A COMPARATIVE STUDY OF LAUGH ACOUSTICS IN CHILDREN WITH AND WITHOUT AUTISM

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CHAPTER I

INTRODUCTION

Ever since Kanner's (1943) initial description of autism, there has been considerable debate about the deficits of children with this disorder. Discussion about the emotion-perception and -expression deficits of children with autism has been central to this debate. Consequently, numerous studies have tested the purported emotional deficits of these children. Empirical outcomes suggest that children diagnosed with autism exhibit various deficits on both emotion-perception and -expression tasks. Studies of emotion perception suggest that children with autism fail to adequately perceive complex emotional displays relative to nonautistic participants. In contrast, studies of emotion expression in children with autism show that they typically exhibit deficits when the expression occurs within the context of either a reciprocal-social interaction or a joint-attention task. During these contexts, children with autism are significantly less likely to display expressions of positive affect relative to comparison participants.

In an effort to further our understanding of the putative expressive deficits of children with autism, the current study examined the acoustic features of laughter in these children within the context of a reciprocal-social interaction. No existing studies have specifically examined laugh acoustics in this population. Related research, however, suggests that the social deficits of children with autism may contribute to a limited range of emotional expressions relative to nonautistic children. Specifically, it was hypothesized that children with autism would exhibit fewer distinct laugh types with less acoustic variability than nonautistic children. Furthermore, based on the established relation between joint attention and affective expression, it was hypothesized that joint attention would mediate the relation between autistic symptoms and both laugh production and acoustic outcomes.

The expression of emotion in children with autism

Studies on the emotion-perception abilities of children with autism obtain conflicting results. Whereas most studies do not report significant deficits in the ability of children with autism to perceive emotional expressions from whole faces (Gepner, Deruelle, & Grynfeltt., 2001; Hobson, Ouston, & Lee, 1988a, 1988b; Jennings, 1973; Ozonoff, Pennington, & Rogers, 1990, Study 1; Prior, Dahlstrom, & Squires, 1990; Weeks & Hobson, 1987), other studies do report impairments (Bormann-Kischkel, Vilsmeier, & Baude, 1995; Celani, Battacchi, & Arcidiacono, 1999; MacDonald et al., 1989). Studies with more difficult task demands also yield conflicting results. For instance, a number of researchers have used a paradigm in which participants are asked to match an audio track containing emotional content with a photograph of the corresponding emotion. Some of these studies report impairments in children with autism (Hobson, 1986a, 1986b; Hobson et al., 1988a; Hobson, Outson, & Lee, 1989), whereas others do not (Haviland, Walker-Andrews, Huffman, Toci, & Altonet ,1996; Loveland et al., 1995). Despite an ongoing debate, conflicting results between emotion-perception studies are generally attributed to the experimental approach used to obtain the results. The pattern that has emerged suggests that when autistic individuals are matched with nonautistic participants on measures of non-verbal IQ (nVIQ), they are more likely to show impairments than when children with autism are matched with comparison participants on measures of verbal IQ (VIQ).[1] These results suggest that fewer overall differences exist between the emotion-perception abilities of children with autism and typically developing children on simple emotion-labeling tasks than previously hypothesized.

In contrast with studies of emotion perception, there is less contention about the emotion-expression abilities of children with autism. The available literature indicates that there are a variety of differences between children with autism and nonautistic children in the way they both label and express their emotions. Both children and adults with autism show impairments in their ability to imitate emotional expressions relative to comparison participants (Hertzig, Snow, & Sherman, 1989; MacDonald et al., 1989). Children with autism have more difficulty describing "complex" or socially derived emotions (Capps, Yirmiya, & Sigman, 1992; Dennis, Lockyer, & Lazenby, 2000), have difficulty labeling their own emotional state after watching affect-inducing videotapes (Yirmiya, Sigman, Kasari, & Mundy, 1992), and exhibit distinct differences in the way they describe causes and experiences of emotion relative to nonautistic participants (Jaedicke, Storoschik, & Lord, 1994). Participants with autism tend to emphasize material causes for emotion such as food, toys, and activities, whereas they deemphasize social interactions. The causes they cite for emotion are frequently idiosyncratic and referred to repeatedly (Jaedicke et al., 1994).

Studies find fewer overall differences than previously hypothesized between children with autism and nonautistic participants in their facial expressions of affect

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[1] The most common measures used to assess VIQ are more accurately described as a tests of receptive-language vocabulary. However, due to the variety of tests used to measure this construct, the term "VIQ" will be used to refer to these measures more generally.

(Capps, Kasari, Yirmiya, & Sigman, 1993; Dawson, Hill, Spencer, Galpert, & Watson, 1990; Kasari, Sigman, Mundy, & Yirmiya, 1990; Snow, Hertzig & Shapiro, 1987; Yirmiya, Kasari, Sigman, & Mundy, 1989). One notable exception to these studies, however, indicated that children with autism showed a *greater* variety of affective expressions than nonautistic participants (Yirmiya et al., 1989). These expressions consisted primarily of affective blends, which are defined as a combination of one or more facial expressions (Izard, 1979). The interpretation of this result is that children with autism do not employ a greater variety of affective expressions per se, but rather produce facial expressions that are often more difficult for others to understand. Despite a lack of overall facial-affective differences between children with autism and nonautistic participants, considerable differences have been observed when specific contexts are examined (Dawson et al., 1990; Snow et al., 1987; Yirmiya et al., 1989). Differences between these children are consistently related to the expression of positive affect during certain social exchanges.

Children with autism do not exhibit deficits in the expression of positive affect in all social contexts, but rather these children have difficulty expressing positive affect during both reciprocal-social interactions and joint-attention interactions. Reciprocal-social interactions refer to verbal or nonverbal exchanges that may typically occur between two or more people. For a reciprocal-social interaction to occur, both parties must actively participate in the social exchange. Examples of reciprocal-social interactions include a child saying “thank you” for a gift, or a child engaging in a game with an adult. During various reciprocal-social interactions, children with autism are less likely to combine eye contact with smiling (Dawson et al., 1990), and are less likely to produce positive affect relative to nonautistic participants (Snow et al., 1987; Yirmiya et al., 1989). Children with autism exhibit an impaired ability to express positive affect during reciprocal-social interactions with multiple partners (Snow et al., 1987), during free play (Dawson et al., 1990), structured play (Dawson et al., 1990; Yirmiya et al., 1989), conversation (Dawson et al., 1990), and “normal” interactions (Snow et al., 1987). These findings contrast with those that show equivalent amounts of positive affect in autistic and nonautistic participants during nonsocial interactions (Dawson et al., 1990; Kasari et al., 1990; Kasari, Sigman, Baumgartner, & Stipek, 1993).

Joint attention is typically defined as the ability of the child to use gestures and eye contact to coordinate attention with another person in order to share the experience of an event or object (Bruner & Sherwood, 1983; Seibert, Hogan, & Mundy, 1982). Joint attention emerges predictably at about 9-12 months of age (Scaife & Bruner, 1975), and is thought to be critical to developments in the integration of cognitive, social, and affective skills in infancy (e.g., Adamson & Bakeman, 1985; Adamson & Russel, 1999; Bates, 1979; Bruner, 1981; Rheingold, Hay, & West, 1976; Stern, 1985; Trevarthen, 1979). Both theory and research suggest that the processes responsible for joint-attention deficits emerge within the first 12 months of life (Adrien et al., 1991; Bruner, 1975; Bruner & Sherwood, 1983; Mundy & Sigman, 1989; Mundy, Sigman, & Kasari, 1993; Osterling & Dawson, 1994; Scaife & Bruner, 1975).

In typically developing children, joint attention is reliably linked with the expression of positive affect (Adamson & Bakeman, 1985; Kasari et al., 1990; Mundy, 1995; Mundy, Kasari, & Sigman, 1992). This relation is more consistent than the relation between positive affect and other forms of nonverbal communication such as requesting bids (Mundy, Kasari, & Sigman, 1992). In fact, it has been suggested that positive affect may distinguish joint attention from all other forms of nonverbal communication (Bruner, 1981; Mundy, 1995). Positive affect is hypothesized to be critical to joint attention because of its ability to facilitate shared interactions. Studies of joint attention show that children with autism exhibit less positive affect than comparison participants during joint-attention tasks with adults. In contrast, children with autism produce the same amount of positive affect as nonautistic children during both requesting and joint-attention acts with objects (Kasari et al., 1990; Mundy, 1995; Paparella, 2000). Conversely, joint attention may be a particularly important indicator of positive affect. Preliminary evidence indicates that joint attention may be such an indicator in children with autism. It has been shown that joint-attention training results in an increase in the expression of positive affect in children with autism (Whalen, 2001). Given these results, it may be that joint attention serves as a mediator between autistic symptoms and positive affect. Therefore an increase in joint-attention skill would result in higher levels of positive affect.

Alternate theories of emotional deficits in children with autism

Some researchers suggest that emotional deficits in children with autism may be secondary to a more central dysfunction. One prominent hypothesis developed by Baron-Cohen, Leslie, and Frith (1985) posits that children with autism may lack a "theory of mind." This phrase, originally used by Premack and Woodruff (1978), describes the ability to represent independent mental states of the self and others in order to predict and explain actions. Indeed, several investigations show that children with autism exhibit impairments in their ability to represent mental states, or “mentalize.”

The first empirical theory-of-mind test evaluated the ability of participants with autism to recognize false beliefs (Baron-Cohen et al., 1985). For this test, researchers used a doll (Sally) to hide a marble in her basket and then leave the room. Afterwards, another doll (Ann) moved the marble to her own box. The child was then asked the question “Where will Sally look for the marble?” Results showed that 80% of the participants with autism answered incorrectly, stating that Sally would look in the box where the marble was now hidden. In contrast, 86% of a group of children with Down Syndrome, and almost all typically developing 4-year-olds answered correctly. This finding was taken to suggest that children with autism have a specific deficit in their mentalizing abilities.

Several studies have since replicated the finding that children with autism have deficits on tests of false belief as measured by the Sally-Ann task (eg., Buitelaar & van der Wees, 1997; Ozonoff, Pennington, & Rogers, 1991). Additional investigations have extended the generalizability of these results by using a “think” instead of a “look” question, using real people instead of toys, and using a control group of language-impaired children to rule out differences in linguistic ability (Leslie & Frith, 1988; Perner, Frith, Leslie, & Leekam, 1989; Reed & Peterson, 1990). This deficit in mentalizing ability is also supported by a variety of studies that do not use the Sally-Ann paradigm (for review, see Happe & Frith, 1995).

Deficits in theory of mind are hypothesized to influence both the emotion-perception and -expression abilities of children with autism (Baron-Cohen, 1991, 1994).

If children with autism are unable to represent another's mental state, it follows that they are not able to accurately evaluate emotional states that rely on this ability. This is consistent with data showing that children with autism have significant difficulties understanding more "cognitive" emotions such as surprise or embarrassment (Baron-Cohen, Spitz, & Cross, 1993; Bormann-Kishkal et al., 1995). In further support of this hypothesis, all of the children with autism who passed simple false-belief tasks in Baron-Cohen et al.'s (1985) original study failed a slightly more sophisticated second-order theory of mind test. This test involved an understanding of what "Mary thinks John thinks" (Baron-Cohen, 1989). Furthermore, Baron-Cohen (1991) found that children with autism only showed deficits on emotion-perception tasks when the emotions were caused by false beliefs.

Despite the support for this alternate explanation of emotional deficits in children with autism, "theory of mind" falls short of explaining all of the impairments observed in these children. First, it does not explain why participants with autism exhibit impairments on some simple emotion tasks (Celani et al., 1999; MacDonald et al., 1989), or on cross-modal experiments (Hobson, 1986a, 1986b; Hobson et al., 1988a; Hobson et al., 1989; Loveland et al., 1995). Second, although deficits in the ability to mentalize may lead to deficits in high-level emotion perception, there is currently no direct causative link between the constructs. For example, it may be that emotion-perception deficits lead to a relative inability to understand the mental states of others. Finally, theory of mind does not explain the lack of perceptual preference given to viewing facial expressions of emotion in children with autism (Jennings, 1973; Weeks & Hobson, 1987). Although the relation is still unclear, there is some evidence indicating that emotion-perception and theory-of-mind deficits are related (Buitelaar & van der Wees, 1997). It is therefore likely that an impairment in either ability will contribute to a decrement in performance across both areas. Thus, theory-of-mind deficits may not be central to autistic functioning, but rather may co-occur with other deficits.

