most likely related to inefficient processing of social information, and that may be interfering with the unconscious acquisition of information that is of a social nature. More work needs to be done in this

area to explore this possibility, and in turn to attempt to improve the deficits these people experience in unconscious acquisition of social information.

Educational interventions need to be designed that will help autistic individuals process this information more quickly. With enough exposure to this intervention, the interpretation of this information may become implicit and eventually happen automatically, without conscious effort. If this improvement should occur, this ability would allow individuals with autism to modulate social interaction and thereby reduce the level of nonverbal communication deficits that are commonly associated with autism. These results may make an important contribution to the understanding of autism as a developmental disorder, its endophenotype and diagnostic classification, and perhaps provide new direction for therapeutic intervention.

Appendix

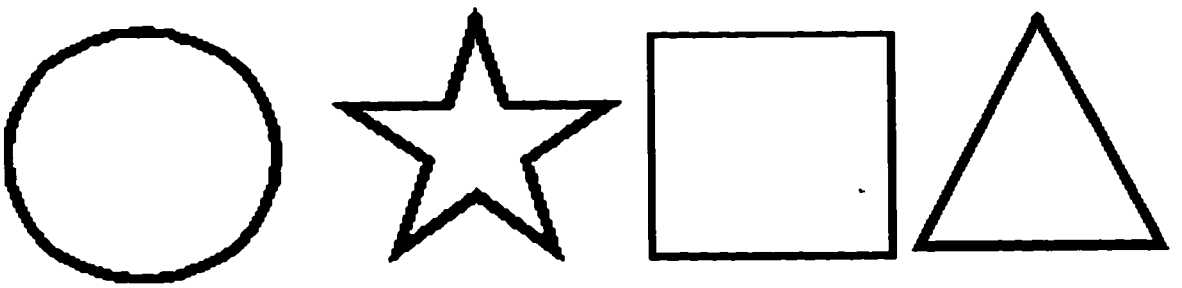
Social Task Model A: Learning Phase and Transfer (Interference) Block

Happy Sad Afraid Angry

Social Task Model B: Block 7, return to sequential presentation

Happy Sad Afraid Angry

Nonsocial Task: Geometric Forms



Circle Star Square Triangle

DSM-IV Diagnostic Criteria for Autistic Disorder (American Psychiatric Association, 1994)

A. A total of six (or more) items from (1), (2), and (3), with at least two from (1), and one each from (2) and (3):

(1) qualitative impairment in social interaction, as manifested by at least two of the following:

(a) Marked impairment in the use of multiple nonverbal behaviors such as eye-to-eye gaze, facial expression, body postures, and gestures to regulate social interaction

(b) Failure to develop peer relationships to the appropriate developmental level

(c) A lack of spontaneous seeking to share enjoyment, interests, or achievements with other people (e.g., by a lack of showing, bringing, or pointing out objects of interest)

(d) lack of social or emotional reciprocity

(2) qualitative impairments in communication as manifested by at least one of the following:

(a) delay in, or a total lack of, the development of spoken language (not accompanied by an attempt to compensate through alternative modes of communication such as gesture or mime.

(b) In individuals with adequate speech, marked impairment in the ability to initiate or sustain a conversation with others

(c) Stereotyped and repetitive use of language or idiosyncratic language

(d) Lack of varied, spontaneous make-believe play or social imitative play appropriate to the developmental level

DSM-IV Diagnostic Criteria for Autistic Disorder (Continued; American Psychiatric Association, 1994)

(3) restricted repetitive and stereotyped patterns of behavior, interests, and activities, as manifested y at least one of the following:

(a) encompassing preoccupation with one or more stereotyped and restricted patterns of interest that is abnormal either in intensity or focus

(b) apparently inflexible adherence to specific, nonfunctional routines or rituals

(c) stereotyped and repetitive motor mannerisms (e.g., hand or finger flapping or twisting , or complex whole-body movements)

(d) persistent preoccupation with parts of objects

B. Delays or abnormal functioning in at least one of the following areas, with onset prior to age 3 years:

(1) social interaction,

(2) language as used in social communication, or

(3) symbolic or imaginative play.

C. The disturbance is not better accounted for by Rett's Disorder or Childhood Disintegrative Disorder.

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