Imitation and Gesture Representation in Autism

by

Isabel Mary Smith

Submitted in partial fulfillment of
the requirements for the degree of
Doctor of Philosophy

at

Dalhousie University
Halifax, Nova Scotia
July, 1996

ISBN 0-612-16032-7

Name Isabel Mary Smith

Dissertation Abstracts International and *Masters Abstracts International* are arranged by broad, general subject categories. Please select the one subject which most nearly describes the content of your dissertation or thesis. Enter the corresponding four-digit code in the spaces provided.

PSYCHOLOGY - CLINICAL — SUBJECT TERM

0622 — SUBJECT CODE

UMI

Subject Categories

THE HUMANITIES AND SOCIAL SCIENCES

COMMUNICATIONS AND THE ARTS
Architecture 0729
Art History 0377
Cinema 0900
Dance 0378
Fine Arts 0357
Information Science 0723
Journalism 0391
Library Science 0399
Mass Communications 0708
Music 0413
Speech Communication 0459
Theater 0465

EDUCATION
General 0515
Administration 0514
Adult and Continuing 0516
Agricultural 0517
Art 0273
Bilingual and Multicultural 0282
Business 0688
Community College 0275
Curriculum and Instruction 0727
Early Childhood 0518
Elementary 0524
Finance 0277
Guidance and Counseling 0519
Health 0680
Higher 0745
History of 0520
Home Economics 0278
Industrial 0521
Language and Literature 0279
Mathematics 0280
Music 0522
Philosophy of 0998
Physical 0523
Psychology 0525
Reading 0535
Religious 0527
Sciences 0714
Secondary 0533
Social Sciences 0534
Sociology of 0340
Special 0529
Teacher Training 0530
Technology 0710
Tests and Measurements 0288
Vocational 0747

LANGUAGE, LITERATURE AND LINGUISTICS
Language
- General 0679
- Ancient 0289
- Linguistics 0290
- Modern 0291

Literature
- General 0401
- Classical 0294
- Comparative 0295
- Medieval 0297
- Modern 0298
- African 0316
- American 0591
- Asian 0305
- Canadian (English) 0352
- Canadian (French) 0355
- English 0593
- Germanic 0311
- Latin American 0312
- Middle Eastern 0315
- Romance 0313
- Slavic and East European 0314

PHILOSOPHY, RELIGION AND THEOLOGY
Philosophy 0422
Religion
- General 0318
- Biblical Studies 0321
- Clergy 0319
- History of 0320
- Philosophy of 0322

Theology 0469

SOCIAL SCIENCES
American Studies 0323
Anthropology
- Archaeology 0324
- Cultural 0326
- Physical 0327

Business Administration
- General 0310
- Accounting 0272
- Banking 0770
- Management 0454
- Marketing 0338

Canadian Studies 0385
Economics
- General 0501
- Agricultural 0503
- Commerce-Business 0505
- Finance 0508
- History 0509
- Labor 0510
- Theory 0511

Folklore 0358
Geography 0366
Gerontology 0351
History
- General 0578
- Ancient 0579
- Medieval 0581
- Modern 0582
- Black 0328
- African 0331
- Asia, Australia and Oceania 0332
- Canadian 0334
- European 0335
- Latin American 0336
- Middle Eastern 0333
- United States 0337

History of Science 0585
Law 0398
Political Science
- General 0615
- International Law and Relations 0616
- Public Administration 0617

Recreation 0814
Social Work 0452
Sociology
- General 0626
- Criminology and Penology 0627
- Demography 0938
- Ethnic and Racial Studies 0631
- Individual and Family Studies 0628
- Industrial and Labor Relations 0629
- Public and Social Welfare 0630
- Social Structure and Development 0700
- Theory and Methods 0344

Transportation 0709
Urban and Regional Planning 0999
Women's Studies 0453

THE SCIENCES AND ENGINEERING

BIOLOGICAL SCIENCES
Agriculture
- General 0473
- Agronomy 0285
- Animal Culture and Nutrition 0475
- Animal Pathology 0476
- Food Science and Technology 0359
- Forestry and Wildlife 0478
- Plant Culture 0479
- Plant Pathology 0480
- Plant Physiology 0817
- Range Management 0777
- Wood Technology 0746

Biology
- General 0306
- Anatomy 0287
- Biostatistics 0308
- Botany 0309
- Cell 0379
- Ecology 0329
- Entomology 0353
- Genetics 0369
- Limnology 0793
- Microbiology 0410
- Molecular 0307
- Neuroscience 0317
- Oceanography 0416
- Physiology 0433
- Radiation 0821
- Veterinary Science 0778
- Zoology 0472

Biophysics
- General 0786
- Medical 0760

EARTH SCIENCES
Biogeochemistry 0425
Geochemistry 0996
Geodesy 0370
Geology 0372
Geophysics 0373
Hydrology 0388
Mineralogy 0411
Paleobotany 0345
Paleoecology 0426
Paleontology 0418
Paleozoology 0985
Palynology 0427
Physical Geography 0368
Physical Oceanography 0415

HEALTH AND ENVIRONMENTAL SCIENCES
Environmental Sciences 0768
Health Sciences
- General 0566
- Audiology 0300
- Chemotherapy 0992
- Dentistry 0567
- Education 0350
- Hospital Management 0769
- Human Development 0758
- Immunology 0982
- Medicine and Surgery 0564
- Mental Health 0347
- Nursing 0569
- Nutrition 0570
- Obstetrics and Gynecology 0380
- Occupational Health and Therapy 0354
- Ophthalmology 0381
- Pathology 0571
- Pharmacology 0419
- Pharmacy 0572
- Physical Therapy 0382
- Public Health 0573
- Radiology 0574
- Recreation 0575
- Speech Pathology 0460
- Toxicology 0383

Home Economics 0386

PHYSICAL SCIENCES
Pure Sciences
Chemistry
- General 0485
- Agricultural 0749
- Analytical 0486
- Biochemistry 0487
- Inorganic 0488
- Nuclear 0738
- Organic 0490
- Pharmaceutical 0491
- Physical 0494
- Polymer 0495
- Radiation 0754

Mathematics 0405
Physics
- General 0605
- Acoustics 0986
- Astronomy and Astrophysics 0606
- Atmospheric Science 0608
- Atomic 0748
- Electronics and Electricity 0607
- Elementary Particles and High Energy 0798
- Fluid and Plasma 0759
- Molecular 0609
- Nuclear 0610
- Optics 0752
- Radiation 0756
- Solid State 0611

Statistics 0463

Applied Sciences
Applied Mechanics 0346
Computer Science 0984
Engineering
- General 0537
- Aerospace 0538
- Agricultural 0539
- Automotive 0540
- Biomedical 0541
- Chemical 0542
- Civil 0543
- Electronics and Electrical 0544
- Heat and Thermodynamics 0348
- Hydraulic 0545
- Industrial 0546
- Marine 0547
- Materials Science 0794
- Mechanical 0548
- Metallurgy 0743
- Mining 0551
- Nuclear 0552
- Packaging 0549
- Petroleum 0765
- Sanitary and Municipal 0554
- System Science 0790

Geotechnology 0428
Operations Research 0796
Plastics Technology 0795
Textile Technology 0994

PSYCHOLOGY
General 0621
Behavioral 0384
Clinical 0622
Developmental 0620
Experimental 0623
Industrial 0624
Personality 0625
Physiological 0989
Psychobiology 0349
Psychometrics 0632
Social 0451

DALHOUSIE UNIVERSITY

FACULTY OF GRADUATE STUDIES

The undersigned hereby certify that they have read and recommend to the Faculty of Graduate Studies for acceptance a thesis entitled "Imitation and Gesture Representation in Autism"

by Isabel Mary Smith

in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Dated July 5, 1996

External Examiner [redacted]

