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Poor Facial Affect Recognition Among Boys with Duchenne Muscular Dystrophy

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Abstract Children with Duchenne or Becker muscular dystrophy (MD) have delayed language and poor social skills and some meet criteria for Pervasive Developmental Disorder, yet they are identified by molecular, rather than behavioral, characteristics. To determine whether comprehension of facial affect is compromised in boys with MD, children were given a matching-to-sample test with four types of visual recognition (Object, Face, Affect, and Situation matching) developed by Lucci and Fein. Within-group analyses on 50 boys with MD found decreased Affect matching relative to the other matching conditions. Between-group comparisons on 20 sibling pairs found the boys with Duchenne performed more poorly only on the Affect-matching condition. Thus, mildly impaired facial affect recognition may be part of the phenotype associated with Duchenne or Becker MD.

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Introduction

The ability to comprehend facial affect is a vital aspect of human social interactions. The universality of understanding emotions through facial expressions has suggested that it is an innate fundamental trait that supersedes language, literacy, and environment in humans (Darwin, 1872). In cross-cultural studies, individuals from completely disparate backgrounds interpret happiness, anger, fear, and sadness similarly by viewing representative facial expressions (Ekman, 1994; Ekman & Friesen, 1971). Additionally, children develop these skills early (e.g., Herba & Phillips, 2004). The early emergence of interest in facial processing suggests an evolutionary selection for this skill, and some have suggested that a component of the ability to recognize facial expressions is unlearned (Nelson, 1987). Affect recognition skills contribute to a child's adaptation in a social environment, and hence to his or her survival.

Some developmental disorders impact on the ability to discern emotional expression of faces. The most extreme forms of this are seen in the pervasive developmental disorders (PDD), including autism, where one of the hallmark characteristics of the disorder is impaired development of social awareness, including (but not limited to) an apparent disinterest in faces and facial affects of others. Autistic individuals have been shown to be less likely to accurately

remember faces, match faces, and describe faces appropriately, the ability to discern facial affect correctly is particularly impaired (Bolte & Poutske, 2003; Braverman, Fein, Lucci, & Waterhouse, 1989; Fein, Lucci, Braverman & Waterhouse, 1992; Gross, 2004; Hobson, 1986a, b; Klin, Sparrow, de Blildt, Cicchetti, Cohen, & Volkmar, 1999; Ozonoff, Pennington, & Rogers, 1990; Tanrturn, Monaghan, Nicholson, & Stirling, 1989).

Further, high-functioning individuals with autism have been shown to recruit different brain areas when examining facial stimuli, both neutral and depicting emotions, indicating a neurodevelopmental aberration in this cognitive trait (Critchley et al., 2000; Haxby, Hoffman, & Gobbini, 2002; Pierce, Haist, Sedaghat, & Courchesne, 2004; Wang, Dapretto, Hariri, Sigman, & Bookheimer, 2004).

When non-autistic children with PDD were tested on a carefully designed matching-to-sample measure examining Object, Face, Affect, and Situation matching, such that among normally developing children performance across the levels was equivalent, they demonstrated poorer performance on both the Facial and Affect matching levels, relative to Object matching. When children with PDD were compared to nonverbal age-matched controls, they demonstrated poorer Affect matching, but performed similarly to the controls on both Object and Face matching (Braverman et al., 1989). The overall effect size was small, but was successfully replicated in a study by Ozonoff et al. (1990). Children with PDD show selective difficulty processing facial affect information.

In a similar matching-to-sample study, children with PDD were tested on a measure of understanding of affect in context (Fein et al., 1992). The children with PDD performed more poorly on the judgment of situation affect task than they did on an object matching task, but did not differ from controls on this task. Again, the data suggested that children with PDD have a subtle, yet replicable, deficit in affect comprehension.

One potentially limiting aspect of work studying individuals diagnosed with PDDs is the fact that some of the behaviors studied contribute to the formation of the diagnosis. That is, according to DSM IV criteria, pervasive impairment in social interaction skills is part of the defining behavioral characteristics for PDD (American Psychiatric Association, 1994). Thus, if individuals are chosen based on poor social skills, and facial affect processing is a hallmark of poor social skills, then an inevitable tautology contributes to the finding that these individuals do poorly on affect processing. One way to avoid this circular reasoning is to study individuals diagnosed based on etiology, rather than behavioral features.

Understanding of behaviors that appear to be associated with etiologies such as Fragile X, Turners or Williams Syndromes, has allowed for the conceptualization of how the underlying causal factors of the disorders may have contributed to the affected individuals' presenting behavior (e.g., Dykens & Hodapp, 2001). The molecular basis of the disorder is established, the behaviors can be examined, and the intervening brain mechanisms can be hypothesized using a neuroscience reductionist approach.