Several converging lines of evidence suggest that emotion-related deficits in children with autism may be linked to impairments of attention to emotional stimuli. Beversdorf et al. (1998) utilized sentences presented orally to children with autism and control subjects in order to evaluate their ability to recall sentences with emotional content. Results showed that children with autism were significantly worse than nonautistic controls at recalling sentences that contained emotional content but not nonemotional content. Children with autism also appear to be less responsive to the emotional expressions of others. Sigman, Kasari, Kwon, and Yirmiya (1992) demonstrated that in comparison with typically developing and mentally retarded children, children with autism appeared to ignore or not notice adults showing distress, fear, or discomfort. In each situation, children with autism spent more time playing with a toy and less time looking at the adults than controls. In some studies, children with autism also spend less time looking at emotional expressions than non-emotional expressions (Haviland et al., 1996) or toys (Huffman, 1994). These findings demonstrate that some emotion-related impairments in children with autism may be attributable to a lack of attention directed toward emotional stimuli. However, these studies fall short of explaining emotion-related deficits exhibited during focused-attention tasks. More research is needed to understand the attentional processes that may mediate emotional abilities in these children.

The production of laughter in children with autism

Despite a growing literature on the expression of emotion in children with autism, there is still little known about the way these children use emotion-related signals in their interactions with others. Yet understanding emotions in this population is vital. Not only are emotions important for regulating internal states and behavior, but the expression of emotion is also critical for developing and maintaining relationships with peers and caregivers. A failure to adequately express emotions during social interactions may contribute significantly to the marked social deficits observed in children with autism. In particular, a lack of positive affect expressed during some reciprocal-social interactions (Dawson et al., 1990; Kasari et al., 1990; Snow et al., 1987; Yirmiya et al., 1989) may hinder the formation of relationships with others.

There are several key gaps in our knowledge about the emotion-related abilities of children with autism. For example, few studies have investigated the vocal expression of emotion in children with autism. It is known that humans often produce facial expressions of emotion that are associated with their internal affective states. However, vocal expressions, such as laughter or vocal inflections in speech, may be equally important for conveying these states. Vocal acoustics also have an important influence on the emotional states of others (Bachorowski & Owren, 2001, Owren & Bachorowski, 2001). To date, the laughter of children with autism has been examined in only four known investigations. In their investigation of vocal atypicalities of children with autism, Sheinkopf, Mundy, Oller, and Steffens (2000) coded laughter as the "proportion of syllables where children were judged as laughing" (p. 349). Post-hoc analyses revealed no significant group differences in the laugh ratios of autistic and nonautistic children. In this study, however, children were not evaluated using the same stimulus sets. Without the use of equivalent laugh stimuli, it is not clear whether Sheinkopf et al.'s results are due to differences in stimulus presentation or similarities in the emotion-expression abilities of the two groups. Snow et al. (1987) also coded laughter. In that study, however, laughter was only analyzed as part of the broader construct of "positive affect."

Only two investigations have explicitly examined the production of laughter in children with autism. St. James and Tager-Flusberg (1994) conducted an observational study of humor in children with autism. In their study, there were no significant differences in the mean rate of laugh production between children with autism and children with Down Syndrome. Due to a number of limitations associated with their study, however, it is not clear if there are differences in the rate of laugh production between these groups. First, laughter was only coded when it was in response to a humorous elicitor. Rates of laugh production may have been dramatically underestimated because laughter occurs frequently outside of attempts at formal humor (Grammer, 1990; Provine, 1993). Second, St. James & Tager-Flusberg (1994) had a sample size of only 6 participants in each group, and did not match stimuli or duration between participants. The small sample size in St. James Tager-Flusberg's study did not allow for sufficient power, whereas the use of different stimuli between children precluded an appropriate comparison of laugh rates.

More recently, Reddy, Williams, and Vaughan (2002) examined humor and laughter in 3-5 year-old children with autism. In their study, parents of children with autism reported that their children's laughter was rare in response to events such as funny faces or socially inappropriate acts, but was common in strange or inexplicable situations. Their analysis of videotaped interactions did not result in significant differences in mean rates of laughter between children with autism and children with Down Syndrome. They did find that participants with autism were significantly more likely to produce unshared laughter than comparison participants. Unfortunately, however, Reddy et al.'s (2002) study was subject to similar methodological constraints as St. James & Tager-Flusberg's work. Namely, Reddy et al. (2002) had a small sample size, and did not match stimuli or duration between participants.

Hypotheses

The current study investigated the acoustics of laughter in children with autism in both humorous and nonhumorous reciprocal-social contexts, with the aim of adding to our understanding of the emotion-related expressions of these children. Based on the existing literature, it was hypothesized that children with autism would exhibit fewer distinct laugh types with less variable laugh acoustics than nonautistic children. Furthermore, it was hypothesized that joint attention would mediate the relation between autistic symptoms and both laugh production and acoustic outcomes. Support for these hypotheses is grounded in both theory and empirical evidence.

Several converging lines of work suggest that children with autism may exhibit a more restricted range of laugh types with less variable acoustics. For example, studies of the characteristics of vocal production in young children with autism indicate that they produce nonspeech sounds that are comprised of atypical vocal qualities (Sheinkopf et al., 2000). These atypical qualities include significantly higher rates of sounds defined as squeals, growls, and non-distress yells. In older children with autism, nonspeech sounds are often idiosyncratic, and only meaningful to their parents (Ricks, 1975). Whereas these findings do not provide clarity regarding the acoustic features of laughter in children with autism, they do indicate that other nonspeech sounds such as laughter may be aberrant in children with autism.

Studies on the production of laughter in typically developing children provide support for the hypothesis that children with autism produce fewer distinct laugh types. Laughter is decidedly a social signal in both adults and children. In adults, it has been shown that individuals are 30 times more likely to laugh with a partner than they are to laugh alone (Provine, 1993). Similarly, children laugh more, smile more, and rate material as funnier when in the presence of other children (Chapman, 1975; Chapman & Chapman, 1974; Chapman & Wright, 1976). Between the ages of three and five, children are reported to produce 95% of their laughter while in the company of others (Bainum, Lounsbury, & Pollie, 1984). Studies further show that in adults, laughter produced between familiar social partners is more likely to be co-active or co-occurring than the laughter produced between stranger-dyad members (Smoski & Bachorowski, 2003). In four-month-old infants, onset and offset of laugh bouts are generally not synchronized with the mother's laughter, but become increasingly coincident by two years of age (Nwokah, Hsu, Dobrowolska, & Fogel, 1994). Taken together, these data show that social factors are critically linked to laugh production. Thus, the social deficits observed in children with autism (for review see Pollard, 1998) may likely be associated with differences in their laugh production relative to typically developing children.

The social deficits of children with autism are likely to prevent them from developing the same variety of laugh types used by typically developing children to negotiate social interactions. Through development, it is likely that the emergence of a greater variety of laugh sounds is partly a result of exposure to increasingly complex social demands. For example, an increase in exposure to peers may have a marked effect on the acoustic features of laugh production in children. Such exposure may result, for instance, in the emergence of affirmative "grunt-like" laughs. As a result, the laughter of children with autism may be more closely linked to their own positive internal state, instead of being modulated by social circumstances.

In addition to a more limited array of distinct laugh types used by children with autism, it is likely that the acoustic qualities of laughs produced by these children may also be restricted. With the exception of descriptive work by Nwokah and colleagues (Nwokah & Fogel, 1993; Nwokah et al., 1994; Nwokah, Hsu, & Fogel, 1993), few studies have investigated the acoustics of laugh production in children. Studies of the acoustic features of laughter in adults, however, may provide a framework for making predictions about the diversity of laugh sounds produced by children. Research shows that adults exhibit a wide variety of laugh sounds (Bachorowski, Smoski, & Owren, 2001, 2004; Owren & Bachorowski, 2003). These laugh sounds may be characterized by a number of features, including the presence or absence of periodic vocal-fold vibration (voiced and unvoiced laughter, respectively), duration of the sound, and variability of the fundamental frequency (F_0). Collectively, these and other acoustic features contribute to the diversity of laugh sounds produced by an individual and are used to distinguish different laugh types (e.g. gunts, snorts, or tonal laughs). In adults, both the rate of production and the acoustic features of laughter are significantly influenced by the sex and familiarity of one's social partner (Bachorowski et al., 2004; Owren & Bachorowski, 2003). As examples, females are more likely to produce acoustically extreme laugh sounds (such as sounds with very high F_0's) when in the presence of male strangers, whereas males are more likely to produce acoustically extreme laughs when tested with a male friend.

Currently, it is not known if the contextual differences in laugh production observed in adults exist in children. It is plausible, however, that children are also sensitive to various contextual variables at an early age. Differences in laugh acoustics observed in adult populations, such as extreme F_0 values related to the sex of a social partner, may also influence the acoustic features of laughter in typically developing children. Conversely, if children with autism do not attend to contextual variables such as gender distinctions, then their laugh acoustics may be inhibited. Though the contextual factors that are influential to the development of different laugh acoustics are currently unspecified in children, the current research may help to advance an understanding of some of the differences in laugh acoustics between children with autism and nonautistic children.

Theoretical work on the hypothesized function of laughter also indicates that there may be differences in both the laugh acoustics and laugh types produced by typically developing children and children with autism. Recent evidence in support of a theoretical "affect-induction" account suggests that laughter is largely a nonconscious strategy to influence the affective and behavioral stance of the listener towards the laugher (Bachorowski et al., 2001; Owren & Bachorowski, 2003; also see Owren & Rendall, 1997, 2001, Owren, Rendall, & Bachorowski, in press). This theory proposes that the function of laughter is to influence the listener through both direct and learned processes. Responses of a listener to these direct and learned processes are thought to be a result of the acoustic characteristics of the laughter. For example, some acoustic qualities are more likely to elicit positive affect in the listener and therefore more apt to result in positive outcomes for the laugher. One such outcome may include an increased interest in affiliating with the laugher as a direct response to the positive affect-inducing characteristics of the laugh (see Grammer & Eibl-Eibesfeldt, 1990). This same outcome may rely on learning to promote associations between the individual characteristics of the laugher and the induced positive affect.

Drawing on an affect-induction account of laugh production (Bachorowski et al., 2001; Owren & Bachorowski, 2003; also see Owren & Rendall, 1997, 2001, Owren, Rendall, & Bachorowski, in press), laughter is in part hypothesized to influence listeners directly through attention, arousal, and emotional response processes. Laughs with features such as abrupt rise times, high F_0's, perceptually salient F_0 modulation, and possibly acoustic nonlinearities should be particularly effective in engaging listener response systems (for review, see Owren & Rendall, 2001). Consequently, core deficits in the social, motivational systems used to engage the response systems of listeners will likely influence the same systems that drive the modulation of laugh acoustics in children with autism. Thus, it was hypothesized that the following laugh acoustics responsible for influencing response systems would be more restricted in range in children with autism relative to nonautistic participants: use of distinct laugh types, range and variability of F_0, laugh duration, and occurrence of acoustic nonlinearities.

The affect-induction account also suggests that typically developing children produce laughter as a nonconscious strategy to influence the affective states of those around them. If children with autism are generally disengaged during social interactions, it is logical to speculate that they are less likely to produce behavior that influences the affective states of listeners. Early in development, laughter is likely to be largely associated with experienced positive affect. Only later are children expected to implicitly learn how and when to use various laugh sounds to best engage listeners. Therefore, as a result of their social disengagement, the variety of laugh sounds produced by children with autism should only include those laugh types that are hypothesized to be most directly linked with a positive internal state. Currently these laugh types have been linked only to voiced laugh production (Bachorowski & Owren, 2001). In short, children with autism were not hypothesized to use laughter in a socially significant way, and instead were hypothesized to use primarily voiced laugh sounds to express positive internal states.

Lastly, research on the social-communication abilities of children with autism supported an additional hypothesis that joint attention would mediate the relation between autistic symptoms and laugh acoustics in this population (see Figure 1). Several researchers contend that joint-attention deficits represent a core feature of the disorder (Capps et al., 1993; Kasari et al., 1990; McEvoy, Rogers & Pennington, 1993; Mundy, 1995; Mundy & Sigman, 1989; Mundy, Sigman, & Kasari, 1993; Sigman, Kasari, Kwon, & Yirmiya, 1992). Joint attention has been shown to distinguish young children with autism from typically developing controls with upwards of 80% accuracy (Mundy, 1995; Mundy & Crowson, 1997). Whereas children with autism have difficulty with the development of joint-attention skills, they exhibit only moderate difficulty with the development of turn-taking skills, and even less difficulty with the development of nonverbal requesting skills (Adamson & McArthur, 1995; Baron-Cohen, 1989; Curcio, 1978; Loveland & Landry, 1986; McEvoy et al., 1993; Mundy, 1995; Mundy et al., 1986; Mundy, Sigman, & Kasari, 1994; Stone, Ousley, Yoder, Hogan, & Hepburn, 1997; Wetherby, Yonclas, & Bryan, 1989). Furthermore, factor analytic studies of measures typically used to diagnose autism, such as the ADI-R and ADOS-G, indicate that joint attention may represent a unique factor that characterizes the disorder (Robertson et al., 1999; Tanguay, Robertson, & Derrick, 1998).