Research Supervisor

Examining Committee

DALHOUSIE UNIVERSITY

DATE: 22 July 1996

AUTHOR: Isabel Mary Smith

TITLE: *Imitation and Gesture Representation in Autism*

DEPARTMENT: Psychology

DEGREE: Ph.D. CONVOCATION: October YEAR: 1996

[redacted]

Signature of Author

Dedicated to the memory of my father, G. Douglas Smith,
and my brother, Alexander G. Smith.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

ABSTRACT

The purpose of this dissertation was to integrate and extend the findings of previous studies of gesture imitation in autism. Major issues were the specificity of deficient gesture imitation to autism, and the qualitative analysis of imitation performance. Participants were 20 children and adolescents with autism, 20 children with receptive language delays (matched to the autistic group for age and language level), and 20 normally-developing children (matched to the clinical groups for language level). Children were individually tested on their ability to imitate nonsymbolic (meaningless) and symbolic manual gestures, consisting of single nonsymbolic postures, sequences of nonsymbolic postures, object-related pantomimes, and communicative gestures. Control tasks for recognition and/or comprehension of the gestures, for object use, and for manual dexterity were employed. Gesture production was videotaped for blind scoring both of overall accuracy, and for specific errors. Consistent with previous research, the children and adolescents with autism in this study performed relatively poorly on gesture production and imitation tasks. A novel finding was that imitation of simple posture sequences was unimpaired. This study showed that problems with imitation in autism were not due to delayed receptive language skills, or to impaired gesture recognition or comprehension. It was also demonstrated that significantly reduced manual dexterity for the participants with autism contributed to, but did not account for, their praxic deficits. Most importantly, a distinctive pattern of imitative deficits was observed for the autistic group, in the presence of intact gesture recognition. It was argued that a common deficit affects imitation of both symbolic and nonsymbolic actions by individuals with autism, and that understanding of this impairment may have both theoretical and practical significance.

ABBREVIATIONS AND SYMBOLS

ABC	Autism Behavior Checklist (Krug, Arick, & Almond, 1980a & b)
AS	Asperger syndrome
χ^2	Chi squared
DSM III-R	*Diagnostic and Statistical Manual of Mental Disorders*, 3rd edition, revised (American Psychiatric Association, 1987)
DSM IV	*Diagnostic and Statistical Manual of Mental Disorders*, 4th edition (American Psychiatric Association, 1994)
HFA	high-functioning autism
ICD 10	*International Classification of Diseases*, 10th edition (World Health Organization, 1992)
M	Mean
PDD	Pervasive Developmental Disorder
PPVT-R	Peabody Picture Vocabulary Test - Revised (Dunn & Dunn, 1981)
SD	Standard Deviation
TOMI	Test of Motor Impairment (Stott, Moyes, & Henderson, 1984)
WAIS-R	Wechsler Adult Intelligence Scale - Revised (Wechsler, 1981)
WISC-R	Wechsler Intelligence Scale for Children - Revised (Wechsler, 1974)
WISC-III	Wechsler Intelligence Scale for Children - 3rd edition (Wechsler, 1991)

ACKNOWLEDGEMENTS

My thanks go first to Susan Bryson, with whom I have had the pleasure of working since 1984. She has been both my employer and my supervisor, and always a mentor and friend; she excels in all of these roles. It will be a privilege to continue our association as colleagues.

I had the advantage of an excellent committee, each of who contributed significantly to this dissertation. I thank Ray Klein, John Barresi, and John Fisk for the considerable time and thought they have devoted to this work, and for their support.

I am grateful to all of the children and families who generously gave their time, as well as to the various professionals who provided assistance.

I also thank Brad Frankland and Dr. Robert Rodger for their statistical advice, Carol Thompson and Paula Bennett for their careful attention to the scoring, and the multitalented Dr. Brian Doan, who drew the illustrations for the gesture comprehension task.

Over the years, the support and encouragement of friends in the Dalhousie Psychology Department and the IWK-Grace Psychology Department have made it seem worthwhile to continue working toward what felt like a distant goal.

When all is said and done, however, completing this dissertation was possible because of my family. Aidan and Molly helped by always putting graduate school into perspective for me. The contributions of William Hayes, PhD, are too varied and numerous to mention . . . he did it all.

INTRODUCTION

Autism is a developmental syndrome characterized by abnormalities of social behaviour, communication, and cognition. Although autism typically results in profound and lifelong disability, the symptoms can occur along a continuum of severity, both between individuals and over an individual's life span. For this reason, the term "autistic spectrum disorder" is sometimes used to convey the sense that individuals with different levels of intellectual functional and diverse behavioural manifestations of the disorder nonetheless share core features defining their autism. For example, the interpersonal impairment in autism may range from aloof indifference to social ineptitude and difficulty in comprehending the viewpoints of others. In some people with autism, communicative skills are essentially absent, with up to half of the population lacking speech (Bryson, Clark, & Smith, 1988; Lotter, 1966). While higher functioning people with autism may have mechanically correct (even pedantic) speech, their disability is in the use of language as a social mediator.

Autism is further characterized by a tendency to act on the environment in limited ways. This tendency may be manifested at the perceptual-motor level in such phenomena as stereotyped repetitive movements, or at the cognitive level in rigid and literal interpretations of words. In addition, a pervasive lack of spontaneity or initiative has been described (Kanner, 1943/1973). One striking feature that has social, communicative, and cognitive implications is the consistent report that people with autism do not readily imitate the actions of others. The extent to which the imitation problem reflects a symbolic (conceptual) deficit, as has been commonly held, or is due to underlying impairment in the programming of integrated movements (DeMyer et al., 1972; Jones & Prior, 1985) has not been adequately addressed. In fact, the two views are not mutually exclusive. Before appealing to a deficit at the conceptual level, a more fundamental inquiry into the representation of the movement components of actions and their associated functional (semantic) representations (Rothi, Ochipa, & Heilman, 1991; Vaina, 1983) should be considered. If there are basic problems at the level of how actions are represented, such deficits could contribute to the development of the social and cognitive manifestations of autism.

Although Kanner's (1943/1973) original description of the syndrome did not refer specifically to imitative skills, deficiencies in this area are frequently observed clinically. Communicative manual gestures tend not to be produced even by mute autistic children, which differentiates this group from children with nonautistic language impairment alone (Bartak, Rutter, & Cox, 1975). The diminished spontaneous use of conventional gestures is most pronounced for those gestures that serve expressive or interpersonal (e.g., "look at this"), as opposed to immediate instrumental (e.g., "I want") needs (Attwood, Frith & Hermelin, 1988; Baron-Cohen, 1989b). These findings are relevant to this discussion of the putative imitation deficit in autism. However, it seems obvious that the *spontaneous use* of conventional gestures must follow the learning of gestures through imitation. Precedence is therefore given here to data on imitation of representational and nonrepresentational gestures. Consideration will also be given to the more limited literature on the production and comprehension of pantomimed actions by children with autism, in light of the significance of these data for understanding the mental representation of objects and events.

Recent psychological literature on autism has heavily emphasized cognitive and social aspects of the disorder (e.g., Baron-Cohen, Tager-Flusberg, & Cohen, 1993; Hobson, 1993). For example, research has focussed on the autistic person's deficient "theory of mind" (e.g., Baron-Cohen, 1989a). In this literature, the ability to engage in joint attention and to imitate others are considered precursors to the development of the capacity to represent mentally the intentions of others (e.g., Hay, Stimson, & Castle, 1990). Mutual imitation is a prominent component of early caregiver-infant social interactions that some argue is essential to the development of self-awareness and awareness of others (Meltzoff, 1990). Through the recognition of correspondences between one's own activities and those with whom one interacts, a task requiring intermodal coordination, the foundation for the capacity to represent others' thoughts and feeling states is laid (Meltzoff & Gopnik, 1993). Deficiencies in the ability to imitate others' actions may thus contribute to the failure to develop a normal theory of mind (Barresi & Moore, 1996a; Meltzoff & Gopnik, 1993; Rogers & Pennington, 1991).