The current study examines facial and affect comprehension skills using such an approach. Fifty boys diagnosed with a neurogenetic disorder, either Duchenne or Becker muscular dystrophy (MD), were tested on the previously described Object, Face, Affect, and Situation matching-to-sample test (Braverman et al., 1989; Fein et al., 1992). In MD, the cognitive and behavioral involvement is generally milder than in the aforementioned syndromes. MD is mainly a disease of muscle, yet it also affects the brain. Both Duchenne and Becker MD are caused by a mutation in a gene on the X chromosome; for Duchenne MD, this results in a lack of the protein dystrophin, while for Becker MD it results in partial dystrophin deficiency (Koenig, Hoffman, Bertelson, Monaco, Feener, & Kunkel, 1987). At the level of the muscle, dystrophin normally provides structural support; without it, muscle cells break down with use. In MD, affected individuals grow progressively weaker over time, generally showing signs of weakness during their preschool years and requiring a wheelchair by their early teens. Most individuals affected with Duchenne MD do not live past their twenties. For Becker MD, the disease course is similar, but less pronounced and age span is greater. On the level of the brain, a lack of dystrophin isoforms has been documented in the cerebral cortex and cerebellum, in specific cell types (especially pyramidal and Purkinje cells) and in specific cell areas (especially the neuronal post-synaptic densities) (for reviews, Anderson, Head, Rae, & Morley, 2002; Mehler, 2000).

What the exact functional role of dystrophin isoforms is in the brain is unknown, but their absence is associated with neuropsychological impairment. Among children affected with MD, overall IQ scores are shifted down about one standard deviation from the population mean, and Verbal IQ scores are more impaired than Performance IQ scores (Cotton, Voudouris, & Greenwood, 2001). Detailed neuropsychological evaluations of children with MD have demonstrated poor performance on tests of language comprehension and immediate verbal memory and

across all areas of academic achievement (Billard et al., 1992; Billard, Gillet, Barthez, Hommet & Bertrand, 1998; Dorman, Hurley, & D'Avignon, 1988; Hinton, DeVivo, Fee Goldstein, & Stern, 2004; Hinton, Nereo, DeVivo, Goldstein, & Stern 2000, 2001; Ogasawara, 1989; Smith, Sibert, & Harper, 1990; Whelan, 1987). Vocabulary and non-verbal skills remain relatively intact across the group. Early language acquisition is delayed, and some individuals demonstrate global impairments, including mental retardation and autism (Cyrulnik, Fee, Kiefel, & Hinton, 2004; Darke, Bushby, Couteur, & McConachie, 2006; Kaplan, Osborne & Elias, 1986; Komoto, Usui, Otsuki, & Terao, 1984; Smith et al., 1990; Wu, Kuban, Allred, Shapiro, & Darras, 2005; Zwaigenbaum & Tarnopolsky, 2003). We, and others, have argued that the cognitive profile represents the brain's role in the disorder and is not primarily due to consequences of the physical disability (Hinton et al., 2000, 2001). Indeed, some researchers have found an association with molecular characteristics and severity of cognitive presentation (Bushby et al., 1995; Felisari et al., 2000; Moizard et al., 1998).

The group profile of primarily verbal difficulties is vaguely suggestive of that associated with PDD. Moreover, reports of higher than expected rates of autism spectrum disorders among children with MD indicate a susceptibility for PDD (Darke et al., 2006; Wu et al., 2005). Across the group, however, there is great variability in the phenotypic aspects of the disorder and most children do not have severely impaired communication skills, nor autistic spectrum disorders. In the course of evaluating the children for a large neuropsychological study, one investigator (VJH) developed the clinical impression that many boys with MD have mild difficulties with social relatedness. Analysis of parent report of the child's behavior on the Child Behavior Checklist (Achenbach, 1991) supported this; parents report increased social behavior problems among their children affected with MD relative to unaffected sibling controls and children with cerebral palsy (Hinton, Nereo, Fee, & Cyrulnik, in press). However, interpretation of these data are limited by the uncertain sensitivity of the measure both in a physically disabled group and for subtle interpersonal skills gleaned through parent report.

The current study directly tests the hypothesis that children with MD have mild deficits in social interaction. Data were collected as part of the ongoing neuropsychological exploration of MD. Performance on the Object, Face, Affect, and Situation matching-to-sample task was analyzed in two-ways: (1) within a large sample of boys affected with MD, and (2) through paired comparisons of carefully matched proband-sibling pairs. The hypotheses that boys with MD would have poorer performance on Affect and Situation matching than on Object and Face matching, and that they would differ from their matched siblings in these areas was tested. Further, within the larger sample, the association between a parent rating of clinically significant social problems and affect recognition was explored.