Figure 1. Joint Attention as a Mediator

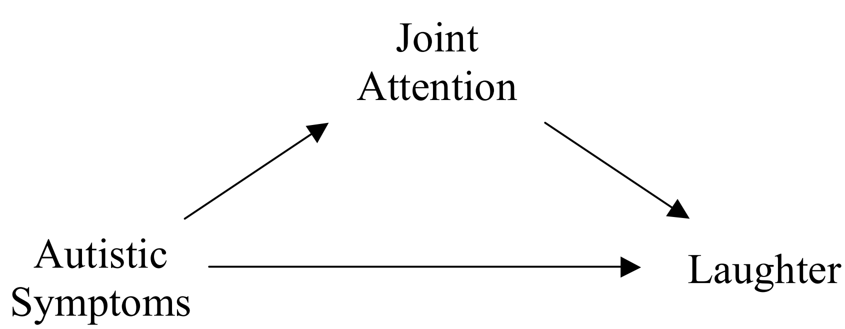

Figure 1. Joint attention was hypothesized to mediate the relation between autistic symptoms and both laugh production and laugh acoustics.

If joint-attention deficits represent a core feature of autism, it is likely that joint attention influences affective expressions such as laughter. Specifically, it was hypothesized that an increase in autistic symptoms would predict an decrease in joint attention skill, and subsequently an increase in the range of laugh sounds produced by children with autism. If these correlations existed, it was predicted that the correlation between autistic symptoms and laughter would approach zero. In order to develop a cogent mediational hypothesis, however, one must demonstrate that a relation exists, or is likely to exist, between joint attention and each observed variable. Accordingly, prior work has demonstrated that such a link exists along the first path of the proposed mediational model between joint attention and symptoms of autism. Measures of joint attention may be an especially valid index of the social symptoms of autism (Kasari, Sigman, Mundy, & Yirmiya, 1990; Mundy, 1995; Mundy, Kasari, & Sigman, 1992; Mundy & Crowson, 1997). Studies of children with autism show that an increase in their ability to engage in joint-attention behaviors predicts both a higher IQ and a decrease in the severity of core symptoms such as relating to others and the ability to use language (Mundy, Sigman, & Kasari, 1994). In their study of home videotapes of children with and without autism, Osterling and Dawson (1994) found a negative correlation between joint-attention behaviors and autistic symptoms. Furthermore, joint-attention disturbance has been related to cerebellar abnormalities (Courchesne, 1989), predictive and concurrent language development (Loveland & Landry, 1986; Mundy et al., 1986; Mundy, Sigman, & Kasari, 1990), and the early identification of autism (Mundy & Crowson, 1997; Stone et al., 1999).

The relation between joint attention and symptoms of autism thus demonstrates that measures of autistic behavior should correlate with joint attention. The one notable study directly comparing joint attention to Childhood Autism Rating Scale (CARS;

Schopler, Reichler, & Renner, 1988) scores (the measure employed in the current study) showed a significant association between CARS social symptoms and joint-attention skills (Stella, 2002). This study found that joint attention was negatively correlated with symptoms of autism as measured by the CARS. Though minor differences exist between Stella's (2002) investigation and the current study, these data strongly suggest that joint attention is correlated with autistic symptom presentation.

The second path of the mediational model between joint attention and acoustic outcomes is supported by research showing a relation between joint attention and positive affect. As mentioned previously, positive affect may distinguish joint attention from all other forms of nonverbal communication (Bruner, 1981; Mundy, 1995). In typically developing children, joint attention is reliably linked with the expression of positive affect (Adamson & Bakeman, 1985; Kasari et al., 1990; Mundy, 1995; Mundy, Kasari, & Sigman, 1992). Similarly, children with autism exhibit a relation between joint attention and expressions of positive affect. Specifically, children with autism produce less overall positive affect than controls during joint-attention interactions (Kasari et al., 1990; Paparella, 2000). This relation is more consistent than the relation between positive affect and other forms of nonverbal communication such as requesting bids (Mundy et al., 1992; Mundy, 1995). Positive affect is hypothesized to be critical to joint attention because of its ability to facilitate shared interactions. Conversely, research shows that effective joint-attention training in children with autism results in an increase in their expressions of positive affect (Whalen, 2001).

The relation between joint attention and positive affect is likely to encompass such expressions as laughter. Unfortunately, however, laughter has never been studied as an isolated component of affective expression in this population. If children with autism exhibit deficits on tasks that require them to share their experience with others, it follows that they will exhibit commensurate deficits in the breadth of expressions that they use to negotiate these interactions. More specifically, the diversity of laugh sounds available to these children will most likely be limited in relation to their joint-attention skills. In the current study, joint attention was hypothesized to influence acoustic outcomes. The mechanism by which this occurs, however, is ultimately thought to be driven by autistic symptom presentation.

If autistic symptoms are related to laugh acoustics, it is reasonable to conclude that joint attention mediates the relation between these variables. It is unlikely, however, that joint attention acts as a complete mediator between autistic symptoms and laugh acoustics. Instead, it was hypothesized that joint attention would partially mediate the relation between these variables. Given the other social deficits of children with autism, it was hypothesized that other unmeasured variables would most likely also contribute to a decrease in the variety of laugh sounds produced by these children. Other factors that may influence the acoustics of laugh production include, for example, deficits in "theory of mind" (Baron-Cohen et al., 1985), deficits in the attention allocated to emotional stimuli (e.g. Beversdorf et al., 1998), or even possible impairments in the auditory cortex of children with autism (Bruneau, Roux, Adrien, Barthélémy, 1999; Foxton et al., 2003; Gomot et al., 2002).

Matching considerations

Due to the unique pattern of deficits observed in children with autism, considerable caution was exercised when selecting an appropriate comparison group to examine the aforementioned hypotheses. This caution is necessary due to the unique IQ profile of autistic individuals (Hobson, 1991; Lincoln, Allen, & Kilman, 1995; Narita & Koga, 1987; Prior, 1979). Not only do approximately 75% of children with autism score within the mentally retarded range of intellectual functioning (DeMyer, 1979; Rutter, 1970), but they also typically exhibit uneven IQ scores across domains. The nonverbal IQ scores of children with autism tend to be significantly higher than their verbal IQ scores. This IQ profile necessitates special consideration in order to ensure that differences between groups are due to autism, and not due to general mental retardation. Similar to typically developing children, children with autism make progress on all types of nonverbal social-communication as their mental capacities expand (Mundy, Sigman, & Kasari, 1994). Therefore, it is difficult to determine which factors comparison participants should be matched on: CA, nVIQ, and/or VIQ.

There are two primary arguments cited in the literature for matching children with autism with typically developing comparison participants on measures of nVIQ. First, studies of emotion perception often require the use of nonverbal social-communication skills as much as they do linguistic skills. For example, a child with autism who is required to match labels of emotional states with videotaped vignettes (eg. Hobson et al., 1988a) arguably must employ a significant amount of nonverbal processing. In these studies children must evaluate nonverbal gestures and facial expressions of the portrayed characters. Similarly, recognizing personal identity and labeling emotional expressions in occluded and inverted faces (Hobson et al., 1988b; Langdell, 1978) requires nonverbal skill. These studies conclude that children with autism may rely largely on nonverbal cues to influence decision-making. Studies on the expression of emotion may also draw on nonverbal abilities. This is likely because children with autism may rely more on nonverbal processing in order to compensate for deficits in verbal performance. In addition, measures of emotional expression in children with autism have focused almost solely on nonverbal behaviors. For example, the majority of studies on emotion expression code facial expression as the dependent measure (Capps et al., 1993; Dawson et al., 1990; Kasari et al., 1990; MacDonald et al., 1989; Snow et al., 1987; Yirmiya et al., 1989). Facial expression is investigated independent of linguistic ability in these studies. If children with autism rely largely on nonverbal means of emotion expression, it may be reasonable to match comparison subjects on their ability level in this domain.

Second, since children with autism typically have limited verbal abilities, typically developing participants who are matched on measures of VIQ are usually quite young. This can be problematic because it is possible that the skills being evaluated may not be fully developed in the comparison group. This problem can be somewhat ameliorated when typically developing comparison participants are matched with autistic individuals on the basis of nVIQ. This pairing is more likely to result in matches where participants with autism and nonautistic comparison participants are closer in CA.

Unfortunately, matching autistic individuals with nonautistic participants on measures of nVIQ has serious limitations. The primary problem with this approach is that children with autism typically function at a lower level on verbal tasks and several related areas than typically developing children who match their nVIQ. Currently the relation between cognitive and emotional development is unclear. It is likely, however, that emotion-perception and -expression abilities draw from both verbal and nonverbal skills in all children. Due to the lower overall performance of children matched on measures of VIQ, matching on VIQ is therefore a more stringent test of emotional abilities. This is the case because children with autism who are matched on VIQ are not expected to function on any level that is lower than their nonautistic counterpart.

In recent years, the majority of emotion-perception and -expression studies of children with autism have used measures of VIQ to match autistic individuals with comparison participants (eg., Beversdorf et al. 1998; Buitelaar, & van der Wees, 1997; Celani et al., 1999; Davies, Bishop, Manstead, & Tantam, 1994). This shift in methodology is largely due to a series of studies which indicate that group differences on emotion-perception tasks are more likely when subjects are matched on nVIQ. In one study, Ozonoff et al. (1990) found group differences in emotion-perception ability when autistic participants were matched on nVIQ with typically developing participants. In contrast, no differences between groups were found on the same task when participants were matched on VIQ. Several additional studies show that there are no differences on simple emotion labeling tasks between children with autism and nonautistic participants when they are matched on VIQ (Hobson et al., 1988a, 1988b; Jennings, 1973; Prior et al., 1990; Ozonoff et al., 1990, Study 1; Weeks & Hobson, 1987). Conversely, most studies of emotion perception that use a typically developing comparison group matched on nVIQ obtain significant differences between groups (Braverman, Fein, Lucci, & Waterhouse, 1989; Hobson, 1986a, 1986b; MacDonald et al., 1989; Ozonoff et al., 1990, Study 2; Prior et al., 1990; Tantam, Monaghan, Nicholson, & Stirling, 1989). Taken together, these results support the conclusion that matching subjects on VIQ is a more stringent test of emotional abilities.

CHAPTER II

METHOD

Participants

Participants consisted of 16 eight to ten-year-old children (*M* = 9.0, *SD* = .78; 14 male) diagnosed with autism. One participant was excluded from analysis because he did not produce any laughter. The remaining 15 (*M PPVT-III IQ* = 78.6, *SD* = 17.9; *M* Verbal Mental Age = 6.8 years-old, *SD* = 2.1 years) eight to ten-year-olds (*M* = 9.1 years, *SD* = .77 years; 13 male) were individually matched with children from two separate comparison groups. Preliminary analyses revealed no significant differences in mean values between male and female participants, thus this distinction was not considered in further analyses. Data on participants with autism were collected through an ongoing longitudinal study (Stone et al., 1999). Participants in this cohort were previously tested at the ages of two, three, and four. The majority of the participants with autism were recruited in and around the greater Nashville, TN, area. In order to participate in the study, children must have received a diagnosis of autism, as measured by the Autism Diagnostic Observation Schedule-Generic (ADOS-G; Lord et al., 2000). Additional diagnostic measures were part of the assessment battery used in the larger study. For inclusion in the present study, however, only the ADOS-G was used to diagnose children because of its validity relative to other measures (Lord et al., 1989, 2000). During the administration of the ADOS-G, the examiner was blind to the previous diagnostic status of the child. Children with autism were included in the study if they were tested with modules two or three of the ADOS-G. When the ADOS-G was administered, the appropriate module was selected based on the child's language ability. Participants with the highest language ability were tested with module three, whereas participants were tested with module one if they exhibited little or no language use. It should be noted that three of the five participants tested with module one (who were consequently excluded from analyses) produced no laughter. Mean CARS score for participants with autism was 29.1 (*SD* = 5.2).

Several factors were taken into consideration when selecting appropriate comparison participants for the children with autism. In summary, participants with autism were individually matched with participants from two comparison groups in order to provide the most rigorous test of emotion-expression abilities in the current study. To negate cohort effects, participants with autism were matched with one comparison group based on CA. Matching these same participants with autism with another comparison group, this time on verbal ability, ensured the most stringent comparison of mental ability level between the two groups. In further support of the data mentioned earlier to match one group of comparison participants on a measure of verbal ability, some studies demonstrate that measures of receptive-language vocabulary correlate with performance on emotion-perception tasks in children with autism (Hobson et al., 1988b; Prior et al., 1990). Although these studies do not evaluate emotional expression, the correlations indicate that some emotional abilities may be most accurately predicted by receptive-language vocabulary.