Rogers and Pennington (1991) have developed a model of autism in which abnormalities in early interpersonal abilities affect subsequent stages in a cascading fashion: lower level deficits then preclude the development of higher level social understanding. These authors thus identified the deficit as one specifically and primarily affecting social processes. In an earlier formulation, Dawson and Lewy (1989a&b) proposed that the complex processing demands of the information inherent in social situations exceed the capabilities of autistic infants, leading to an impaired capacity to engage in social exchanges (including mutual imitation). These impoverished early experiences then provide an inadequate basis for later developing social-cognitive abilities. Their model provides for a basic information-processing deficit that is nonsocial in nature but has particularly devastating consequences for social development. Dawson has also constructed an important link between empirical work on deficient imitation in autism and an approach to treatment (Dawson, 1991; Dawson & Galpert, 1990) based on evidence that children with autism are sensitive to being imitated by others (Dawson & Adams, 1984; Tiegerman & Primavera, 1984). These findings suggest that whatever the cause of the imitation problem, it is not simply one of recognizing correspondences between the actions of self and others.

Imitation in Autism

In this thesis, the evidence for a specific imitative deficit in autism is reviewed. Throughout, a distinction is made between movements, defined by physical properties, and actions (typically more complex, goal directed movements), defined by intentions. Such distinctions pose both theoretical and empirical dilemmas (Meijer & Roth, 1988), but they are useful (even necessary) in the present context. For example, imitation studies can focus on the match between the outcomes of an act (e.g., communication of an intended meaning through an approximated gesture), or on the match between the physical parameters of movements (e.g., positions of the fingers in a manual gesture). Essentially, these two approaches map onto two broad classes of imitation studies. In the first, imitation is an assay for the mental representation of events; this literature emphasizes the relationship between imitative ability and other cognitive milestones. The second approach emphasizes the impact of neurologically-based constraints on imitative action. The failure to distinguish among the conclusions of studies which adopt these alternative stances is a source of some confusion in the literature. Therefore, for the purposes of this thesis, these types of studies are reviewed separately where appropriate, prior to an integrated discussion of the conclusions.

In the first section, studies which emphasize the symbolic nature of imitation are reviewed. These are primarily in the Piagetian tradition (cf. Piaget, 1952). Next, those investigations which derive from a cognitive neuropsychological perspective are discussed. These studies tend to adopt a more molecular approach to the study of imitation. The intent of these reviews is to identify factors which appear to influence the ability of individuals with autism to imitate the actions of others. A more limited review of the literature on comparable abilities in children with nonautistic developmental difficulties follows. The summary discussion addresses issues such as the specificity of the deficit in autism, as well as the identifiable contributions of separate factors to imitative performance. The research described in later sections of this thesis then tests the contributions of some of these factors to the imitative performance of groups of children and adolescents with autism, as compared with control groups of normally-developing children and those with developmental language problems.

Imitation and Other Sensorimotor Skills

Much of the work on imitation in autism is derived from the tradition of Piaget (e.g., 1952), who emphasized the importance of imitation as a precursor of symbolic thought and thereby, of language. In this context, then, deficient imitative skills are construed as indications of an inability to represent mental events. Specifically, much has been made of the dissociation in autistic children between levels of imitative skill and other sensorimotor skills, notably object permanence. In Piaget's theory, these behaviours indicate, at their highest level of development, the capacity to form mental representations of objects or actions which are not directly accessible to perception (Piaget, 1962). By the age of approximately two years, coincident with the development of language, normal children have achieved this symbolic capacity through the gradual internalization of actions. The co-occurrence of these accomplishments reflects the fact that language requires abstract symbolic thinking. It is not surprising, given the delayed language development seen in autism, that prelinguistic skills should be similarly affected. The striking claim in a number of studies, however, is that sensorimotor abilities are not uniformly delayed in children with autism, and more important, that patterns of association among skills are different in autism than in normal development.

Uncontrolled studies. Curcio (1978), Dawson and Adams (1984), Morgan, Cutrer, Coplin, and Rodrigue (1989), and Abrahamsen and Mitchell (1990) each administered the Uzgiris and Hunt (1975) scales to autistic children (see Table 1 for study summaries). These ordinal scales are designed to evaluate

Table 1 Studies of the imitation and/or pantomime abilities of individuals with autism.

Author(s)	Sample		Controls	Imitation / Pantomime tasks	Results
	M CA[a]	Level of function			
Abrahamsen & Mitchell (1990)	5-10	Language range: 5-36 mo	None	Uzgiris-Hunt Scales, Vocal and Gestures (simple familar; sequence of familiar; unfamiliar visible; unfamiliar, invisible)	Imitation < object permanence; Better imitation by verbal children; Vocal imitation alone correlated with verbal ability
Bartak et al. (1975)	range 4-6 to 9-11	Nonverbal IQ >70	Dysphasic: nonverbal IQ match	Comprehension (point to object or picture appropriate to model's action) and production (cued by objects, pictures or words) of pantomimed actions	Autistic < controls in pantomiming use of object, miming action to verbal request, and naming modelled action
Charman & Baron-Cohen (1994)	11-8	Verbal MA *M* =3-10 Nonverbal MA *M* =7-1	MR: CA, verbal MA match	Novel actions with objects from Meltzoff (1988); Nonsymbolic gestures (familiar, unfamiliar visible, unfamiliar invisible)	Autistic=controls on both types of imitation tasks; ceiling effects
Curcio (1978)	8-1	All mute	None	Uzgiris-Hunt Scales, Gestures	Gesture imitation < other sensorimotor tasks
Curcio & Piserchia (1978)	10-8	"Some speech"	None	Object use (imitation); Object use (verbal direction); Non-symbolic hand movements	Pantomime immature; No difference between body- and object-directed pantomime; No problem with nonsymbolic imitation; Performance positively correlated with language
Dawson & Adams (1984)	5-1	*M* IQ = 57	None	Uzgiris-Hunt Scales, Gestures; Spontaneous imitation during play	Imitation < object permanence; Imitative ability associated with language and social fluency

Dawson et al. (1983)	range9 to 34	"Mild-moderate MR"; Normal IQ	Normal: sex, CA, handedness match	Manual postures (deaf alphabet; Berges & Lezine, 1965); Oral gestures and movements	Autistic showed increased right hemisphere activation with oral imitation; Autistic difficulty with accurate imitation
DeMyer (1975)	Not avail	*M* IQ's = 29, 47, 59	MR: *M* IQ = 70	Hand and finger movements: Model present/partial cues/ absent; Lower limb imitation (e.g., hopping)	High functioning autistic = controls, but inferior on lower limb tasks; Mid autistic < high on hand and finger imitation; Low autistic < all others, but = on lower limb tasks
DeMyer et al. (1972)	5-6	IQ range: <30-109	MR Minimal brain dysfunction	Manual postures and movements; Object use	Autistic imitation < controls; For autistic, body imitation < object use imitation
Hammes & Langdell (1981)	9-10	*M* MA[b] = 4-6	MR: sex, CA, MA match	Object use (imitation); Object use (verbal direction); Pretend and real object use; Object-action mismatch	Imitation of object use = controls; Pantomime with pretend object < controls; Autistic unable to imitate unconventional object use
Jones & Prior (1985)	8-7	*M* verbal MA = 4-4	Normal: CA match Normal: MA match	Hand and arm postures (Berges & Lezine, 1965); Arm and leg postures and movements	Imitation < controls; Autistic performance very variable; Most difficulty with tasks using two limbs
Morgan et al. (1989)	8-4	*M* MA = 3.0 ("with speech")	MR: sex, CA, MA match Normal: MA match	Uzgiris-Hunt Scales (Dunst revision), Vocal and Gestures	No group differences
Ohta (1987)	10-2	Nonverbal IQ > 70 (*M* = 85)	Mixed normal and hyperkinetic: CA, PIQ match Normal preschoolers	Finger and hand postures; "T" signs	Autistic showed "partial imitation " errors