Methods

Participants

MD Probands

Fifty boys with MD were studied (Duchenne MD $n = 46$, Becker MD $n = 4$). As part of a large ongoing neuropsychological study of MD, participants were recruited from private physicians associated with the Muscular Dystrophy Association clinics at Columbia Presbyterian Medical in New York, NY, Children's Healthcare at the Scottish Rite Children's Medical Center in Atlanta, and announcements and mailings through the Muscular Dystrophy Association and the Parent Project for MD. All subjects were male, between 4 and 12 years of age, in otherwise good general health, spoke English as their primary language and were willing to participate. Diagnosis of MD was based on clinical onset of progressive weakness before 5 years of age, elevated serum creatine kinase levels, and either molecular assessment of mutation in the MD gene or muscle biopsy that was deficient in dystrophin and compatible with MD. Molecular confirmation was done in all boys. In families where more than one boy was affected, data are presented from only one child, alternating every other family between the older and younger eligible child. All children were recruited because of their diagnosis of MD, yet among the 50 children three had received a diagnosis of PDD as well. Cognitive data on some of these children ($n = 26$ of current sample) have been published previously (Hinton et al., 2000, 2001).

Sibling Pairs

Twenty siblings who were within 3 years of their affected brother's age were also tested. Molecular data were not available on sibling controls, but none had any physical signs of illness. Family paired comparisons were done to control for background environmental and genetic variation. Twelve control participants were male and eight were female. Eleven siblings were older

than the proband (six males and five females), one participant was a fraternal female twin and eight participants were younger (six males and two females). Cognitive data on some of these sibling pairs have been published previously (n = 13 of current sample, Hinton et al., 2001).

Procedure

The present study was approved by the Columbia University Institutional Review Board. Prior to data collection, parents of all participants provided written informed consent and all participants gave verbal assent. Parents completed questionnaires while their children were being tested. Participants were assessed for the larger study in either an office in the medical center or in a quiet room in their homes.

Measures

The measures for the current study were part of a larger neuropsychological study. As estimates of intellectual function, participants were individually administered the Peabody Picture Vocabulary Test (PPVT-III, Dunn & Dunn 1997), an untimed test of receptive vocabulary, and the Ravens Colored Progressive Matrices (Raven, Court, & Raven, 1990), a non-verbal untimed spatial reasoning task. Both tests are appropriate for use across a wide age-range, as well as range of intellectual function, and do not involve any significant motor response that might confound performance among the physically disabled children. For the PPVT-III, each test item has four simple black and white illustrations in a multiple-choice array, from which the child selects the one that best illustrates the meaning of a word presented orally by the examiner. For the Ravens, the child views a colored sample design and chooses from six items the one that best completes the sample. Design matching, design completion and reasoning skills are all assessed. Parents of all children who participated completed the Child Behavior Checklist (CBCL, Achenbach, 1991), which segregates 118 behavior items into eight separate problem scales. Our prior work demonstrated that parents of children with MD were more likely to rate their children as being in the ''clinically significant'' range on the Social Problem scale than on any other scale (Hinton et al., in press), so data from this scale were used.

As a measure of affect recognition, the Object, Face, Affect, and Situation matching task developed by Lucci and Fein and described in detail in Braverman et al. (1989) and Fein et al. (1992) was used. The task was developed to test the hypothesis that children with PDD have a primary dysfunction in their social or affective systems. The test uses a matching-to-sample format with photographs as the visual stimuli. The stimulus item and four response items are shown simultaneously. The child is requested to choose one item from the four choices. The test has four levels, each with 16 test items and four sample training items that ensure the child understands the procedure.

The Object matching level includes photographs of simple familiar objects. The correct choice is a modification of the target item, such as a photograph of the same item from a different perspective. The Face matching level includes photographs of people's faces, and the correct response is a photograph of the same person's face from different orientation. The Affect matching level uses photographs developed by Ekman, Friesen, & Ellsworth (1972) of actors portraying one of four emotions (happy, sad, mad, and scared). The Situation matching level is comprised of a photograph of a child in an affect-laden context (such as a child at a birthday party or a child about to get an injection), yet the child's face is covered so no facial cues of the appropriate emotion are displayed. The four response items are of a girl looking happy, sad, angry, and scared. The subject is requested to look at what the child in the target photograph is doing and chose the response photograph that best shows how the target child is likely feeling. Experimental use of the test confirmed that normal children perform similarly across all four levels (Braverman et al., 1989; Fein et al., 1992).

Data Analysis

For the different groups, mean ages, PPVT, and Ravens scores were calculated. To examine for potential confounds introduced by the gender differences in the control group, t-tests compared boys and girl controls on age, intellectual estimates, and performance on each level of the experimental measure.

To determine whether the range of scores across the four scales were normally distributed, Kolmogrov Smirnov analyses were run to ensure the appropriateness of the statistical analyses to be performed.