The first comparison group consisted of 15 typically developing children. These children were individually matched with autistic participants on the variables of chronological age (CA) and sex (within 6 months of participant with autism; *M* CA = 9.0 years, *SD* = .7 years). Participants from the second comparison group also consisted of 15 typically developing children. These participants were individually matched with autistic individuals on the variables of sex and verbal mental age (mental age equivalent within 6 months of participant with autism; *M* CA = 5.7 years-old, *SD* = 1.8 years; *M PPVT-III IQ* = 78.6, *SD* = 17.9; *M* Verbal Mental Age = 6.9 years-old, *SD* = 2.1 years). Verbal mental age of children with autism was calculated from their score on the Peabody Picture Vocabulary Test Third Edition (PPVT-III; Dunn & Dunn, 1997). One participant with autism was not tested with the PPVT-III due to an inability to complete the task demands. For this child, mental age equivalent was calculated based on his full-scale IQ score from the Kaufman Assessment Battery for Children (K-ABC; Kaufman & Kaufman, 1983). Comparison participants were recruited through afterschool daycare programs in the greater Nashville Metropolitan area. With the cooperation of the daycare supervisor, potential participants were given a recruitment letter through their aftercare classes. Upon completion of the testing session, comparison participants were compensated for their time with small toys and prizes.

Procedure for children diagnosed with autism

Upon arrival at Vanderbilt University's Child Development Clinic, participants were greeted by one of the experimenters and brought to the testing room. Written informed consent was obtained from a parent of each child, and written assent was obtained from the child whenever possible. Next, children completed a battery of tests. The measures used in this study were administered as part of a more comprehensive assessment that participants received as part of their involvement in the larger longitudinal study (Stone et al., 1999). The measures relevant to this study are described below.

Language/verbal ability evaluation

Language ability of participants with autism was evaluated with the PPVT-III, a measure of receptive-language vocabulary. For this test, children are asked to point to a picture that matches a word presented orally by the examiner. A sample test item might be "Show me the picture of a *bird*." The PPVT-III is untimed and requires no reading ability. Testing words are selected to include a relatively balanced number of gerunds, nouns, and modifiers that span 19 content categories. Each item on the PPVT-III contains four pictures. As items are presented, the level of difficulty increases. The PPVT-III has good test-retest reliability for children over seven years-old (correlation coefficient = .88; Dunn & Dunn, 1997) and is found to exhibit concurrent validity with the verbal section of the Weschler Intelligence Scale for Children III (correlation coefficient = .88; Hodapp & Gerken, 1999). The PPVT-III takes approximately 15 min to administer.

Diagnostic evaluation

Three assessments were conducted to diagnose children with autism; the ADOS-G, CARS, and Autism Diagnostic Interview -Revised (ADI-R; LeCouteur et al., 1989; Lord, Rutter, & Le-Couteur, 1994). For inclusion in this study, however, solely the ADOS-G was used to diagnose children because of its validity relative to other measures (Lord et al., 1989, 2000). The ADOS-G is a standardized, interactive, diagnostic assessment that consists of four distinct modules. The first three of these modules are appropriate for testing children. Each module is administered in accordance with the developmental level of the child. Items in the ADOS-G are comprised of a series of play-like social "presses," in which the examiner rates the child along 28 dimensions. These dimensions include social communication, language ability, stereotyped behaviors, and emotional ability. Item scores on the ADOS-G range from 0, indicating no abnormal behavior, to 3, indicating severely abnormal behavior or deficient functioning. The ADOS-G has strong interrater and test-retest reliability (correlation coefficients are .92 and .82 respectively; Lord et al., 2000). The ADOS-G takes approximately 1 hour to administer.

Laugh assessment

Children with autism were audio- and videotaped during a laugh-assessment sequence (LAS). The LAS consists of a 10-min period designed explicitly to elicit laughter. The LAS procedure is not strictly standardized as there is considerable inter-individual variability associated with the appreciation of humorous stimuli (McGhee, 1979). Though a standardized procedure is typically advantageous for examining group differences, initial data indicated that there were insufficient instances of laughter when the examiner lacked the flexibility to induce spontaneous laughter. As data from the LAS was used to examine differences in laugh acoustics but not rate of production between children with autism and nonautistic participants, minor procedural differences were not critical for this measure. Nevertheless, in an effort to control for variance associated with procedural differences, participants were exposed to similar laugh-eliciting stimuli with the provision that the task was terminated after approximately 1-2 min if it did not successfully elicit laughter.

Laugh-eliciting stimuli for the LAS consist of the following series of highly interactive procedures: a “surprise” tickle game, popping bubbles, playing with a balloon, and knocking over a tower of blocks. For the surprise tickle game, the child is asked to count to three and then raise his/her arms. When the child raises his/her arms, the examiner gently tickles the child under his/her arms in a playful manner. This procedure is repeated several times. Following the tickling game, the child is asked to stand up. The experimenter then blows bubbles and asks the child to “pop as many as you can before they hit the ground!” After this procedure, the experimenter instructs the child to go to the side of the room and wait until the experimenter counts to three before rushing over to pop the bubbles.

For the balloon procedure, the experimenter blows up a balloon and occasionally releases air, creating a high-pitched sound. Once the balloon is inflated, the experimenter asks the child to catch it when it is released. After several repetitions of this game, the experimenter ties off the balloon and hits it back and forth with the child, stipulating that it must not touch the ground. Finally, if time permits the experimenter builds a tower with some colorful wooden blocks. After the tower is constructed “as high as it can go,” the child is asked to knock it down. Following this procedure the child is asked to help the experimenter build a tall tower and then knock it down.

Measurement of joint attention

Children with autism were evaluated on their ability to initiate and respond to joint attention with an examiner. Joint attention was evaluated from videotapes of the ADOS-G. Two tasks from the ADOS-G were examined: "Make-Believe Play," and "Joint Interactive Play." In the ADOS-G, the purpose of Make-Believe Play is to observe the child's creative or imaginative use of small play objects during an unstructured task. To assess the child's abilities, a number of standardized toys are placed in front of the participant, and the child is asked "Could you play with these now for awhile?" If the child is unresponsive or appears uncomfortable after a few moments, the examiner models a short play sequence with the toys. Throughout the assessment, the examiner occasionally asks the child what he or she is playing with, while being careful not to direct the child's play. Following the Make-Believe Play task, the examiner initiates the Joint-Interactive Play phase by saying "Can I play too?" or "Now I'd like to join you, if I may." The same objects used during the Make-Believe Play task were used during the Joint-Interactive Play task. Of the ADOS-G items, these tasks are most similar to those used during the standardized assessment of joint attention and requesting behaviors (eg. Kasari et al., 1990; McEvoy et al., 1993; Mundy & Gomes, 1997; Mundy, Kasari, Sigman, & Ruskin, 1995; Mundy, Sigman, Kasari, & Yirmiya, 1988).

Joint attention was coded during both the Make-Believe Play and Joint Interactive Play tasks. Joint-attention behaviors were coded according to criteria established in the Early Social Communication Scales (ESCS; Seibert et al., 1982). The ESCS is the most commonly used instrument to measure joint attention and requesting behaviors. Coding criteria were adapted in collaboration with P. Mundy in order to examine interactions specific to the ADOS-G (personal communication, June 5, 2002). Rate of joint-attention behaviors were summed from both tasks to create a composite score for each child. Joint-attention behaviors were identified based upon their perceived function. The function of these behaviors was to “share attention with the interactive partner or to monitor the partner's attention…. their function seems to be more social sharing or declarative in nature” (Mundy, Hogan, & Doehring, 1996). The following five behaviors were coded according to these criteria: Eye Contact, Alternating (referencing), Pointing, Showing, and Following Proximal Point/Touch (see Appendix A). According to the specific coding instructions, joint-attention behaviors could not co-occur, and were not coded for their duration. Pilot work on the ESCS indicates that coding the duration of joint-attention behaviors significantly reduces interrater reliability of the measure (P. Mundy, personal communication, May 8, 2002).

Joint attention was coded from videotapes of the ADOS-G by undergraduate research assistants at Vanderbilt University. Research assistants were trained to code joint attention by reading the ESCS coding manual, and through supervised coding of at least three practice tapes. A second rater coded 50% of all taped interactions to ensure that a high interrater reliability was achieved ($k > .80$). Interrater reliability is usually high for ESCS coding. Generalizability coefficients (*G*) typically range from .81 to 1.0 on the coding of response to joint attention (Mundy et al., 1995; Mundy et al., 1994), and between .80 to .99 on initiating joint attention (McEvoy et al., 1993; Mundy et al., 1992; Mundy et al., 1995). A G-coefficient above .50 indicates adequate interrater reliability (Mitchell, 1979).

Modified procedure for comparison participants

All comparison participants underwent the LAS procedure as well as the Make-Believe Play and Joint-Interactive Play tasks from the ADOS-G. Those comparison participants who were matched according to their VIQ score were tested with the PPVT-III. Comparison participants were not assessed with the diagnostic and cognitive instruments used specifically for the evaluation of participants with autism. The stimuli used for the LAS items were matched in duration and type of activity with those used for participants with autism. Duration of the Make-Believe Play and Joint-Interactive Play tasks from the ADOS-G were also matched with those of the participants with autism. The sex of the examiner was matched with the sex of the original examiner who tested the child with autism. This matching controlled for possible confounds associated with gender dynamics between the experimenter and the child. Nonautistic comparison participants were tested in designated classrooms within the Metropolitan Nashville school system. Testing of each comparison participant took approximately 30 min.

Acoustic analysis

Laugh production for both children with autism and nonautistic participants was recorded with an Audio-Technica 1400 series lapel-mounted UHF wireless cardiod microphone system (Stow, OH). If the child refused to wear the lapel-mounted microphone, laugh production was recorded with a Shure Dynamic Low Z microphone, model SM48. The audio signal was amplified by 10 dB with an Applied Research Technology 254 preamplifier (Rochester, NY) and recorded via a Panasonic SV-4100 digital audio-tape (DAT) recorder (Los Angeles, CA) using BASF digital audio-tapes

(Mount Olive, NJ). For comparison participants, the audio signal was recorded via a Superscope PSD300 CD Recording System (Aurora, IL) using 80-min CD-R compact discs. The audio equipment used to record sounds from comparison participants was slightly different than that used for participants with autism due to the recent acquisition of the aforementioned recording hardware. To resolve any disagreements regarding the identification of laugh sounds, the child was also videotaped with a Magnavox EasyCam VHS video recorder (Greenview, TN) during the LAS. Laugh sounds were digitized at 11.025 kHz using Datman, a native Silicon Graphics audio-application program. Acoustic analysis was performed using ESPS/waves+ 5.3 digital signal processing software (Entropics; Washington, DC) and interactive script routines. Files were normalized using multiplicative scaling to a common maximum-amplitude value prior to acoustic analysis. Both unix- and linux-based computer systems were used to analyze laugh sounds.

Laugh sounds were coded according to criteria established by Bachorowski et al. (2001). Laughs were coded at both the “bout” and “call” level. Laugh bouts are episodes of laughter typically produced during one exhalation, which are separated by more than 1-s of silence or speech sounds. Laugh calls are separable bursts of sound contained within the laugh bout (see Figure 2). Laugh calls were coded according to the presence or absence of quasi-periodic vocal-fold vibrations (voiced or unvoiced, respectively). Additional coding included an indication of whether the laugh sound contained acoustic nonlinearities due to non-normative vocal-fold vibrations. Bouts were coded according to the predominant features of the embedded calls. Both laugh bouts and laugh calls were coded as unvoiced if there was an absence of quasi-periodic vocal-fold vibration in 50%

or more of the sound. In the current study laughs were not coded as “mixed,” a designation used to describe near equal amounts of voiced and unvoiced sound in prior research (Bachorowski et al., 2001). The exclusion of mixed laughter resulted in a more conservative estimate of unvoiced laughter present in the laugh repertoire of each child. Interrater reliability is typically high for the coding of laugh sounds using the criteria established by Bachorowski et al. (2001, 2004), with kappa coefficient values being about .91.

Figure 2. Segmenting of Bouts and Calls

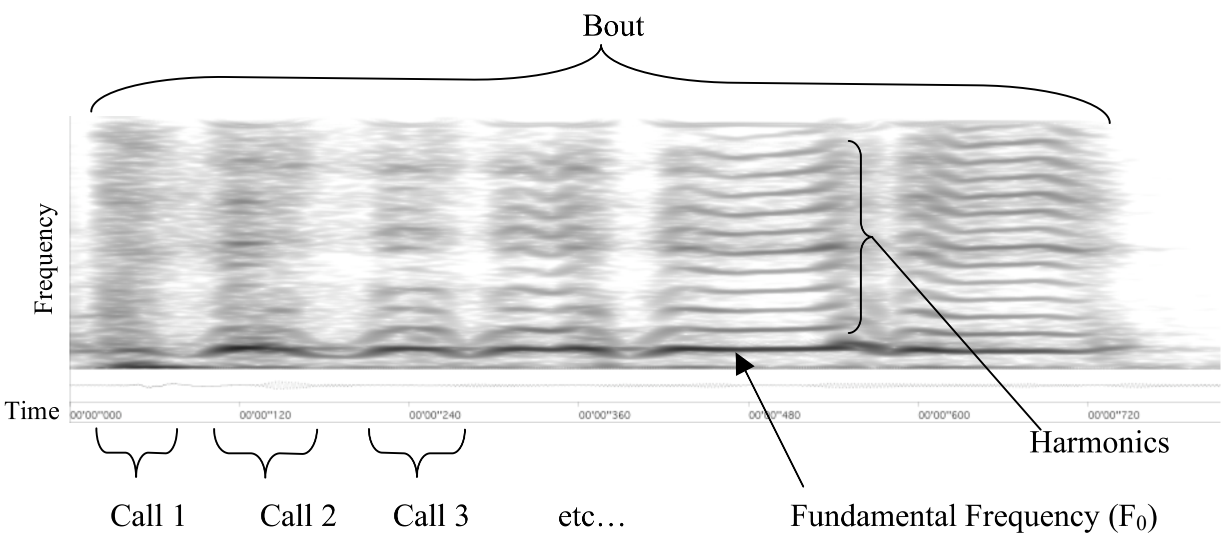

Figure 2. The spectogram above is a visual representation of sound (frequency vs. time) that is used to determine the amount of acoustic energy at different frequencies. The spectrogram allows a researcher to code laughter according to its acoustic features. The laugh presented above would be coded as “voiced” at both the bout and call levels. This label indicates that the laugh contains primarily periodic vocal fold vibrations, and thus contains a fundamental frequency (F_0). Laugh bouts are typically characterized by an initial inhalation and they typically conclude with an exhale. Laugh bouts are separated by one second of silence or speech sounds. Laugh calls are individual bursts of sound within the laugh bout.