Prior (1977)	11.0 11.8	*M* verbal IQ's = 72, 42.4	MR: sex, CA, IQ match for each group	Object use (picture cue; from Illinois Test of Psycholinguistic Abilities)	Autistic < controls
Rogers & McEvoy (1993)	15-6	*M* verbal IQ=84.8 *M* performance IQ=96.2	Mixed MR, learning disabled, attention deficit disorder; IQ match	Recognition and production; Nonsymbolic and symbolic gestures; Facial and manual movements; Object pantomime. Control tasks for recognition, motor ability, object use	Autistic < controls on all tasks except symbolic single hand movements and syumbolic facial gestures. No differences on control tasks. Few details available
Sigman & Ungerer (1984)	4-4	*M* MA = 2-9	MR: CA, MA match Normal: MA match	Uzgiris-Hunt Scales (Dunst revision), Vocal and Gestures; Casati-Lezine Scales	Autistic < controls in vocal and gesture imitation; Language and imitation correlated in all groups, but relationships with other sensorimotor skills different for autistic
Stone et al. (1990)	4.6	*M* IQ = 54.1	MR: CA, IQ match Hearing impaired: CA Language impaired: CA Normal: CA match	Body and object use (derived from DeMyer et al., 1972)	Autistic = lowest imitation scores; Imitation best predictor of groups in discriminant function analysis

[a] Chronological age
[b] Mental age

the child's level of development across the sensorimotor domains, as conceptualized by Piaget (1952). The imitation tasks in the Uzgiris-Hunt (1975) series progress from imitation of familiar single acts (or "schemes," such as patting an object), to combinations of familiar acts, to unfamiliar "visible" acts (i.e., those that can be observed by the actor, such as opening and closing a fist), to unfamiliar "invisible" actions (e.g., patting one's own head). Morgan et al. (1989) found no differences among autistic, retarded, and normal children with respect to imitation or other sensorimotor tasks, whereas differences were found in each of the other studies. In addition to a number of potentially critical subject variables that distinguish Morgan et al.'s study from others (e.g., all of the children had speech), all groups performed at or near ceiling levels on the tasks, which may explain the authors' anomalous results.

Curcio's (1978) main finding was that, for mute 4- to 12-year-old boys with autism, gestural imitation was the lowest-level ability (i.e., 9 of 12 children scored below Stage 5), but this impairment was often associated with near-ceiling levels of performance on the object permanence scale (i.e., no child scored below Stage 5). Dawson and Adams (1984) replicated Curcio's result with a somewhat younger group of children, finding that imitation ability was below the level of object permanence in 10 of 15 children (rather than equivalent as would be predicted). They demonstrated further that when the children were classified as relatively good or poor imitators, higher levels of both verbalization and social behaviours were associated with better imitative skills. Results for vocal and gestural imitation were not presented separately, although the Uzgiris - Hunt scales include both. Thus, it is unknown whether gestural imitation alone was related to other skills.

Together, these two studies of children with autism provide some indication that imitative skills are poorly developed relative to other skills and that imitative ability is correlated with linguistic and social development. Given the prevalence of echolalic speech in this population, the inability to imitate appears somewhat paradoxical (Abrahamsen & Mitchell, 1990). Investigators must be alert to the potential for spurious associations between amount of echolalic (vs. spontaneous) speech and ability to imitate, when the imitation measure includes both vocal and gestural tasks. On the other hand, Rogers and Pennington (1991) predicted dissociations between vocal and gestural imitation, on the basis of the hypothesis that neurological circuitry for immediate verbal repetition is preserved in autism (as in transcortical sensory aphasia). They advocated including the presence of echolalia as a variable in imitation studies. Recently, Abrahamsen and Mitchell (1990) examined more specific associations among sensorimotor skills in a young, low-functioning group with autism, focussing on communicative speech (as opposed to nonfunctional forms of echolalia). They confirmed that expressive language was not correlated with level of object permanence; expressive language was related to imitative ability, but only to vocal imitation and not to the reproduction of gestures. Thus, the mechanisms underlying these two forms of imitation may indeed differ in autism, as Rogers and Pennington (1991) proposed.

Controlled studies. The selection of appropriate controls is critical in autism research (Hobson, 1991; Yule, 1978). A major shortcoming of the studies just described is that the children with autism were assessed only relative to the "ideal" inherent in the scales rather than either to norms or to the performance of controls. As noted by Sigman and Ungerer (1981), a correlation exists for normally developing children between imitative ability and language level but not between object permanence and language level (Bates, Benigni, Bretherton, Camaioni, & Volterra, 1979). Thus Sigman and Ungerer (1981) argued that the dissociations reported by Curcio (1978) and others may not be unique to autism. Because autism is always characterized by communicative impairment, usually in addition to general intellectual retardation (in approximately 75% of cases; Bryson et al., 1988), controls for each of these handicapping conditions are required.

Sigman and Ungerer (1984) administered sensorimotor tasks from Casati and Lézine's (1968) Piagetian scales and the Uzgiris-Hunt (1975) imitation scales to children with autism, and to appropriately matched controls (mentally retarded children matched to the children with autism for chronological age [CA] and mental age [MA] and normal MA-matched children). The basic claim of previous researchers was confirmed, in that deficits in both vocal and gestural imitation, relative to other cognitive skills, were specific to the children with autism. In addition, imitation skills (both vocal and gestural) were correlated with receptive language level for all three groups, as Bates *et al.* (1979) found for normal children. Vocal imitation and expressive language were correlated for the normal and autistic groups, consistent with Abrahamsen and Mitchell's (1990) results. In contrast, other sensorimotor tasks (including object permanence) were correlated with language comprehension (not production) only for normal and mentally retarded children. Within the group with autism, few consistent relationships were seen. Imitation appeared to be related to level of language comprehension for all groups. However, on the basis of the evidence just described, it seems reasonable to conclude that imitation, particularly of gestures, is differentially impaired for autistic children, in comparison with normal and mentally retarded children of matched general developmental levels.

Stone, Lemanek, Fishel, Fernandez, and Altemeier (1990) attempted to control for level of language development, to ascertain the autism-specificity of the imitative deficit. They investigated play behaviours and imitation skills in 3- to 6-year-olds, comparing the performance of children with autism with that of mentally retarded children (matched to the autistic group for CA and IQ) and groups of language impaired, hearing impaired, and normal children (all CA matched). Imitation ability was assessed with tasks derived from those of DeMyer et al. (1972); some were actions using objects and others were simple movements of the body alone. The autistic group obtained a significantly lower mean imitation score than any control group, and, in a discriminant function analysis, imitation was the best measure for distinguishing autistic from nonautistic children (among measures of functional and symbolic play). Although the autistic group was significantly more impaired on a measure of communication than was the language impaired group, analyses controlling for this variable suggested that language differences did not account for the imitation findings. This result requires replication with other samples and other measures of language. Of particular concern is that the measure chosen by Stone et al. (1990), the Communication subscale of the Childhood Autism Rating Scale (Schopler, Reichler, & Renner, 1988), includes the use of gestures in its rating of general communicative competence and thus is not independent of the variable of interest.

Summary. The studies just described, most of which have examined relationships between imitation and other symbolic skills, provide some support for the existence of a specific imitative deficit in autism but are uninformative as to its nature. For example, criteria for successful imitation have seldom been clearly defined. Imitation has been treated in some studies as an "all-or-none" phenomenon (as indicated by pass/fail scoring), that is, as a skill which is either present or absent, as opposed to one which may be assessed in terms of degree of accuracy to a model.