MD Probands

To determine whether children with MD performed similarly on each scale of the test, multiple paired t-tests were run. All six possible comparisons (Object versus Face, Object versus Affect, Object versus Situation, Face versus Affect, Face versus Situation,

and Affect versus Situation), were run. The null hypothesis that performance will be equivalent on each test level, as it is in normally developing children, was tested. To control for multiple comparisons, the Bonferoni correction was applied. Alpha was set at 0.008 (0.05/6).

Sibling Pairs

To determine whether within family proband-sibling pairs of comparable age and non-verbal intellectual level differed on the four test measures, paired *t*-tests were run. The null hypothesis that children who share family genetic and environmental background and are of similar age will perform similarly across each level of the test measure was tested. To control for multiple comparisons, the Bonferoni correction was applied. Alpha was set at 0.012 (0.05/4).

Relation to Parent Report

To determine whether within the group of children with MD the poor affect recognition was related to poor social skills as would be expected of children with PDD, a post hoc chi-square analysis was run. The children with MD were segregated into two groups: (1) those for whom raw scores on the Affect level were below their scores on the Faces level ($n = 33$), and (2) those for whom scores on both levels were comparable or the Faces' score was lower ($n = 17$). We hypothesized that if poor affect matching is associated with PDD, then those children with MD who score lower on Affect matching will also be those who are reported as having significantly increased social problems. The Social Problem *T* scores from the Child Behavior Checklist were segregated into those with a *T*-value greater than or equal to 70 (or two standard deviations above the expected norm, the ''clinically significant'' range) and those with Social Problem *T*-values below 70 to select only those children who have marked social skill deficits by parent report. Eight children from the group had very elevated ($T \geq 70$) social problem scores.

Results

Participant characteristics are presented in Table 1. The twenty boys with MD in the matched samples were also members of the large sample. For the between-group comparisons, mean ages and Ravens scores did not differ. Controls did, however, perform slightly better on the PPVT-III than the boys with MD.

Control characteristics segregated by gender indicated that girls and boys did not differ with respect to age, intellectual estimates, or performance on three of the experimental test levels. On one experimental level, Situations, the control brothers performed better than the control sisters (mean, SD: boys 14.54, 1.29, girls 13.28, 0.95, $t = 2.21$, $p = 0.04$).

The scores for the groups of fifty probands and the twenty probands included in the paired analyses were normally distributed across each test level. The scores for the sibling group ($n = 20$) were normally distributed for the Object, Affect and Situation levels of the test. For the Face level, however, scores were skewed such that the majority of responses were at the high end of the distribution (Kolmogrov–Smirnov $z = 1.6$, $p < 0.01$). The positive skewing of the distribution for the control group indicates that control subjects consistently did well on the Face matching level and there was little variation across the group.

MD Probands

To examine relative performance of the subjects with MD across the different task levels, six paired *t*-tests examining all possible comparisons were run. Results are presented in Table 2. The MD group consistently performed more poorly on the Affect Recognition level relative to other task levels, with differences observed on all three comparisons. Only the Face versus Affect and Situation versus Affect comparisons were significantly different at an alpha level of 0.008. On average, subjects with MD got one to two fewer items correct on the Affect level than on the Object, Face or Situation levels.

Within the proband group, boys with either Duchenne or Becker MD were included. To ensure there were no confounding effects related to illness type, repeat analyses were run after removing the four boys with the more mild diagnosis of Becker's MD. Results indicated that the findings were the same as with the combined Duchenne–Becker group and only performance on the Affect level was lower than the other levels (Face-Affect paired t (1,47) = 3.68, $p = 0.001$; Affect-Situation paired t (1,47) = 3.07, $p = 0.004$).

Sibling Pairs

Results from four paired *t*-tests between probands and their siblings on each level of the task are presented in Table 3. After controlling for multiple comparisons, no significant between-group findings were found at an alpha level of 0.01. Yet, probands on average got two

Table 1 Participant characteristics

	50 boys w/MD	20 boys w/MD	20 siblings	Paired-*t* (1, 19)	*p*-value
Age in years					
Range	4–12	4–12	4–12	0.34	Ns
Mean, SD	8.92, 2.33	8.84, 2.51	8.32, 2.12		
PPVT-III SS					
Range	67–159	67–159	82–160	2.81	0.01
Mean, SD	101.96, 18.94	104.91, 21.34	112.91, 17.59		
Ravens CPM					
Range	78–130	78–127	90–135	1.16	Ns
Mean, SD	100.86, 12.65	100.56, 13.87	109.10, 12.68		