Additional measures consisted of F_0, laugh-bout duration, and number of calls per bout. F_0 was extracted from voiced calls, and the mean, variability, and range of F_0 was measured. Bout durations were calculated according to the start and stop times of individual laugh episodes. Both bout durations and variability of bout durations were averaged for each participant and compared between groups. To examine laugh type, the laugh types coded for each participant were converted into relative proportions of their total laugh repertoire and then used in comparisons between participant groups. Proportions were used to control for differences in base rates of laughter between participants.

Statistical analyses

A three-level repeated-measures ANOVA was utilized to evaluate group effects. Planned contrasts were conducted between the group with autism and each comparison group. Fisher's least significantly different (LSD) test was conducted for the unplanned contrasts between the typically developing comparison groups in effort order to control for the large number of comparisons being examined and reduce type I error. At the bout level, laughs were compared according to the following criteria: Proportion of voicing, occurrence of laughter during speech, occurrence of nonlinearities, and laugh type (whether the bout was predominantly tonal, grunt-like, or snort-like). Measures of voicing and laugh type were calculated from the relative proportions of each mutually exclusive category of coding (see Figure 3). At the call level, laughs were compared according to the presence or absence of voicing.

Figure 3. Calculation of Relative Proportions for Voicing and Laugh Type

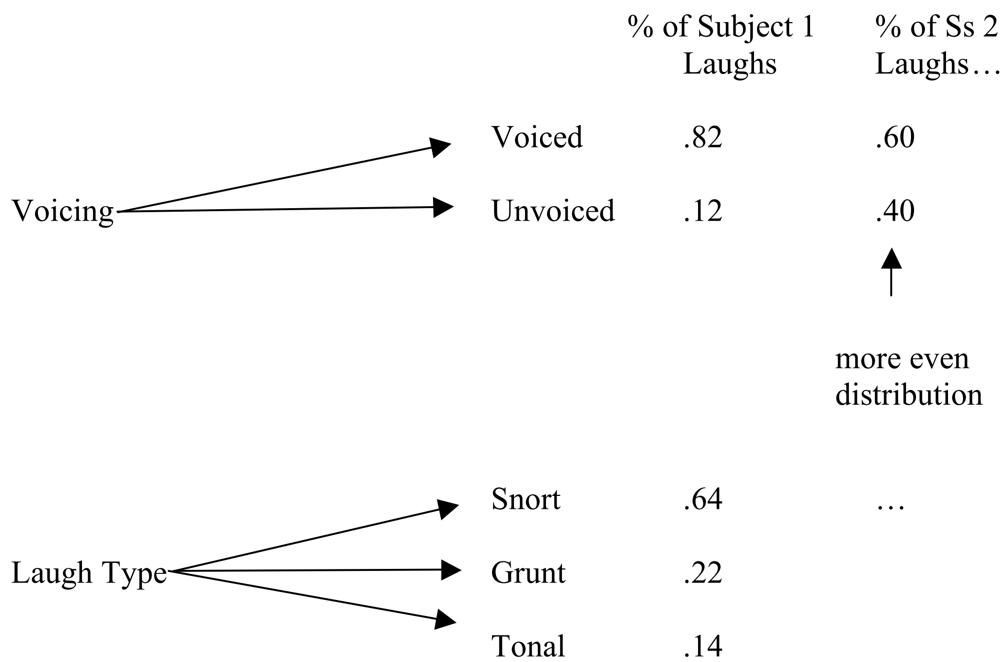

Figure 3. To examine voicing, laughs were coded mutually exclusively as either voiced or unvoiced. This procedure was also used to determine the amount of distinct laugh types produced.

A series of regression analyses (Baron & Kenny, 1986) were conducted to evaluate whether joint attention mediated autistic symptoms and acoustic outcomes. The first regression equation tested the relation between autistic symptoms as measured by the CARS and the dependent variables (i.e., voiced bouts/calls, laugh type, laugh-bout duration, F_0 mean, F_0 change, F_0 variability, and the presence of laughter during speech). The second equation tested the relation between CARS scores and the proposed mediator, joint attention. It should be noted that the first two equations were essentially partial correlations, with time entered as a covariate for joint attention due to the matched duration of sessions between pairs. If the first two equations both led to statistically significant outcomes, a third regression was planned to test for mediation by using both CARS score and joint attention as simultaneous predictors of acoustic outcomes. Correlations between joint attention and each acoustic measure were also examined for both comparison groups. These correlations were conducted to provide an exploratory test of joint attention as a mediator of autistic symptoms and laugh acoustics for each comparison group.

CHAPTER III

RESULTS

Matched-pair t-tests were conducted to evaluate experimenter effects. Participants from each testing group were separated according to the experimenter who conducted the testing. This procedure was used to rule out differences in laugh acoustics resulting from the sex or identity of the experimenter. No group differences were found, therefore individual examiners will not be considered in further analyses. Interrater reliability was calculated for 50% of all laugh bouts and calls coded, and resulted in a kappa value of .95. Interrater reliability was also calculated for 50% of the videotaped joint-attention interactions and resulted in a kappa value of .85.

At the bout level there was a significant main effect of voicing between children with autism and both comparison groups $F(2,13) = 20.28$, $p < .001$, $\eta^2 = .59$. Planned contrasts revealed that children with autism exhibited significantly more voiced laughter in their laugh bouts than children matched on either VIQ $F(1,14) = 22.74$, $p < .001$, $\eta^2 = .62$, or CA $F(1,14) = 47.96$, $p < .001$, $\eta^2 = .77$. There were no significant differences in voicing between the two comparison groups. On average, 97% of the laugh bouts produced by children with autism were voiced. In contrast, 63% of the laugh bouts produced children matched on VIQ and 52% of those produced by children matched on CA were voiced (see Figure 4). Of the group with autism, only 47% of the children produced any laugh bouts characterized as unvoiced.

Figure 4. Percentage of Voicing in Bouts for Each Group

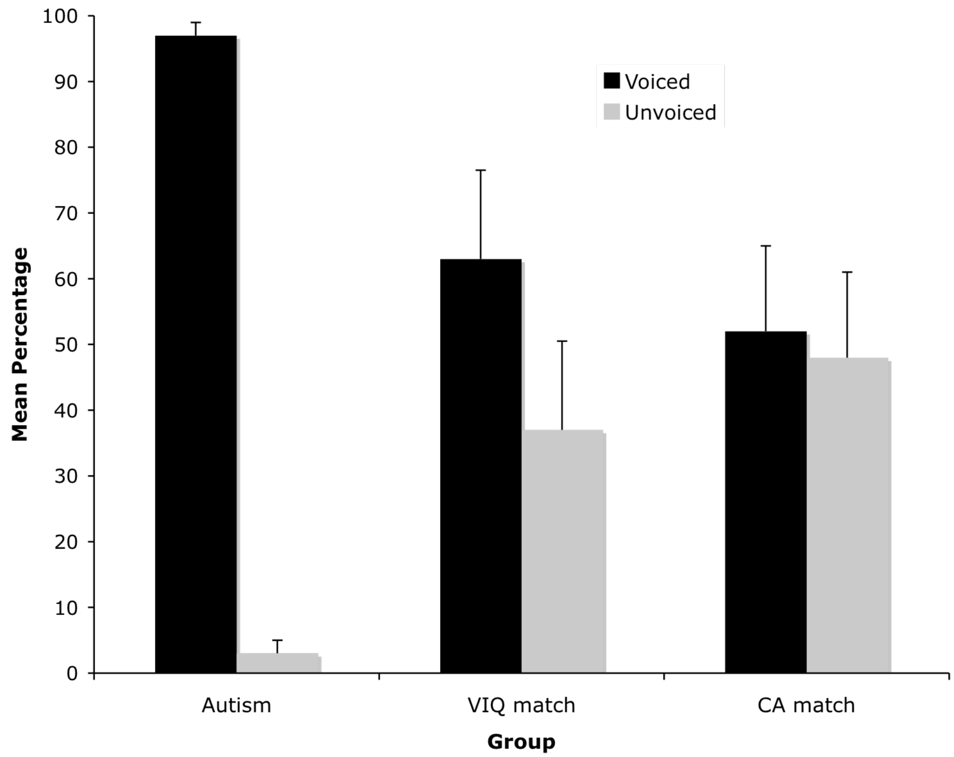

Figure 4. Children with autism produced a significantly higher proportion of voiced laugh bouts than either comparison group. Conversely, children with autism produced a significantly lower proportion of unvoiced laugh bouts than either comparison group. There were no significant differences in voiced or unvoiced laugh-bout proportions between comparison groups, though participants matched on chronological age produced a more even distribution of voiced and unvoiced laugh bouts.

This pattern of effects was also observed at the call level, with statistical analyses showing a main effect of voicing between groups $F(2,13) = 13.72$, $p < .001$, $\eta^2 = .50$. Planned contrasts showed that children with autism exhibited significantly more voicing in their calls compared with children matched on VIQ $F(1,14) = 14.96$, $p = .002$, $\eta^2 = .52$, or children matched on CA $F(1,14) = .67$, $p < .001$, $\eta^2 = .52$. There were no significant differences between the two comparison groups at the call level. Children with autism produced an average of 94% voiced calls, whereas the calls of nonautistic comparison participants matched on VIQ were 74% voiced and the calls of children matched on CA were 67% voiced (see Figure 5).

Figure 5. Percentage of Voicing in Calls for Each Group

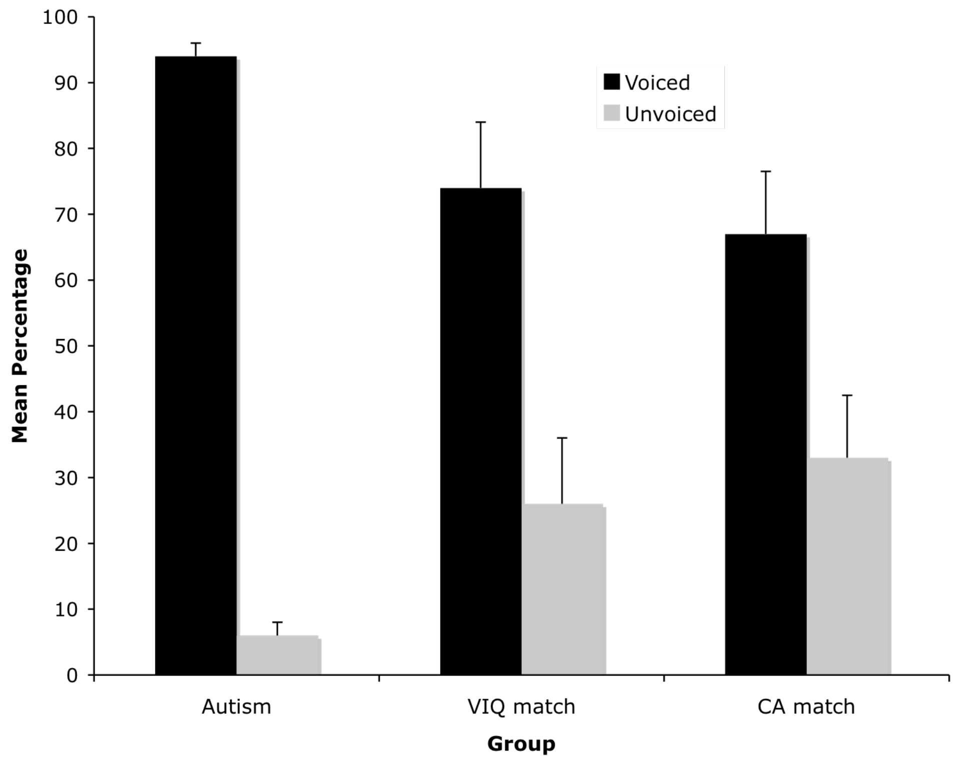

Figure 5. Similar to laugh-bout outcomes, children with autism produced a significantly higher proportion of voiced laugh calls and a significantly lower proportion of unvoiced laugh calls relative to either comparison group. There were no significant differences in voiced or unvoiced laugh-bout proportions between comparison groups. Interestingly, there were more voiced calls and fewer unvoiced calls in the comparison groups at the call level as compared with the bout-level outcomes.