Although dimensions such as familiarity/novelty, complexity, and availability of visual feedback have varied within the sets of tasks used by the various investigators, the effects of these factors have not usually been examined systematically. Furthermore, the emphasis has tended to be placed on actions that are themselves symbolic or at least conventional: familiar pantomimed actions with real or imagined objects (e.g., drinking and hammering) or conventional communicative gestures (e.g., "OK" sign and salute). When deficits are seen on such tasks, questions remain as to whether the problem lies with attending to, perceiving, or remembering the details of the modelled action, with apprehending the meaning of the act (e.g., the function of the imagined object), or with actually executing the act. A more analytic approach which evaluates the contribution of such factors is required, if the imitative problem in autism is to be better understood.

Imitation and Praxis

The class of studies to be reviewed in this section adopts the view of imitation as a nonunitary skill. This point of view emphasizes the actual performance of the acts; that is, the form of the movements in addition to the intent (meaning) of the action. In contrast to the approach described above, the focus is on the limitations on action which autism might impose by way of a neurologically-based deficit. DeMyer et al. (1972) were the first to suggest that the autistic child's inability to imitate reflects a disturbance of "praxis". Acquired apraxia in adults is typically defined in terms of failure to carry out skilled (learned) movements in spite of intact elementary motor and sensory functioning (Liepmann, 1905/1980; Geschwind, 1975), although performance of novel movements is also characteristically impaired (Kimura & Archibald, 1975).

Symbolic versus nonsymbolic imitation. DeMyer et al. (1972) found that autistic children performed at a lower level than mentally handicapped controls on a series of imitation tasks. The tasks were derived from standard infant and preschool developmental scales and included both conventional (i.e., symbolic) and arbitrary (i.e., nonsymbolic) actions, either with objects or with the fingers and hands alone. DeMyer et al. reported that tasks without an object present were relatively more difficult for children with autism. They speculated that the absence of visual cues in this condition was critical, and that disturbances of visual memory (particularly pertaining to body image) might underlie the difficulties observed. Although this hypothesis merits further exploration, it must be noted that the presence of an object provides more than visual cues; for example, the degrees of freedom of possible movements are constrained when an object is in the hand (Rothi et al., 1991). This would facilitate imitation of an action using an object, but presumably especially so if the internal representation of the body were deficient.

In a later article, DeMyer (1975) examined differences in the abilities of autistic children at three levels of overall intellectual functioning to carry out various kinds of movements. The inability to imitate distinguished autistic children from nonautistic mentally retarded children and also differentiated among autistic children at different functional levels. However, the pattern of results is difficult to interpret. For example, the "middle-functioning" autistic group was more impaired in the imitation of arbitrary hand and finger movements than was the highest-functioning group, which did not differ from controls. In contrast, the highest-functioning autistic children had the greatest difficulty with leg movements. Conclusions based on the results of this study are limited by the lack of controls matched directly to the groups with autism, by the failure to distinguish between familiar (indeed highly practiced) conventional actions and novel movements, and by the lack of explicit scoring criteria.

On the basis of the work reviewed thus far, two main distinctions appear to be crucial: that between symbolic and nonsymbolic gestures and that between actions involving objects and bodily actions. If the imitative deficit in autism extends to arbitrary movements, it is difficult to regard it only as part of a general symbolic-linguistic impairment, as many have. Rather, a more basic and pervasive impairment in the ability to organize and represent actions may be involved.

Pantomimed actions with objects. The suggestion that bodily actions are relatively more impaired than actions involving objects is of particular interest in light of the social impairment in autism. It is not difficult to suppose, for example, that deficient early attention to the actions of others might impede the development of one's own self-awareness and body image (Ungerer, 1989) and thereby impair the ability to imitate others. Indeed, such an effect on body image has been suggested in cases of congenital sensory impairment (Ratner, 1985; Sonksen, Levitt, & Kitsinger, 1984). This is a less parsimonious argument than the suggestion above that imitation with objects is easier by virtue of the reduced degrees of freedom of movement possible when using an object. Nonetheless, it bears consideration when examining differences in the patterns of imitative ability seen in individuals with and without autism.

Curcio and Piserchia (1978) were among the first to recognize the potential importance of the distinctions just mentioned, which they pursued in a study of pantomimed symbolic actions. Children with autism had difficulty pantomiming actions involving imaginary objects (e.g., cutting with scissors), when provided with a real object toward which to direct the action (e.g., a piece of paper to "cut"). In contrast, 96% of nonsymbolic movements (e.g., clapping fists) were successfully imitated by the autistic children in this study. However, these were very simple nonsymbolic movements; moreover, because the criteria for success were unspecified and no control group was used, the significance of this finding is unclear. Unlike DeMyer et al. (1972), Curcio and Piserchia (1978) observed no difference between the autistic children's ability to copy pantomimed actions directed to objects (e.g., cut paper) versus actions directed to the body (e.g., comb hair). Again, lack of controls hinders interpretation; the body and object tasks were not equated for difficulty with normal or mentally retarded children. Furthermore, contextual cues (e.g., paper) were provided that might have primed the expected action.

Input modality and pantomimed actions. Curcio and Piserchia (1978) did demonstrate that for children with autism, copying a model conferred an advantage over verbal directions to carry out a given act, despite the general imitative problem. That is, the children's ability to generate a symbolic action after a verbal request was particularly impaired. This finding replicates in part the systematic work of Bartak et al. (1975), who included appropriate control groups.

Bartak et al.(1975) compared a group of high-functioning children with autism and a group of children with developmental receptive language disorders who were matched to the autistic group for nonverbal IQ and (as closely as possible) for level of language comprehension. Bartak et al. examined the comprehension and production of pantomimed actions, assessed with both verbal and visual (i.e., pictures and actual objects) modes of input and output. For the comprehension tasks, the experimenter mimed an action (e.g., throwing) without the relevant object. The child was asked either to name what the model was doing or to point to the appropriate picture or object in an array. For the production component, the child's task was to mime the use of an object when shown the object or a picture or when asked in words only to show the action. Children with autism were significantly less able than controls to gesture the use of an object (production: visual input), to mime an action to verbal request (production: verbal input), and to name an action when modelled by the experimenter (comprehension: verbal output). Direct imitation of actions was not assessed in Bartak et al.'s study. Prior (1977) also found that in both high- and low-functioning children with autism, the ability to pantomime use of an object in response to a picture was impaired, replicating the finding of Bartak et al. (1975). In her study, the control group consisted of mentally retarded, rather than language impaired children.

Hammes and Langdell (1981) demonstrated that in comparison with nonautistic children with mental retardation, those with autism had difficulty copying the actions of a model using imaginary and real objects together (e.g., pouring from an imaginary teapot into a real teacup). Of particular interest is a condition in which the child was given the "wrong" object to substitute in a pantomimed action (e.g., drinking from the toy teapot). In this condition, children with autism were far more likely than their counterparts with retardation alone either not to respond, or to use the object in the conventional way. Thus, although the imitation of simple, concrete actions with objects was relatively intact in their study, Hammes and Langdell (1981) argued that there was inflexibility in the application of these action representations to more complex imitative acts. The resulting deficit, very apparent in the "wrong" object condition, was that the behaviour of individuals with autism was highly contextually bound. That is, it appeared that the presence of cues to perform a familiar act overrode the modelled input.