The 20 boys with MD were also included in the group of 50 boys with MD. Matched comparisons were done on the 20 proband-sibling pairs. *MD* = Duchenne or Becker muscular dystrophy. *Ns* = non-significant. *SD* = standard deviation. *PPVT-III* = Peabody Picture Vocabulary Test-III. *SS* = standard score. *Ravens CPM* = Ravens Colored Progressive Matrices

Table 2 Within-test performance for 50 boys with MD

Comparison	Range of differences	Mean difference	Standard deviation	Paired-*t* (*df* 1,49)	p-value
1. Object-Face	–5, +5	–0.72	2.40	2.21	Ns
2. Object-Affect	–6, +10	1.22	3.70	2.33	Ns
3. Object-Situation	–6, +5	–0.40	2.66	1.01	Ns
4. Face-Affect	–4, +12	1.94	3.46	3.96	0.000
5. Face-Situation	–5, +6	0.29	2.34	0.83	Ns
6. Affect-Situation	–9, +6	–1.51	3.18	3.19	0.003

fewer items correct on the Affect level than their siblings, and the data suggest a trend toward significance ($p = 0.02$) that might be confirmed with a larger sample size. The two groups performed similarly on the Object, Face and Situation levels.

Relation to Parent Report

All participants with MD whose scores on the CBCL Social Problems scale was in the ''clinically significant'' range (*T* score ≥70, $n = 8$) were in the group who did more poorly in Affect than Face matching ($n = 33$) ($\chi^2 = 4.91$, $p < 0.05$). Thus, among children with MD, poor affect matching was associated with increased social problems.

Discussion

These data demonstrate that boys with MD: (1) can visually discriminate objects and faces accurately, (2) can perform most levels of a visual matching-to-sample test similarly to their unaffected siblings, (3) can discern appropriate affect for situations, and (4) have subtle deficits in their abilities to match affect accurately. Children with MD showed subtle difficulties in facial affect recognition. This was demonstrated in within-group analyses (where they consistently made one to two more errors in the Affect matching condition than they did in the other conditions), and was suggested in the between-group analysis (where they tended to make an average of two errors more than did their siblings). Thus, although the overall effect size was small (0.58 for the sibling comparisons), children with MD demonstrated a selective impairment in facial affect matching. Moreover, among children with MD, parent report of having pronounced social skill problems was associated with poor affect matching.

The current findings are comparable to the work done with children with PDD using the same measure (Braverman et al., 1989; Ozonoff et al., 1992). Just as was observed in PDD, the Affect condition was the one area that children with MD showed poorer performance relative to controls matched for non-verbal intelligence. And, just as in PDD, the overall effect size was modest. Yet, notably different from

Table 3 Between-group performance on matched sibling pairs

Measure	20 boys with MD range, mean, SD	20 siblings range, Mean, SD	Paired-*t* *df* (1,19)	*p*-value
Objects	6–16, 12.35, 2.50	9–16, 12.90, 2.10	1.15	Ns
Faces	9–15, 13.25, 1.58	8–15, 13.55, 1.93	0.52	Ns
Affects	5–15, 10.95, 2.74	9–16, 13.15, 1.93	2.59	0.02
Situations	9–16, 12.94, 2.23	9–16, 14.05, 1.30	1.72	Ns

PDD, children with MD were diagnosed based on traits other than their behavioral characteristics. In PDD, a crucial aspect of the behavioral diagnosis is compromised social skills, which is associated with an impaired understanding of emotion. This can be observed across a number of areas, including limited understanding and use of speech prosody, limited understanding of the emotional context of a situation, limited or inappropriate display of emotions, in addition to limited recognition of emotions.

The current study examined only recognition of facial affect and recognition of affect-laden situations. The investigation was not comprehensive, so no diagnoses of PDD can be made on the basis of these data. Interestingly, the children with MD did not show an effect of compromised understanding of affect in context, as expected of some children with PDD, and contrary to our initial hypothesis. Rather, the boys with MD performed comparably on the Situation matching condition to the Object and Face matching conditions. Thus, it appears that the children with MD understand contextual information appropriately, at least within the scope measured. Given that the majority of children with MD were not diagnosed with PDD, their presumed difficulties with social skills are by definition less pervasive than those with such a behavioral diagnosis. Nonetheless, if children with MD are less adept at processing facial affect cues than their peers, this may have real impact on their daily interactions with others.

These data add to the growing body of literature that indicates children with MD have a select cognitive and behavioral profile. In addition to impairments in immediate verbal memory, language and academic skills, children with MD demonstrate a selective difficulty on matching facial affect. This, taken together with increased parental reports of social skills problems, is suggestive of a behavioral cluster that is similar to that seen in mild PDD. However, of the fifty boys who were recruited based on their MD diagnosis, only three had been diagnosed with PDD as well. To ensure that these three children were not the main contribution to the observed effects, the analyses were repeated on the forty-seven boys with MD who did not have any diagnosis of PDD. The findings remained the same; only performance on the Affect level was lower than the other levels (Face-Affect paired t (1,46) = 3.38, $p = 0.000$; Affect-Situation paired t (1,46) = 3.08, $p = 0.004$).