Children with autism exhibited significantly less variability in the types of laughs they produced relative to children matched on VIQ or CA. Whereas there was no main effect for the amount of snorts produced by each group ($\eta^2 = .14$), there was a main effect for both grunts $F(2,13) = 14.72$, $p < .001$, $\eta^2 = .51$ and tonal laughs $F(2,13) = 14.87$, $p < .001$, $\eta^2 = .52$. It is unlikely that the number of snorts produced between groups would differ statistically due to the small sample size of snorts. Whereas the laugh repertoire of participants with autism consisted of an average of less than 1% snorts, participants matched on VIQ produced only 7% and participants matched on CA produced an average of 4% snorts. Planned contrasts between groups showed that children with autism exhibited significantly fewer grunts in their laugh bouts than children matched on VIQ $F(1,14) = 29.72$, $p < .001$, $\eta^2 = .68$, or children matched on CA $F(1,14) = 27.13$, $p < .001$, $\eta^2 = .66$. Children with autism produced significantly more tonal laughs than typically developing participants matched on VIQ $F(1,14) = 16.33$, $p = .001$, $\eta^2 = .54$ and CA $F(1,14) = 32.95$, $p < .001$, $\eta^2 = .70$. There were no significant differences between comparison groups on measures of laugh type. Children with autism produced an average of 98% tonal laugh bouts, whereas the bouts of children matched on VIQ were 69% tonal and the laugh bouts of children matched on CA were 58% tonal (see Figure 6).

Figure 6. Percentage of Laugh Types for Each Group

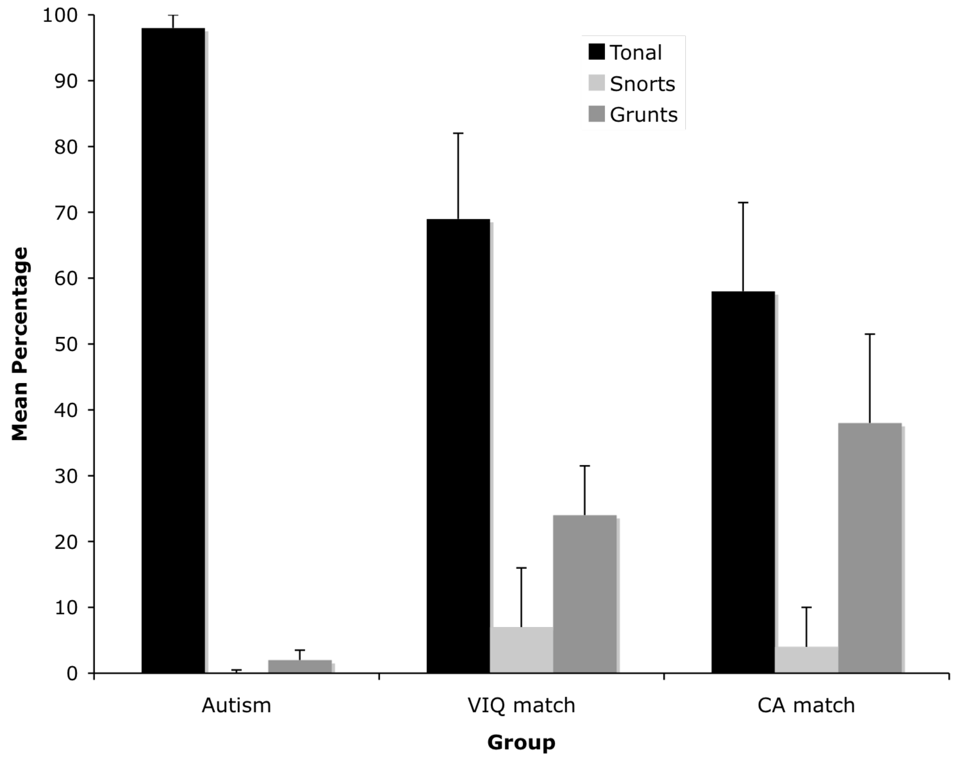

Figure 6. Children with autism produced a significantly higher proportion of tonal laughs, and a significantly lower proportion of grunts than either comparison group. Few snorts were produced by any group, with no statistical differences between groups on this measure. There were also no significant differences in tonal or grunt proportions between comparison groups.

Laugh acoustics

A total of 1280 laugh bouts and 7556 calls were analyzed across groups. Of these laughs, 85 out of 6732 voiced laugh calls were not analyzed due to overlapping background noise. Duration of laugh bouts and number of calls per bout were averaged for each participant and evaluated between each group. F_0 analyses were conducted on all voiced calls to further examine differences in the acoustic features of laughter between the three groups. Mean F_0 and measures of F_0 variability were averaged for each participant to provide stable F_0 estimates. Range of F_0 was calculated by subtracting the minimum F_0 value from the maximum F_0 value for each call.

Children with autism produced a mean of 26 laugh bouts. Typically developing participants matched on CA produced a mean of 25 laugh bouts, whereas participants matched on VIQ produced a mean of 35. Further analyses were not conducted to examine differences in rate of laugh production due to a lack of appropriate controls to adequately examine group rates.

There were no significant main effects for laugh-bout duration $\eta^2 = .02$ or number of calls per bout $\eta^2 = .07$ between the three groups. Similarly, no significant main effect was found for mean F_0 values between children with autism and either comparison group $\eta^2 = .02$. There were no significant differences in the variability ($\eta^2 = .005$) or range ($\eta^2 = .005$) of F_0 between children with autism and either comparison group. Lastly, At the bout level, there were no significant differences between children with autism and either comparison group in the amount of laughter produced during speech $\eta^2 = .02$. Acoustic nonlinearities resulting from non-normative vocal fold vibration occurred in less than 1% of all bouts; therefore nonlinearities were not further characterized.

Joint attention

Initial correlations (see Appendix B) revealed that the data did not conform to a mediational model of joint attention (see Table 1 for a summary of joint attention results).

Table 1.

Joint Attention Outcomes

Group	Mean JA events	SD	Range
Autism	14.3	6.7	6-30
VIQ Match	19.0	9.7	7-39
CA Match	14.8	11.9	2-44

The first test examined the relation between CARS score (M = 29.13, SD = 5.17, range = 22-41) and each acoustic measurement (i.e., voiced bouts/calls, laugh type, laugh-bout duration, F_0 mean, F_0 change, F_0 variability, and the presence of laughter during speech). Correlations between CARS score and acoustic outcomes were all nonsignificant (see Appendix B). The second test demonstrated that CARS score was not significantly correlated with joint attention ($r = -.21$, $p = .45$). Therefore, the necessary relation between autistic symptoms and joint attention was not present to continue with the mediational analysis. Correlations showed that only the presence of speech produced during laugh bouts was correlated with joint attention in children with autism ($r = .71$, $p < .01$). The six remaining correlations between joint attention and each acoustic measure were also examined for both comparison groups to provide an exploratory test of joint attention as a mediator for each comparison group. Joint-attention scores were not correlated with any acoustic outcome for comparison participants matched on VIQ. In contrast, proportion of snorts and bout duration were positively correlated with joint attention in participants matched on CA ($r = .72$, $p < .01$, $r = .56$, $p = .03$, respectively).

A three-level repeated-measures ANOVA was conducted to further evaluate group differences in joint attention ability. Repeated-measures analysis revealed no main effect of joint attention ($\eta^2 = .07$). Planned contrasts between participants with autism and each comparison group showed that children with autism produced significantly fewer instances of joint attention than children matched on VIQ $F(1,14) = 7.46$, $p < .05$, $\eta^2 = .35$. There were no significant differences in joint attention between participants with autism and participants matched on CA ($\eta^2 = .001$). Post hoc contrasts revealed no significant differences in joint attention between the nonautistic groups. Due to the wider age range of participants matched on VIQ, the correlation between joint attention and age was examined for this group. Statistical analysis revealed that age was positively correlated with joint attention in children matched on VIQ, with the relation approaching significance ($r = .40$, $p = .07$).

CHAPTER IV

DISCUSSION

The present study isolated the acoustics of laugh production to test if participants with autism exhibit a restricted range of laugh sounds compared to nonautistic children. Results confirmed that significant differences in laugh acoustics exist between children with and without autism. Of primary interest is the finding that participants with autism exhibited almost solely “voiced” laughter. This result was consistent at both the bout and call levels of analysis.

At the bout level, participants with autism produced significantly more voiced laugh episodes than either comparison group. This result was in accordance with the primary hypothesis of the study. At the call level, participants with autism also produced significantly more voiced laugh sounds than either comparison group. This result was expected because of the striking difference in voiced laughter found between groups at the bout level. Laugh bouts are defined by the predominant features of the embedded calls; therefore, it was likely that differences would also exist at the call level. This was particularly likely because the results were strongly skewed toward one mode of laugh production.

Despite similarities in bout- and call-level results, laugh-call data are informative. Laugh-call analysis provides a more detailed examination of sounds being produced than bout-level comparisons. For example, if a bout is labeled “voiced,” it must be over 50% voiced. Thus, voiced bouts may be comprised of up to 50% unvoiced calls that are only accounted for by call-level analysis. Similarly, bout labels may be unduly influenced by the duration of a particularly long voiced or unvoiced call. Whereas the percentages of voiced laugh calls were approximately proportional to the percentages of voiced laugh bouts of all three groups, some differences were observed. Most notably, participants with autism produced a higher proportion of voiced bouts than voiced calls. In contrast, both comparison groups produced more voiced calls than voiced bouts. This suggests that participants with autism produced more voiced laugh bouts that contained undetected unvoiced calls than typically developing participants. In contrast, typically developing participants most likely produced fewer and longer unvoiced calls than indicated by their laugh-bout labels.

There were no statistical differences between the comparison groups in the proportion of voiced laughter produced by each group. It should be noted, however, that participants matched on VIQ produced more voiced laugh bouts and calls than participants matched on CA (see Figure 1 & Figure 2). This trend is consistent with the hypothesis of a developmental progression of laugh acoustics. Participants matched on VIQ were a mean of 3.3 years younger than participants matched on CA. Accordingly, the data suggest that as participants increase in age, they begin to reduce their level of voiced laughter compared with their other laugh sounds. This is consistent with the hypothesis that typically developing children produce a more diverse repertoire of laugh sounds with age. Interestingly, the participants matched on CA, who had a mean age of 9 years, produced rates of voiced laughter that were consistent with adult rates of voiced laugh production. If future studies replicate this finding, it may be shown that a fuller range of laugh sounds is a developmental achievement that occurs in large part between the ages of 5 and 9.

So why did children with autism produce almost solely voiced laughter? There are several possible explanations for this finding. It was hypothesized that children with autism would produce more voiced laughter relative to nonautistic comparison children due to their marked social deficits. This hypothesis receives theoretical support from an "affect-induction" account of laugh production (Bachorowski et al., 2001; Owren & Bachorowski, 2003; also see Owren & Rendall, 1997, 2001, Owren, Rendall, & Bachorowski, in press), which claims that the function of laughter is primarily to influence the affective state of listeners. Despite a current lack of data on the development of laugh production in children, it is likely that early in ontogeny laughter is largely associated with experienced positive affect. Only later in development are children expected to implicitly learn how and when to use a variety of laugh sounds to best engage the affective state of listeners. Therefore, as a result of their social deficits, the variety of laugh sounds produced by children with autism should only include those laugh types that are hypothesized to be most directly linked with a positive internal state. Currently these laugh types have been linked only to voiced laugh production (Bachorowski & Owren, 2001). Whereas children with autism may not advance in their ability to learn implicit social cues that are associated with the development of other laugh sounds, it appears that typically developing children do. Data from the current study show that typically developing children may, in part, make developmental strides in laugh production between the ages of 5 and 9 years-old. The reduction of solely voiced laugh production in the comparison groups could suggest that these children are using laughter in a way that is less tied to their emotional state, or perhaps even fully under volitional control. This possible reduction in spontaneous, emotion-based laughter is in stark contrast with no apparent reduction of voiced laughter in children with autism. Furthermore, a decrease in the production of voiced laughter in the older comparison group supports the hypothesis that there is an increase in the sophistication of laugh production between younger and older children.