Nonsymbolic imitation. Although the issues of body versus object imitation (Curcio & Piserchia, 1978), the dissociations between modalities of input and output (Bartak et al., 1975), and the effects of context (Hammes & Langdell,

1981) have not been pursued systematically, more recent work has confirmed that the imitative deficit in autism is not restricted to symbolic (learned, familiar) actions. Jones and Prior (1985) evaluated the hypotheses outlined by DeMyer et al. (1972) and DeMyer (1975), that the problems experienced by autistic children in imitating the actions of a model are due to neurological dysfunction affecting the organization of movements. Subjects were required to copy meaningless hand and arm postures and movements from the series developed by Bergès and Lézine (1965; standardized for young normal children) and a static and dynamic arm and leg series devised by the authors. The main finding was that children with autism were less successful than both CA- and MA-matched normal controls in reproducing these movements. It was also noted that performance within the autistic group was highly variable. The most difficult tasks for the autistic children involved integrating the activities of two limbs, or, possibly, integrating the left and right sides of the body (e.g., placing the two arms at different heights). In contrast with the tasks used by DeMyer et al. (1972), the models remained visible in Jones and Prior's study in an attempt to rule out the effects of simple visual memory differences between groups. However, this manipulation does not ensure that the models were accurately perceived and adequately encoded.

In addition, Jones and Prior (1985) assessed "soft" neurological signs (Shafer, Shaffer, O'Connor, & Stokman, 1983; Shaffer, O'Connor, Shafer, & Prupis, 1983) to evaluate the evidence for elementary problems of movement control indicative of neurological dysfunction. An increased incidence of these nonspecific indicators was seen in the autistic group; particularly common in this sample were problems of balance, isolated jerking movements of the hands and arms, and extinction to double simultaneous stimulation (i.e., failure to report one of two simultaneous, laterally presented tactile stimuli). No analysis of the relationships between individual scores on the soft signs battery and imitation performance was presented. Thus, although both measures differentiated the autistic group from young normals, the findings are not necessarily related for individual autistic children. A more important limitation of the Jones and Prior study was the failure to include mentally retarded or language impaired controls, in whom one might expect an increased incidence of soft signs (Shaffer et al., 1983) in the absence of an imitation deficit (Sigman & Ungerer, 1984).

Charman and Baron-Cohen (1994) assessed imitation in a group of children and adolescents with autism, compared with a control group of children with mental handicaps, matched for verbal mental age. In addition to the language-level matching, the contribution of this study was that the ability to imitate novel actions with objects (Meltzoff, 1988) was tested, as well as nonsymbolic gestures. No significant differences were reported between the autistic and control groups. This study had the potential to provide information of interest, relevant to the preceding discussion of possible differences between imitation of body movements versus imitation of actions with objects. However, it appears that ceiling effects on these tasks, which were scored only as imitation "present" or "absent", may account for the failure to find group differences. The demonstration that children with autism *can* learn to imitate simple nonsymbolic gestures, with and without objects is not very revealing. Among the more interesting questions might be: what features characterize unsuccessful imitative attempts by children with autism, and what factors account for the variability in autistic imitative performance?

Errors in nonsymbolic imitation. Ohta (1987) assessed the ability of a group of relatively high-functioning children with autism to reproduce arbitrary manual gestures, in comparison with two control groups. The first group was matched to the autistic group for age and Performance IQ (half of these children were normal and half were "hyperkinetic"); the other control group consisted of normal preschoolers. The tasks involved the reproduction of four one-handed gestures and six variations on Luria's bimanual "T" signs. Ohta (1987) reported that a particular type of error on the bimanual tasks was specifically associated with autism. These "partial imitations" were seen only rarely in the youngest controls and never in older controls but were observed quite frequently in the autistic participants (i.e., half of the children with autism showed this type of error on at least one of the last two bimanual T-sign tasks). Ohta interpreted partial imitation errors as indicating problems with the representation of the body image rather than motoric difficulties. Insufficient data about the errors was provided to permit evaluation of this claim, but Barresi and Moore (1996a) have suggested the intriguing possibility that these errors represent the attempts of the children with autism to reproduce the gesture so that their view of their own hands matches their view of the model. Regardless, Ohta's study, with that of Jones and Prior (1985), does suggest specific types of errors in the imitative performance of autistic subjects, permitting hypotheses about the nature of the deficit. For example, the errors highlighted in both studies involved the use of two limbs, and could derive from difficulty coordinating the left and right sides of the body.

Imitation and lateralization of functions. One other investigation, by Dawson, Warrenburg, and Fuller (1983), is relevant in the context of the above suggestion regarding left-right coordination difficulties. The focus of Dawson et al.'s (1983) research was on lateralized hemispheric activation during manual and oral imitation tasks. Manual tasks included reproducing letters of the deaf alphabet, in addition to postures and movements from

Bergès and Lézine's (1965) series. The oral tasks included both postures (e.g., protruded tongue) and movements (e.g., lips protruded, then retracted, with teeth clenched) and were performed without visual feedback. Normally, the left hemisphere is believed to guide skilled movements of both hands, as well as oral movements needed for speech (Kimura, 1982; Kimura & Archibald, 1974). Measures of right versus left hemisphere activation (electroencephalographic activity ratios) were increased in the autistic group in comparison with normal controls of the same ages, but only for oral tasks. That is, the normal pattern tended to be reversed for oral imitation in the autistic group. Although data on the actual performance of the tasks were not reported, the authors noted that accurate reproduction of these arbitrary actions was difficult for their high-functioning autistic participants. Again, because the focus of the study was patterns of cerebral specialization rather than imitative behaviour as such, conclusions are necessarily constrained. However, there is a strong suggestion that the quality of imitations produced by the autistic individuals differed from normals and that the cerebral processes associated with the production of some imitative actions might be differently organized in those with autism.

Additional evidence suggests that, in autism, hemispheric functions are organized atypically (for detailed discussions of cerebral dominance and peripheral motor asymmetries in autism, see Bryson, 1990; Dawson, 1988;

Fein, Humes, Kaplan, Lucci, & Waterhouse, 1984; and Kinsbourne, 1987). In general, one can conclude that autistic people display an increased incidence of left- or mixed-handedness, in addition to inconsistent hand preference across tasks (Bryson, 1990; Bryson, Porac, & Smith, 1994), and on a given task over time (Soper et al., 1986). Investigations of manual motor behaviour in autism must take these differences into account.

Summary: Imitation in Autism

It does appear that the pattern of low imitative ability relative to other sensorimotor skills obtained for autistic children is not seen in mentally handicapped controls, at the very least when the imitative tasks are predominantly of a familiar or symbolic nature (DeMyer et al., 1972; Sigman & Ungerer, 1984). In addition, autistic children's ability to produce symbolic actions either to the sight of an object associated with the action or to a verbal request is deficient (Bartak et al., 1975). Furthermore, it is clear that the imitative deficit extends to nonsymbolic, arbitrary gestures (Jones & Prior, 1985; Ohta, 1987; Rogers & McEvoy, 1993). That is, individuals with autism have difficulty not only duplicating the symbolic goal of an action but also reproducing the postures and movements that are the foundation of conventional (learned) gestures. The difference between these two senses of "imitation" and their implications for theories of autism needs to be explicitly addressed. In some circumstances, learning of simple novel actions may be intact (e.g., Charman & Baron-Cohen, 1994), but individuals with autism may lack flexibility in matching actions to contextual information (Hammes & Langdell, 1981; cf. Smith & Bryson, 1994).

Motor Skills in Autism

The integrity of basic motor skills is of importance with respect to praxic abilities in autism (Smith & Bryson, 1994). Kanner (1943/1973) reported in his original description of autism that although several of the children were "somewhat clumsy in gait and gross motor performances ... all were very skilful in terms of finer muscle coordination" (p.40). While the majority of children with autism are characterized as relatively dextrous and well-coordinated, Wing has proposed three autistic subtypes (Wing & Attwood, 1987; see also Castelloe & Dawson, 1993). The first consists of aloof, agile, well-coordinated children. In both other groups, gross motor clumsiness and/or impaired fine motor coordination are more common; these groups are distinguished by the quality of their social behaviour (i.e., "passive" versus "active, but odd" in their interactions, rather than "aloof"). The question of whether clinical features of the autistic syndrome are reliably associated with different patterns of motor skill, independent of the ability to imitate, remains unanswered.