To determine whether there was a bias for affect type among the group with MD, a post hoc error analysis was done. No a priori hypothesis was formed, but the question of whether children with MD may process some facial affects better than others was explored. For each subject, each affect item that was incorrect was examined and the selected response was noted. Tallies of both which item types (happy, angry, sad, and frightened) were more likely to be missed and which affect types were most likely to be chosen in error were calculated. Overall, some items were more likely to be missed than others, but no evidence of a particular affect type being susceptible either to being missed or to being chosen in error was noted. Across subjects and items, no bias for or against any particular facial affect was found.

One notable difference between the proband and sibling groups is that the children with MD are all male while their siblings are either male or female. Examination of the control data comparing age, PPVT, Ravens, and each level of the experimental measure between the control boys and girls demonstrated no differences on most measures. There was a difference between the control boys and girls on the Situation level of the test; yet the girls scored lower than the boys, so gender was not exacerbating the differences between the boys with DMD and the combined control group. When the combined sibling group was compared to the boys with MD, there was a trend for boys with MD to perform more poorly on the Affect level. Additionally, in the within-group analysis examining only the boys with MD, the Affect level was demonstrated to be the lowest. Taken together, this evidence suggests that the mixed gender of the comparison group is not responsible for the findings of lower performance on the Affect matching observed in the MD group.

Although the possibility that the physical disability associated with MD may contribute to poor affect recognition cannot be definitively ruled out, the evidence suggests that the genetic basis of MD and the subsequent effects on the developing nervous system are the basis for the cognitive and behavioral phenotype observed. When the four children with Becker's were removed from the current analyses, the results did not differ. Moreover, the data from the four participants with Becker's MD indicated that they all performed more poorly on Affect than Face matching, with individual scores ranging from 1 to 5 fewer items correct on Affect than Face matching items. This suggests that the severity of physical presentation in MD is not the primary factor influencing affect recognition. Studies comparing children with MD to physically disabled children with a different neuromuscular disorder, spinal muscular atrophy (SMA), have demonstrated that the children with MD are selectively worse on IQ tests and in language and

reading skills than those with SMA (Billard et al., 1992, 1998; Ogasawara, 1989; Whelan, 1987). When physical characteristics are statistically controlled for, children with MD still perform significantly worse in all academic areas than their unaffected siblings (Hinton et al., 2004). And parental reports of behavior in children with MD demonstrated significantly more social problems than observed in children with cerebral palsy or other chronic illnesses (Hinton et al., in press). Further, given the design of the Object-Face-Affect-Situation matching test, and the finding that children with MD do similarly to their siblings on most levels, the possibility that these findings are driven by physical impairment seems remote.

Rather, we propose that the poor affect recognition is due to the underlying etiology of MD. The mutated gene results in a lack of dystrophin isoforms in the developing central nervous system, which likely predisposes children with MD to have selective cognitive and behavioral difficulties. Lack of dystrophin products in cerebral cortical and cerebellar areas may impact on the structure of the developing brain and interfere with the functioning of specific brain networks. Results from PET scan data indicate hypometabolism in areas where dystrophins are missing (Lee et al., 2002). Significant cerebellar hypometabolism has been demonstrated both in children with MD and those diagnosed with autism, suggesting perhaps a shared brain mechanism that contributes to the behavioral profile that includes language difficulties, poor social skills and modestly impaired facial affect recognition. Further assessment of both social and interpersonal skills and brain function in children with MD is necessary to delineate the full behavioral phenotype associated with the disorder.

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References

Achenbach, T.M. (1991). *Manual for the child behavior checklist/4-18 and 1991 Profile*. Burlington, VT: University of Vermont, Department of Psychiatry.

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

Anderson, J.L., Head, S.I., Rae, C., & Morley, J.W. (2002). Brain function in Duchenne muscular dystrophy. *Brain, 125*, 4–13.

Billard, C., Gillet, P., Barthez, M.-A., Hommet, C., & Bertrand, P. (1998). Reading ability and processing in Duchenne muscular dystrophy and spinal muscular atrophy. *Developmental Medicine and Child Neurology, 40*, 12–20.

Billard, C., Gillet, P., Signoret, J.L., Uicaut, E., Bertrand, P., Fardeau, M., Barthez-Carpentier, M.A., & Santini, J.J. (1992). Cognitive functions in Duchenne muscular dystrophy: A reappraisal and comparison with spinal muscular atrophy. *Neuromuscular Disorders, 2*, 371–378.