Alternately, it is also possible that children with autism produced more voiced laughter than either comparison group because of how they reacted to the stimuli. Stimulus type and duration were matched closely between the children with autism and the comparison participants, thereby eliminating these stimulus factors as possible confounding variables. However, is it possible that the children with autism were more engaged by the stimuli because the stimuli were targeted toward less socially advanced children. Consequently, the children with autism may have been more aroused than the comparison participants and only produced voiced laughter. This reaction of the participants with autism would support the hypothesis that they produce voiced laughter in response to high levels of arousal or experienced positive affect; however, it may be that children with autism produce equivalent amounts of voiced laughter in other contexts when they are less aroused. This explanation is unlikely due to the varied social contexts of the interactions observed. Both humorous and nonhumorous interactions were recorded in the current study, thus supporting the notion that children with autism were provided with several opportunities to exhibit their full laugh repertoire. Another explanation of the findings may be that one group was more comfortable with the experimenter. It is possible that children with autism were less wary of the examiner due to a lack of social boundaries, and therefore produced fewer “social” laugh sounds in response. Again, this is unlikely given that participants from all three groups were tested by multiple examiners, and no significant experimenter effects were found.

In addition to voiced laugh production, it is equally important to understand the function of unvoiced laughter in children with and without autism. Currently there is insufficient research available to directly address its use. Nevertheless, studies of laugh acoustics provide clues about its use and development. In adults, unvoiced laughter has been shown to comprise as much as 50% of all laugh sounds (Bachorowski et al., 2001). Unvoiced laughter is produced more by males (Bachorowski et al., 2001), and appears to be influenced by social context (Bachorowski et al., 2004). Due to the relation between voiced laughter and positive emotions (Bachorowski & Owren, 2001; Grammer & Eibl-Eibesfeldt, 1990), it is tempting to conclude that unvoiced laughter may be used in a comparatively volitional fashion to manipulate the affective state of the listener. If this is the case, it is logical that participants with autism do not use unvoiced laughter to influence others. This conclusion, however, may be specious. For instance, it is quite probable that many forms of unvoiced laughter are related to lower levels of arousal, but nonetheless are linked with the experience of positive affect on the part of the laugher. Thus, an alternate interpretation of these results is that in comparison to typically developing children, children with autism have a higher arousal threshold associated with laugh production. It would be of interest for future work to concurrently examine levels of arousal. Such work might employ the use of psychophysics or detailed behavioral observation to monitor arousal levels.

In addition to less unvoiced laughter produced by children with autism, results showed that participants with autism exhibited a significant restriction in the type of laugh sounds that they produced relative to both comparison groups. This result is consistent with the hypothesis that children with autism would produce a restricted range of laugh sounds, which is perhaps an outcome secondary to their social deficits. If children with autism are not as motivated to interact socially with others, it is logical that they do not produce the same breadth of laugh sounds that typically developing children use to negotiate social interactions. Alternately, it is possible that the children with autism did not produce the same types of laugh sounds because of a differential response to the laugh stimuli that were presented. Despite attempts to produce a wide variety of laugh elicitors, it may be the case that children with autism only produce laugh types such as grunts or snorts when they are confronted with stimuli that were not experienced in the present study.

Whereas snorts comprise approximately 30% of the laugh repertoire of adults (Bachorowski et al., 2001), this laugh type was relatively absent in all three groups. Therefore, the primary distinction between the laugh types produced by participants with autism and the typically developing comparison groups derived from the higher proportion of grunts produced by the comparison participants. There was no a priori evidence to suggest that all three groups would produce dramatically lower levels of snorts relative to their other laugh types. These data are intriguing, however, as they may demonstrate that the development of different laugh types continue beyond the ages of 5 to 9 years-old. The data suggest that snorts may be used more commonly later in development, and that they may encompass one of the final stages of laugh development in children. Although there were slightly higher proportions of snorts in the VIQ comparison group, low levels of this laugh type in any group precluded a valid comparison.

Differences in laugh type between children with autism and both comparison groups are informative yet predictable based on voiced laughter outcomes. Due to the coding scheme used to identify distinct laugh types, the presence of voicing in a given laugh bout or call was instrumental to the label of the laugh type. For example, if a laugh bout contained more than 50% unvoiced laughter, it was labeled as either a grunt or a snort based on the acoustic features of the laugh. Therefore, the virtual absence of unvoiced laughter in participants with autism made it likely that significant differences in laugh type would also exist between groups. Nevertheless, it is very informative that the difference in laugh types among groups can be attributed to the production of solely grunts in nonautistic participants. In future studies this information may be used to identify the developmental level of laugh production in typically developing children and autistic children alike.

A number of measurements were taken to further examine the acoustic features of laugh production in each group. Summarily, all acoustic outcomes were nonsignificant. Children with autism did not have significantly different laugh-bout durations, mean F_0 values, or F_0 variability compared with either of the nonautistic groups. There were no significant differences between groups in the amount of laughter produced during speech, or in the amount of non-normative vocal fold vibrations. Although it was hypothesized that children with autism would exhibit less variable laugh acoustics (e.g., duration of the sound, variability of F_0), multiple factors contributed to low power to detect group differences (power for these outcomes was generally between .2-.4). Effect sizes for the acoustic outcomes were generally small and ranged mostly between $\eta^2 = .005$ to $\eta^2 = .02$, suggesting that a larger sample size was necessary to rule out the null hypothesis. Studies of laughter in young adults also indicate that there is notable variability in F_0 values both within and between individuals (e.g., Bachorowski et al., 2001). This high degree of variability in other studies of laughter is consistent with the current findings, and consequently contributes to decreases in observed effect size.

Despite this overall absence of significant differences in laugh acoustics among groups, there were a number of intriguing findings. For example, similar to typically developing children and young adults, the laugh acoustics of children with autism were remarkably variable. In this study, the F_0 values of children with autism ranged from as low as 300 to as high as 2800 Hz in a single laugh bout. Whereas 300 Hz is reported to be a mean F_0 value for laughs produced by typically developing children (Nwokah et al., 1993), a value of 2800 Hz is more than twice the typical F_0 achieved by a trained Soprano (Benolken & Swanson, 1990). There are multiple interpretations of this result. It may be that children with autism do modulate their laugh acoustics in some ways to influence listener response systems. This arguably nonconscious process may indicate that children with autism are attempting to engage listeners in some way. This result may also suggest that the evolutionary underpinnings of laugh production are powerful, and influence the range of laugh acoustics produced by children with autism in a similar way as nonautistic participants. Regardless of the cause, both comparison participants and children with autism clearly have the capacity to produce a wide array of voiced laugh sounds. Whereas participants with autism may not produce the same types of laugh sounds, it appears that they produce similar ranges of variability in their voiced laughter compared with typically developing children.

It was further intriguing that participants in all three groups produced almost no non-normative vocal fold vibrations. Although these laugh sounds are infrequent in the laugh repertoire of adults, it was anticipated that typically developing participants would produce similar levels. Again, the evidence suggests that this form of laughter may occur at a later developmental time point. Of all acoustic outcomes, perhaps the most surprising was a lack of group differences between the amount of laughter produced during speech. Based on the language deficits observed in participants with autism, it was anticipated that laughter would occur more frequently during speech in the nonautistic comparison participants. This result should occur due to a hypothesized difference in the base rate of speech production alone. Although speech production was not measured in the current study, it is likely that the participants with autism used less meaningful speech than the comparison participants. Unfortunately it is not clear if a lack of difference between groups is due to similar levels of laughter during speech production or an insufficient sample size.

It should be noted that subjective investigation of the data produced one final observation regarding the acoustics of laughter between the groups. While coding laugh types it was discovered that participants with autism produced some laughs that contained an odd temporal quality that sounded echolalic and “fake” in nature. These laughs were observed only in the participants with autism but consisted of less than 1% of the total number of laughs produced by the autistic sample. Unfortunately no formal criteria are available to distinguish between genuine and “fake” laughter. Nonetheless, it may be that some laughs produced by children with autism are simply repetitive and produced as echolalic representations of sound they hear from other laughers or their own voice. The repetitive and echolalic aspects of language in autism have been widely documented and researched (e.g. Fay, 1967, 1969, 1974; Local & Wootton, 1995, Rydell & Mirenda, 1991; Tager-Flusberg, 1996; Violette & Swisher, 1992). Whereas most studies of echolalia document the echolalic production of speech and the associated brain networks, recent work suggests that echolalia may be the result of a more generalized perceptual disturbance of mirror neurons in the frontal cortex (Williams, Whiten, Suddendorf, & Perrett, 2001). This evidence suggests that several forms of echolalia, including the kind produced in laughter, may at times be a result of an impairment in imitation. Further work is needed to both more accurately identify these echolalic sounds and distinguish these sounds from other more spontaneous instances of laughter.

It was hypothesized that joint attention would mediate the relation between autistic symptoms and a variety of acoustic outcomes. This hypothesis derived from prior work demonstrating a link between joint-attention ability, positive affect, and symptom presentation. Unfortunately, a mediational model of joint attention failed to account for the data in multiple ways. First, there were no significant correlations between CARS scores and any laughter outcomes. This result suggests that the severity of autistic symptoms is not related to laugh production. This outcome was not expected. Prior research suggests that some emotion-related abilities of children with autism are directly related to the severity of their disorder (Le Couteur et al.,1989; Schopler et al., 1988; Tanguay et al., 1998). Furthermore, the data suggested that those participants who were most impaired (and subsequently excluded from participating in the study) produced no laughter, suggesting that there may in fact be some relation between acoustic outcomes and level of symptom presentation. Due to the small sample size (only three participants were excluded), however, this possibility should be interpreted with caution.

Second, the correlation between CARS score and joint-attention ability was nonsignificant. Only a handful of investigations have examined the relation between joint attention and symptom presentation (Loveland & Landry, 1986; Mundy et al., 1994; Mundy et al., 1986; Mundy et al., 1990). However, these studies demonstrate that an increase in joint-attention ability is inversely related to symptom presentation in children with autism. It was therefore surprising that there was no relation in the current study between these variables. Again, a lack of correlation between these variables may be the result of low power.

Lastly, joint-attention ability was correlated with only one laugh-related measure: the presence of laughter during speech (see Table 2 for raw data). This was not a hypothesized result. Research suggests, however, that a link exists between joint attention and language use (Loveland & Landry, 1986; Mundy et al., 1986; Mundy et al., 1990). Despite admittedly high rates of variance, it may be that joint-attention ability is related to speech production but not laugh production. This would explain why only the amount of laughter produced during speech production was positively correlated with joint-attention ability. Though joint attention may be related to some expressions of positive affect such as smiling (Kasari et al., 1990; Paparella, 2000), it is possible that there are features unique to laugh production that preclude this relation. For example, it may be that joint attention is facilitated by only some expressions of positive affect such as smiling. Further research is needed to elucidate the relation between joint attention and positive affect.

Table 2.

Amount of Laughter Produced During Speech (Bout Level)

Group	Mean	SD	Range
Autism	1.2	1.4	0-4
VIQ Match	1.7	1.7	0-5
CA Match	1.5	2.0	0-5

Due to the lack of fit with a mediational model of joint attention, repeated-measures ANOVA were conducted to investigate group differences in joint-attention ability between autistic and nonautistic participants. Whereas participants with autism exhibited significantly fewer joint-attention interactions relative to participants matched on VIQ, there were no significant differences between children with autism and participants matched on CA. This result was highly surprising. Due to the older chronological age and relative developmental sophistication of the comparison participants matched on CA, it is not clear why participants with autism did not exhibit significant differences in joint-attention ability from this group. Perhaps the participants matched on CA did not relate as well with the examiner. It is also possible that these participants reacted with less interest or more caution toward the stimuli, thereby not engaging the examiner to the same degree as the other participants. Finally, it is possible that there is a developmental progression of joint attention, whereby it becomes less salient in the interactions of children as they reach a certain developmental period. Interestingly, when the relation between age and joint-attention ability in the participants matched on VIQ was examined, it was found that there was a positive correlation, with the relation approaching significance. This result suggests that there may be an effect of age on joint-attention ability, but that typically developing 9 year-olds may use this ability less than their younger counterparts. Overall these results may suggest that the comparison group matched on VIQ are a better comparison group for participants with autism when examining joint-attention ability.

There are a number of limitations associated with this study. Of primary concern is the small number of participants. Whereas a striking effect was observed between children with autism and both control groups on some measures of laughter, a number of comparisons were potentially inconclusive because the power was not present to detect small or even medium effect sizes. In particular, some laugh acoustics such as F_0 and laugh-bout duration are traditionally subject to tremendous variability both within and between participants (Bachorowski et al., 2001, 2004). Thus, a much larger sample size may be needed to detect differences between comparison groups on these measures.

Another limitation of the present study concerns the measurement of joint attention. The current study examined joint attention during the ADOS-G, which was independent of the measurement of laughter during the LAS. Theoretically, if joint-attention ability is related to laugh acoustics, a difference in the measurement time of these variables should not influence the results. However, similar investigations of the relation between joint attention and positive affect have only examined the relation between these variables during the same assessment period (Kasari et al., 1990; Paparella, 2000). Thus, it may be that joint attention is only related to concurrent presentations of positive affect. In this study positive affect was not measured during the ADOS-G due to insufficient levels of laugh production during these interactions. Similarly, it was not possible to attain other measurements of positive affect, such as smiling, due to limitations with the initial video recording of the testing sessions.