The relationship between autism and the syndrome described by Asperger (Asperger, 1944/1991; Wing, 1981) is somewhat controversial (Bishop, 1989; Bowman, 1988; Green, 1990; Szatmari, Bartolucci, Finlayson, & Krames, 1986; Tantum, 1988). The essence of the debate is whether autism and Asperger syndrome are separate disorders or whether they merely occupy different regions on a continuum. Individuals with the two diagnoses share the core autistic deficits in social interaction and pragmatic communication, and have severely restricted and inflexible interests and behavioural routines. The manifestations of these deficits in childhood tend to be more subtle in Asperger's syndrome than in autism, although they are essentially indistinguishable from those seen in older, high-functioning people with autism (but see Ozonoff, Rogers, & Pennington, 1991, for a recent attempt to discriminate empirically between these groups).

Among the features that have been used to differentiate Kanner's from Asperger's syndromes are the relative impairment of motor skills and preservation of formal language and verbal fluency in people with Asperger's syndrome (Wing, 1981). Typically, individuals with Asperger's syndrome are characterized as having poor coordination, often involving both fine and gross motor skills (cf. Ghaziuddin, Tsai & Ghaziuddin, 1992). However, Manjiviona and Prior (1995) recently failed to find support for that contention in their comparison of children and adolescents with high-functioning autism (HFA) and Asperger syndrome (AS) on a standardized motor assessment battery (the Test of Motor Impairment - Henderson Revision, TOMI; Stott, Moyes, & Henderson, 1984).

Data from Manjiviona and Prior (1995) indicated that 50% of the HFA and 67% of the AS individuals presented with significant motor impairment, relative to norms. However, the two subgroups did not differ from each other, either in total scores, or on any of the three subscales of the TOMI (manual dexterity, ball skills, and balance). For all subjects, significant negative correlations were observed between the TOMI total scores and both Full-Scale and Performance IQ's. Manual dexterity scores and their relationships to other variables were not reported separately. Handedness was also not reported, although the authors noted anecdotally that at least 6 children showed hand-switching during some tasks, with an associated inability to report their preferred hand for that task. Manjiviona and Prior (1995) concluded that, on the basis of their findings, motor impairment was not a differentiating characteristic of HFA versus AS, within the autistic spectrum. Rather, their study provided an illustration of the heterogeneous manifestations of motor difficulties and their relationships to cognitive profiles in autism.

Manual motor skills. For the present purpose, further consideration will be given only to those studies that examined the manual motor skills of individuals with autistic spectrum disorders relative to controls, in view of the obvious potential contribution of these skills to differences in manual praxic abilities. (See Smith & Bryson, 1994, for additional discussion of the implications of motor deficits in autism.)

Szatmari, Tuff, Finlayson, and Bartolucci (1990) found that a combined group of high-functioning autistic (HFA) and Asperger syndrome (AS) individuals (ages 7 to 32) performed more slowly on the Grooved Pegboard than did a mixed group of outpatient psychiatric controls. These controls, however, had significantly higher Verbal and Performance IQ's than did the HFA/AS group. The Szatmari et al. (1990) study is therefore inconclusive with respect to the uniqueness of manual motor coordination deficits to autistic spectrum disorders. Their analyses are more revealing with respect to comparisons between the HFA and AS groups, that were matched for IQ. Both dominant and nondominant hand performance were significant variables in a discriminant function analysis predicting HFA versus AS diagnoses. Of interest in the Szatmari et al. (1990) study is that HFA participants did not show the typical dominant hand advantage, while individuals diagnosed with AS did. This finding may be related to that of McManus, Murray, Doyle and Baron-Cohen (1992), who reported a dissociation of manual preference and motor skill (assessed by the Annett pegboard task (Annett, 1970) in children with autism. In the same study, skill differences did not obtain for the group with autism, compared with verbal mental age matched, typically-developing controls. Children in a "learning disabled" (mentally retarded) control group were slower to complete the pegboard than those in either the autistic or normal groups, but had a significantly lower mean verbal mental age than did the normal group.

Rumsey and Hamburger (1988) compared adult men with high-functioning autism and normal controls on a neuropsychological battery that included the Grooved Pegboard. The two groups were matched for chronological age and for educational levels, and quite closely matched for IQ, with slightly lower mean Verbal and Performance IQ's for the autistic group ($p < .06$). A trend ($p < .06$) toward slower performance overall on the Grooved Pegboard for the men with autism was obtained. In addition, the authors described a tendency ($p < .07$) toward slower completion of the pegboard with the nondominant hand for the autistic group.

No clear picture emerges from these studies of manual motor skills. As with the research on imitation, the choice of control groups appears to have a great impact on the conclusions that may be drawn. As discussed above, there is a great deal of heterogeneity in motor skills apparent within the overall category of autistic spectrum disorder. Thus far, no simple relationship between diagnostic subgroups and motor skills has been observed. Perhaps additional information about the relationship between simpler motor abilities (such as those assessed by pegboard tasks) and praxic (imitative gesture and object use) abilities in individuals with autism would inform this debate.

Visual-Kinaesthetic Integration

Final related issues that bear mentioning in this context are the role of visual-kinaesthetic integration in imitation, and the intactness of cross-modal processing in autism. Successful imitation is assumed to demand the integration of visual and kinaesthetic information (Barresi & Moore, 1996a; Meltzoff, 1990; Rogers & Pennington, 1991; Smith & Bryson, 1994), although direct visual-visual matching is also possible (Barresi & Moore, 1996b; Hughes, 1996a). Meltzoff and Gopnik (1993) and Rogers and Pennington (1991) have argued that evidence of imitative deficits in autism suggests an early underlying failure to integrate cross-modal information specifying social interactions. Smith & Moore (in preparation) question whether such a deficit is necessarily specific to social information, as assumed by both Meltzoff and Gopnick (1993) and Rogers and Pennington (1991). Instead, they present an overview of the evidence for abnormal intersensory functioning in autism, and suggest that a nonspecific failure of intersensory integration might be implicated in the imitative impairment and, consequently in the development of the deficient social understanding that characterizes autism (cf.

Barresi & Moore, 1996a&b). Some illustrative evidence will be presented here; additional discussion of crossmodal functioning in autism can be found in Hermelin and O'Connor (1970), Prior (1979), DeMyer, Hingtgen, and Jackson, and Smith and Moore (in preparation).

Frith and Hermelin (1969) conducted an experiment comparing children with autism, children with mental retardation, and typically-developing children on a motor tracking task. The task required children to guide a stylus through grooved tracks which varied in regularity, under conditions either allowing or preventing visual guidance of hand movements. Thus, redundant visual and kinaesthetic information was available for carrying out the task in one condition, but only the felt position of the hand could be used in the other (i.e., the child's view of the hand was screened). The negative effect on motor control (as measured by the time to navigate the tracks) of eliminating visual information in the latter condition was significantly reduced for the children with autism, compared with both control groups. Frith and Hermelin (1969) concluded that the autistic group's relatively faster performance under the "no vision" condition was based on immediate feedback from kinaesthetic cues, reflecting reduced visual dominance.

Masterton and Biederman (1983) examined the performance of a low-functioning group of children with autism in a reaching task in which a prism was used to induce conflict between the seen and the felt positions of the hand. Following a pretraining phase, autistic children showed the same level of accuracy as mentally handicapped and young normal controls. After adaptation to reaching in the prism condition, the groups showed equivalent degrees of adaptation when tested with the adapted (right) hand. However, only the children with autism showed transfer of adaptation when tested with the left (unadapted) hand. Normally, visual dominance over proprioception results in adaptation being specific to the actively-adapted hand. Again, this study provides evidence of an unusual relationship between kinaesthetic and visual feedback in children with autism.