Bolte, S., & Poustka, F. (2003). The recognition of facial affect in autistic and schizophrenic subjects and their first-degree relatives. *Psychological Medicine*, *33*(5), 907–915.

Braverman, M., Fein, D., Lucci, D., & Waterhouse, L. (1989). Affect comprehension in children with pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 19*(2), 301–316.

Bushby, K.M., Appleton, R., Anderson, L.V., Welch, J.L., Kelly, P., & Gardner-Medwin, D. (1995). Deletion status and intellectual impairment in Duchenne muscular dystrophy. *Developmental Medicine and Child Neurology*, *37*(3), 260–269.

Cotton, S., Voudouris, N.J., & Greenwood, K.M. (2001). Intelligence and Duchenne muscular dystrophy: Full-scale, verbal, and performance intelligence quotients. *Developmental Medicine and Child Neurology, 43*, 497–501.

Critchley, H.D., Daly, E.M., Bullmore, E.T., Williams, S.C., Van Amelsvoort, T., Robertson, D.M., Rowe, A., Phillips, M., McAlonan, G., Howlin, P., & Murphy, D.G. (2000). The functional neuroanatomy of social behaviour: Changes in cerebral blood flow when people with autistic disorder process facial expressions. *Brain, 123*(Pt 11), 2203–2212.

Cyrulnik, S., Fee, R., Kiefel, J., & Hinton, V.J. (2004). Preschool children with Duchenne muscular dystrophy exhibit deficits in communication skills and social skills that are characteristic of Pervasive Developmental Disorder. *Proceeding of the 33rd International Neuropsychology Society Annual Meeting*, Baltimore, MD, p. 48.

Darke, J., Bushby, K., Couteur, A.L, & McConachie, H. (2006). Survey of behaviour problems in children with neuromuscular diseases. *European Journal of Paediatric Neurology, 10*(3), 129–134.

Darwin, C. (1872). The expression of emotions in man and animals. London: Albermarle.

Dorman, C., Hurley, A.D., & D'Avignon, J. (1988). Language and learning disorders of older boys with Duchenne muscular dystrophy. *Developmental Medicine and Child Neurology, 30*, 316–327.

Dunn, L.M., & Dunn, L.M. (1997). *Examiner's manual for the PPVT-III peabody picture vocabulary test third edition* (3rd ed.). Circle Pines, MN: American Guidance Service.

Dykens, E.M., & Hodapp, R.M. (2001). Research in mental retardation: Toward an etiologic approach. *Journal of Child Psychology and Psychiatry, 42*, 49–71.

Ekman, P. (1994). Strong evidence for universals in facial expressions: A reply to Russell's mistaken critique. *Psychological Bulletin, 115*, 268–287.

Ekman, P., & Friesen, W.V. (1971). Constants across cultures in the face and emotion. *Journal of Personality and Social Psychology, 29*, 288–298.

Ekman, P., Friesen, W.V., & Ellsworth, P. (1972). *Emotion in the human face: Guidelines for research and an integration of findings*. New York: Pergamon.

Fein, D., Lucci, D., Braverman, M., & Waterhouse, L. (1992). Comprehension of affect in context in children with pervasive developmental disorders. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 33*(7), 1157–1167.

Felisari, G., Martinelli Boneschi, F., Bardoni, A., Sironi, M., Comi, G.P., Robotti, M., Turconi, A.C., Lai, M., Corrao, G., & Bresolin N. (2000). Loss of Dp140 dystrophin isoform and intellectual impairment in Duchenne dystrophy. *Neurology*, *55*(4), 559–564.

Gross, T.F. (2004). The Perception of four basic emotions in human and nonhuman faces by children with autism and other developmental disabilities. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 32*(5), 469–480.

Haxby, J.V., Hoffman, E.A., & Gobbini, M.I. (2002). Human neural systems for face recognition and social communication. *Biological Psychiatry, 51*(1), 59–67.

Herba, C., & Phillips, M. (2004). Annotation: Development of facial expression recognition from childhood to adolescence: Behavioural and neurological perspectives. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 45*(7), 1185–1198.

Hinton, V.J., De Vivo, D.C., Fee, R., Goldstein, E., & Stern, Y. (2004). Investigation of poor academic achievement in children with Duchenne muscular dystrophy. *Learning Disabilities Research and Practice, 19*, 146–154.

Hinton, V.J., De Vivo, D.C., Nereo, N.E., Goldstein, E., & Stern, Y. (2000). Poor verbal working memory across intellectual level in boys with Duchenne dystrophy. *Neurology, 54*, 2127–2132.

Hinton, V.J., De Vivo, D.C., Nereo, N.E., Goldstein, E., & Stern, Y. (2001). Selective deficits in verbal working memory associated with a known genetic etiology: The neuropsychological profile of Duchenne muscular dystrophy. *Journal of the International Neuropsychological Society, 7*, 45–54.