As mentioned previously, defining appropriate comparison groups for participants with autism is of paramount importance in any study of the disorder. The unique IQ profile and social deficits of children with autism necessitates special consideration when selecting valid comparison participants. Whereas every effort was made to obtain appropriate comparison participants, it is possible that alternate comparison groups may yield contrasting results. In particular, additional studies employing comparison groups of developmentally delayed comparison participants will be informative.

Lastly, comparison participants were not formally assessed for the presence of any autism-spectrum disorders. It is possible that autistic-like symptoms in the comparison participants may have influenced the results. Although no direct measure was administered, clinical judgment was exercised by the examiner to exclude children from participating if they exhibited symptoms consistent with a diagnosis of autism. Two participants were excluded in this manner.

The current study was also characterized by a number of strengths, including the use of a matched-pair design. Unlike some investigations of the emotion-related abilities of children with autism, the present study controlled for a number of potentially problematic variables such as sex of the experimenter, the type and duration of stimuli, and a precise measurement of the verbal and chronological age of comparison participants. These matched variables allowed for more accurate measurement of the dependent variables, as well as more confidence that the outcomes were purely a result of the diagnosis of autism. Furthermore, the matched-pair design allowed for more power, and subsequently larger effect sizes with smaller numbers of participants.

Second, this study represents the first comprehensive investigation of laugh acoustics in children with autism. Whereas Reddy et al. (2002) roughly distinguished laughs by their duration, these laughs were not directly associated with the acoustic features of the laugh signal. Instead, the majority of research on the production of laughter in children with autism has focused on mean rates of laugh production (Reddy et al., 2002; Sheinkopf et al., 2000; St. James & Tager-Flusberg, 1994). Studies show that children with autism produce some correlates of positive affect during reciprocal-social interactions, such as smiling, less often than nonautistic participants (Dawson et al., 1990; Yirmiya et al., 1989). Currently these results have not extended to rates of laugh production in children with autism (Reddy et al., 2002; Sheinkopf et al., 2000; St. James & Tager-Flusberg, 1994). Several methodological constraints, however, make it difficult to obtain an accurate estimate of laugh rate from children with autism. These constraints include difficulties associated with matching comparison participants, failures to match the type or duration of stimuli, and differences in the operational definition of laughter. In the present study, rates of laugh production were not examined due to minor differences in the stimuli used to elicit laughter. Instead, differences that depend on reliable acoustic analysis of laugh sound were examined in lieu of the more subjective inter-rater measures used in previous investigations. Due to a paucity of prior research on the production of laughter in this population, a further strength of this study derives from its reliance on an established coding and classification system of laughter (Bachorowski et al., 2001).

Lastly, the current study constitutes the first examination of the connection between joint attention and laugh production. Some studies have examined laughter as a part of positive affective expression during joint-attention tasks in participants with autism (Kasari et al., 1990; Paparella, 2000). This is the first study, however, to isolate laugh production. Furthermore, only one other investigation has utilized a dimensional approach to examine the relation between autistic symptomology and joint attention (Stella, 2002). The results of the current study did not replicate associations found between joint-attention ability and symptoms of autism as measured by the CARS. Nevertheless, the current results suggest that there may instead be a critical level of autistic symptoms that are needed to produce differences in joint-attention ability between groups. Further research is needed to elucidate the relation between both joint attention and positive affect as well as joint attention and autistic symptom presentation.

Despite a number of exciting findings in the current study, considerable work is needed to better understand the emotion-related abilities of children with autism. It was hypothesized that the social and emotional deficits of children with autism would cause a more restricted range of laugh sounds relative to typically developing participants. This hypothesis was motivated by the idea that children with autism would not use laughter in a socially appropriate way, and would instead only produce laughter in response to a positive internal state. Although the results were generally consistent with this hypothesis, there was no direct measure of positive affect in the present study. Further work is necessary to confirm that positive internal states are responsible for differences in laugh acoustics observed between children with and without autism.

It is my hope that future studies will address the internal states of children with autism by examining variables that are known to correlate highly with reported emotional states. Such studies might employ the use of psychophysics, or the measurement of Duchenne smiles (Ekman, Davidson, & Friesen, 1990) to examine correlations between the expression of emotion and the child's experienced affect. Psychophysiological measures such as skin conductance response (SCR), startle reflex, and heart rate have been shown to correlate with reported states of positive affect in adults (e.g., Codispoti, Bradley, & Lang, 2001; Davis & Lang, 2003; MacDowell, & Mandler, 1989; Reich & Zautra, 2002). Unfortunately, fewer studies have used these measures to examine the reported internal states of children (de-Haan, Nelson, Gunnar, & Tout, 1998; Fox & Davidson, 1986; Perez & Fox, 2003; Pollak, Cicchetti, Klorman, & Brumaghim, 1997). Theoretical work and research alike, however, suggest that there should be no major differences in the psychophysiological responses of minors as compared with adults (Izard & Read, 1986; Pine, 2001). Studies that correlation laugh production with psychophysiological measures may provide support for the hypothesis that only typically developing participants produce laughter that is not consistently associated with a positive internal state.

Despite the potential utility of psychophysiological studies of laughter in children with autism, there are a number of difficulties associated with this approach. Primarily, due to the aerobic and frequently kinetic nature of laugh production, it may be difficult to collect psychophysiological data in the absence of movement artifacts. However, under controlled conditions it may be possible to obtain valid measures of SCR and event-related brain potentials (ERP) in this population. This would be a positive step toward making connections between psychophysics and experienced affect in children with autism.

A more feasible approach to studying correlates of internal states in children with autism may involve the use of Duchenne smiles (Ekman et al., 1990). Duchenne smiles are considered to be emotion-based smiles that involve simultaneous contractions of the obicularis oculi and zygomatic muscles, whereas volitional smiles typically result in contractions of solely the zygomatic. Work on the production of smiles in typically developing adults suggests that Duchenne smiles are more commonly associated with positive internal states than other smiles (Ekman et al., 1990; Surakka & Hietanen, 1998). Further work may suggest that children with autism exhibit Duchenne smiles as honest expressions of their internal positive affect. Due to the frequent relation between smiling and laughing behaviors, it is likely that videotaped coding of Duchenne smiles associated with laugh production may provide clues about experienced affect in this population. Conversely, typically developing comparison participants may demonstrate the use of more volitional smiling during social interactions.

Future studies are needed to accurately examine base rates of laugh production between children with and without autism. These studies will help to determine the influence of laugh production on the interactions of children with autism. The present results tentatively showed that children with autism produced similar rates of laughter as the group matched on CA, and fewer laughs than the children matched on VIQ. These data suggest that only age may influence the rate of laugh production between groups. If further work confirms this finding, it may be that laugh rates do not distinguish children with autism from typically developing children, but rather the way in which they use these laughs is important. Studies that further examine the contexts that are associated with distinct laugh acoustics in each group will be critical to furthering our knowledge in this area.

Ultimately, this research may lead to clinical applications. Currently, therapeutic interventions for children with autism vary from pharmacological interventions (e.g. Buitelaar & Willemsen-Swinkels, 2000; Silka & Hurley, 2002; Towbin, 2003; Tsai, 2000) to social skills training (e.g. Broderick, 2000; Howlin & Yates, 1999; Kransny, Williams, Provencal, & Ozonoff, 2003; Taylor & Jasper, 2001). Given that the disorder is characterized by marked deficits in social skills, it may be possible to use laughter as a tool to promote positive social interactions between higher-functioning children with autism and their typically developing peers.

APPENDIX A

CODING JOINT ATTENTION

Joint Attention

The function of these behaviors is to share attention with the interactive partner or to monitor the partner's attention. They differ from Requesting bids in that they do not appear to serve an instrumental or imperative purpose. Rather, their function seems to be more social sharing or declarative in nature. A "show" gesture is prototypical of this type of behavior. These behaviors are most often observed during active object presentation, and during the child's examination of toys. However, they may also be observed when novel events spontaneously occur during testing (e.g., a sound is distinctly heard outside the testing room or a toy breaks).

Initiating Joint Attention

Lower Level Behaviors:

1) Eye Contact: the child makes eye contact with the tester while manipulating or touching a toy. Note: The video recording of the ADOS-G should enable coders to reference the general position of the tester's eyes and reliably determine when the child is looking at the upper orbital region of the tester's face (the definition of eye contact) as opposed to looking at the lower portion of the tester's face.

2) Alternating (referencing): the child alternates a look between an object and the tester's eyes. Each example of this bid is recorded. This is typically recorded when an object is on the table, floor, or in the tester's hand. It is also recorded if the child looks up to the tester after an object is in their own hands.

Higher level behaviors:

3) Pointing: the child points to a toy, pictures in a book before the tester has pointed, or to objects in the room before the tester has pointed. Pointing may occur with or without eye contact.

4) Showing: The child raises a toy upward toward the tester's face. This behavior may be difficult to distinguish from "giving" in the young child. If the tester responds to a show gesture as though it were a give and attempts to retrieve the object the child may resist giving, albeit briefly. Observations of resistance to giving may be used in rating this behavior. Shows are typically brief bids with the child quickly retracting the offered object.

Scoring: Three scores are typically obtained: a) the Total Frequency of Joint Attention bids, b) the Frequency of High Level Joint Attention Bids and c) the Ratio of High Level to All Joint Attention Bids.

Responding to Joint Attention

1) Following proximal point/touch: During the Joint Interactive Play task the child receives credit if s/he orients his/her head and eyes toward a toy or book upon the request

of the examiner. This orienting bid may or may not include a vocal request by the examiner.
Scoring: Scoring is accomplished by measuring the total frequency of joint attention bids.

*Coding procedure adapted from ESCS manual (Mundy, Hogan, & Doehring, 1996) with the permission of P. Mundy (Personal communication, June 5, 2002).

APPENDIX B

CORRELATION MATRIX

		CARS	Voiced Bouts	Voiced Calls	Grunts	Snorts	Tonal	Voiced Dur.	UnVcd Dur.	F0 Mean	F0 Change	F0 Variability	Speech - Bouts	Speech - Calls	Joint Attn.	Calls Per BT
CARS Score	Correlation	1														
	Sig.	.														
Voiced Bouts	Correlation	.361	1													
	Sig.	.186	.													
Voiced Calls	Correlation	.037	.341	1												
	Sig.	.897	.214	.												
Grunts	Correlation	-.380	-.967	-.310	1											
	Sig.	.163	.000	.261	.											
Snorts	Correlation	-.221	-.808*	-.320	.631	1										
	Sig.	.428	.000	.245	.012	.										
Tonal	Correlation	.361	1.000*	.341	-.967*	-.808*	1									
	Sig.	.186	.000	.214	.000	.000	.									
Voiced Duration	Correlation	-.050	-.019	.546*	.031	-.014	-.019	1								
	Sig.	.859	.946	.035	.912	.961	.946	.								
Unvoiced Duration	Correlation	-.045	-.034	.538*	.038	.018	-.034	.999*	1							
	Sig.	.873	.903	.039	.894	.949	.903	.000	.							
F0 Mean	Correlation	.313	.188	.253	-.160	-.201	.188	.032	.030	1						
	Sig.	.256	.503	.364	.569	.473	.503	.910	.916	.						
F0 Change	Correlation	.230	.228	-.058	-.220	-.186	.228	-.104	-.109	.770*	1					
	Sig.	.410	.413	.838	.430	.506	.413	.713	.698	.001	.					
F0 Variability	Correlation	.266	.097	.241	-.040	-.203	.097	.137	.134	.833*	.536*	1				
	Sig.	.337	.732	.387	.889	.469	.732	.627	.635	.000	.039	.				
Speech - Bouts	Correlation	-.425	-.186	.046	.345	-.231	-.186	-.020	-.043	-.046	-.241	-.035	1			
	Sig.	.114	.507	.869	.208	.407	.507	.943	.879	.872	.386	.902	.			
Speech -Calls	Correlation	-.094	-.128	-.038	.262	-.215	-.128	-.141	-.155	-.015	-.271	-.105	.738*	1		
	Sig.	.740	.649	.893	.346	.442	.649	.615	.582	.957	.329	.709	.002	.		
Joint Attentionτ	Correlation	-.314	-.148	.021	.295	-.183	-.148	-.265	-.281	-.179	-.405	-.063	.737*	.467	1	
	Sig.	.274	.615	.943	.306	.531	.615	.360	.330	.540	.151	.830	.003	.092	.	
Calls Per Bout	Correlation	-.076	-.034	.501	.016	.067	-.034	.891*	.888*	-.012	.033	-.069	.008	-.229	-.220	1
	Sig.	.787	.904	.057	.955	.814	.904	.000	.000	.965	.907	.807	.976	.412	.450	.
		CARS Score	Voiced Bouts	Voiced Calls	Grunts	Snorts	Tonal	Voiced Dur.	UnVcd Dur.	F0 Mean	F0 Change	F0 Variability	Speech - Bouts	Speech - Calls	Joint Attn.τ	Calls Per BT

* Correlation is significant at the 0.05 level (2-tailed). τ Joint attention included with partial correlations controlling for duration of session

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