Hinton, V.J., Nereo, N.E., Fee, R., & Cyrulnik S. (in press). Social behavior problems in boys with Duchenne muscular dystrophy. *Journal of Developmental and Behavioral Pediatrics.*

Hobson, P.R. (1986a). The autistic child's appraisal of expressions of emotion. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 27*, 321–342.

Hobson, P.R. (1986b). The autistic child's appraisal of expressions of emotion; a further study. *Journal of Child Psychology and Psychiatry and Allied Disciplines*, *27*, 671–680.

Kaplan, L.C., Osborne, P., & Elias, E. (1986). The diagnosis of muscular dystrophy in patients referred for language delay. *Journal of Child Psychology and Psychiatry and Allied Disciplines, 27*, 545–549.

Klin, A., Sparrow, S.S., de Bildt, A., Cicchetti, D.V., Cohen, D.J., & Volkmar, F.R. (1999) A normed study of face recognition in autism and related disorders. *Journal of Autism and Developmental Disorders, 29*(6), 499–508.

Koenig, M., Hoffman, E.P., Bertelson, C.J., Monaco, A.P., Feener, C., & Kunkel, L.M. (1987). Complete cloning of the Duchenne muscular dystrophy (MD) cDNA and preliminary genomic organization of the MD gene in normal and affected individuals. *Cell*, *50*, 509–517.

Komoto, J., Usui, S., Otsuki, S., & Terao, A. (1984). Infantile autism and Duchenne muscular dystrophy. *Journal of Autism and Developmental Disorders, 14*(2), 191–195.

Lee, J.S., Pfund, Z., Juhasz, C., Behen, M.E., Muzik, O., Chugani, D.C., Nigro, M.A., & Chugani, H.T. (2002). Altered regional brain glucose metabolism in Duchenne muscular dystrophy: a pet study. *Muscle Nerve, 26*(4), 506–512.

Mehler, M.F. (2000). Brain dystrophin, neurogenetics and mental retardation. *Brain Research Reviews, 32*, 277–307.

Moizard, M.P., Billard, C., Toutain, A., Berret, F., Marmin, N., & Moraine, C. (1998). Are Dp71 and Dp140 brain dystrophin isoforms related to cognitive impairment in Duchenne muscular dystrophy? *American Journal of Medical Genetics, 80*(1), 32–41.

Nelson, C.A. (1987). The recognition of facial expressions in the first two years of life: Mechanisms of development. *Child Development*, *58*(4), 889–909.

Ogasawara, A. (1989). Downward shift in IQ in persons with Duchenne muscular dystrophy compared to those with spinal muscular atrophy. *American Journal of Mental Retardation*, *93*, 544–547.

Ozonoff, S., Pennington, B.F., & Rogers, S.J. (1990). Are there emotion perception deficits in young autistic children? *Journal of Child Psychology and Psychiatry and Allied Disciplines, 31*(3), 343–361.

Pierce, K., Haist, F., Sedaghat, F., & Courchesne, E. (2004). The brain response to personally familiar faces in autism: Findings of fusiform activity and beyond. *Brain, 127*(Pt 12), 2703–2716.

Raven, J.C., Court, J.H., & Raven, J. (1990). *Coloured Progressive Matrices*. Oxford, UK: Oxford Psychologists Press.

Smith, R.A., Sibert, J.R., & Harper, P.S. (1990). Early development of boys with Duchenne muscular dystrophy. *Developmental Medicine and Child Neurology, 32*, 519–527.

Tanturn, D., Monaghan, L., Nicholson, H., & Stirling, J. (1989). Autistic children's ability to interpret faces: A research note. *Journal of Child Psychology and Psychiatry, 39*, 623–630.

Wang, A.T., Dapretto, M., Hariri, A.R., Sigman, M., & Bookheimer, S.Y. (2004). Neural correlates of facial affect processing in children and adolescents with autism spectrum disorder. *Journal of the American Academy of Child and Adolescent Psychiatry, 43*(4), 481–490.

Whelan, T.B. (1987). Neuropsychological performance of children with Duchenne muscular dystrophy and spinal muscular atrophy. *Developmental Medicine and Child Neurology, 29*, 212–220.

Wu, J.Y., Kuban, K.C., Allred, E., Shapiro, F., & Darras, B.T. (2005). Association of Duchenne muscular dystrophy with autism spectrum disorder. *Journal of Child Neurology, 20*(10), 790–795.

Zwaigenbaum, L., & Tarnopolsky, M. (2003). Two children with muscular dystrophies ascertained due to referral for diagnosis of autism. *Journal of Autism and Developmental Disorders, 33*(2), 193–199.