Hermelin (1976) argued that what distinguishes the performance of children with autism is their lack of flexibility in producing amodal representations of stimuli (see also Frith & Baron-Cohen, 1987). Instead, autistic representations were described as being stimulus-bound, in the sense that they remain tied to the sensory modality in which they were originally encoded. This is consistent with a failure to integrate multiple sources of information into higher-order perceptual representations. In the experimental work reported by Hermelin and O'Connor (1970), the predominant autistic perceptual coding strategy was spatial (versus temporal). However, when spatial information could be coded with reference either to a visual or to a tactile/proprioceptive context, the children used either strategy, depending on the demands of the specific task. Unfortunately, this formulation does not allow for specific predictions about the task conditions under which visual or proprioceptive dominance will be observed.

An alternative framework is provided by the theoretical account of visual dominance by Posner, Nissen, and Klein (1976) and Klein (1977). They postulated that when vision and kinaesthesis provide redundant sources of information, normal adults show a bias toward vision. This attentional bias was hypothesized to exist as a compensatory strategy, off-setting the low capacity of visual information to recruit attention. An explanation of unusual interactions among sensory modalities in autism in terms of abnormalities in basic attentional processes has been suggested by Smith & Moore (in preparation).

Summary: Imitation and Related Skills

What conclusions can be drawn from this literature review? The issue is not whether individuals with autistic spectrum disorders can produce any imitative responses at all (cf. Baron-Cohen, 1996), as it is clear that in all studies, some imitative behaviour was observed. The issues of importance include whether imitative skills are merely delayed in autism, or whether they differ qualitatively from those of other children, both typically-developing children and those with other developmental problems. Based on this review, it is argued that there is evidence for delay. However, a critical lack in most studies is that level of language functioning in the children with autism has not been adequately controlled, although the need has been recognized (e.g., Stone et al., 1990; Charman & Baron-Cohen, 1994). The importance of this control is underscored by the fact that in children with autism (as in normal children and those with intellectual retardation), the ability to imitate familiar gestures is correlated with language comprehension (Abrahamsen & Mitchell, 1990; Sigman & Ungerer, 1984). Similarly, a strong relationship in brain-damaged adults (between acquired apraxia and aphasia) is well documented (Kertesz, 1985), although the relationship between measures of language and imitation of meaningless gestures has not been closely examined in normally developing children.

The more tentative conclusions that may be drawn from this literature include the possibility that children with autism who differ in functional level (e.g., in terms of language or social ability) may exhibit distinct patterns of imitative performance (DeMyer et al., 1972), and/or motor skills. The debate regarding autistic subgroups is of relevance here, as motor skills, but not praxis, have been compared for high-functioning autistic and Asperger syndrome subgroups. There is also some suggestion that particular types of imitative errors may distinguish individuals with autism from controls (Ohta, 1987). Difficulty integrating the movements of different limbs (Jones &

Prior, 1985) might be an additional example of a type of error common in autism, and may be related to unusual patterns of both cerebral lateralization and handedness in this population (Dawson et al., 1983; McManus et al., 1992). Although Jones and Prior (1985) argued that visual memory impairment cannot account for the poor imitative performance of children with autism, testing recognition of the model gestures would be useful in dissociating encoding and production problems (Carroll & Bandura, 1990). This is of particular importance in view of evidence that the integration of visual and kinaesthetic information, required for accurate imitation, may be compromised in autism.

Recent Findings

Preliminary findings from an unpublished study have begun to address some of the critical issues outlined above. Rogers and McEvoy (1993) investigated the ability of high-functioning adolescents and young adults with autism to produce symbolic and nonsymbolic manual and facial gestures. Their study included controls for visual memory and motor ability, as recommended in the preceding review. The clinical controls were matched on age and IQ (verbal and full scale; also on sex, race and socioeconomic status), and had learning disabilities, attention deficit disorder, or mental retardation. Despite adequate memory and motor skill, the group with autism obtained lower scores on praxis tasks involving nonsymbolic hand and arm postures and sequences, and single and sequential facial movements. Pantomimed actions using common objects were also impaired in the individuals with autism. Performance of meaningful (symbolic) manual and oral gestures did not differentiate the autistic group from controls. These results suggest that in older, high-functioning people with autism, difficulty with imitation is largely an expressive problem, rather than one of recognition or comprehension. Further, the reported normal performance on symbolic gestures suggests that perhaps well-learned, familiar gestures can be accurately imitated by this population.

It is difficult to interpret Rogers and McEvoy's (1993) findings, as the brief report available does not provide sufficient information about the methods or results. However, on the basis of the available information, it appears that the study has some important limitations. Firstly, it was claimed that visibility and sequentiality of movements, as well as symbolic content, were manipulated. However, as with previous studies, "visibility" was confounded with type of movement (facial versus hand). Nonsymbolic movement sequences were compared with single movements only for facial (i.e., not for hand) movements, the details of which are not provided. Information on how pantomimed actions were elicited was also lacking in this preliminary report. Thus, although the Rogers and McEvoy (1993) study appears to have been the most comprehensive investigation of praxis in autism to date, full consideration of the implications of their findings must await the publication of the details of the study.

Praxis in Other Developmental Disorders

Despite considerable recent discussion of imitation problems associated with autism, little is known about the relationship between these and comparable problems in other developmentally handicapped populations. Roy, Elliott, Dewey, and Square-Storer (1990) defined praxis as the ability to perform gestures (meaningful or not) and to use tools; for them, "developmental dyspraxia" entails impairment in the acquisition of these functions.

Although the term developmental dyspraxia is commonly encountered in the child neurology and occupational therapy literatures, there is little consensus regarding its definition (Dewey, 1995). A number of different forms of apraxia have been described in adults; a detailed perspective is available in Roy (1985). There is general agreement that disruptions in motor acts can occur at various points in a process that begins with the conceptualization of the act and terminates in its execution. That is, the apraxias represent different degrees of impairment in what to do and/or how to do it (Freund, 1987). The resemblance with the previously-mentioned contrasting approaches to the study of imitation in children, focussing on either the conceptual or on the perceptual and motoric requirements of actions, is noteworthy.

Roy et al. (1990) have discussed the advantages of conceptualizing developmental dyspraxia in neuropsychological terms, based on adult models. However, others use the term more broadly than do Roy and his colleagues, often synonymously with "clumsy child syndrome" (Gubbay, 1975), referring to generalized problems of motor coordination (which are explicitly excluded in the definition of acquired apraxia). Cermak (1985) has highlighted differences between the literatures on adult-onset apraxia and developmental dyspraxia and has identified a number of parameters relevant to the description of praxic disorders. Despite differences in emphasis between studies of apraxic adults and dyspraxic children, the distinctions made are broadly similar including, for example, symbolic versus nonsymbolic gestures, and static postures versus dynamic sequences. Clinical apraxia examinations typically include performance of symbolic actions to verbal request in addition to imitation, and performance may also be elicited by showing an action-appropriate object (De Renzi, 1985). Cermak (1985) speculates that it may be possible to subcategorize forms of developmental dyspraxia, as with acquired apraxia, into types which are primarily conceptual, primarily executive, or a mixed type in which there are conceptual and executive problems.

Roy et al. (1990) have reviewed the evidence for developmental dyspraxia in populations with various developmental disorders - learning disabilities, "sensorimotor dysfunction", and "sequenced motion rate disorder", as well as those with verbal or oral apraxia, Down syndrome, and other forms of organic and nonorganic mental retardation (no mention is made of autism in this review). Many children with these diagnostic labels (some of which are only vaguely defined) reportedly show praxic (in the sense of gesture and tool use) and motor sequencing disorders.

Children with developmental dysphasia and reading disabilities children are reportedly impaired in the imitation of nonsymbolic manual gestures relative to normal controls matched for age and IQ (Archer & Witelson, 1988; Cermak, Coster, & Drake, 1980; Conrad, Cermak, & Drake, 1983). For example, Cermak et al. (1980) found that children with verbal learning disabilities made more spatial errors in imitating nonsymbolic movements than did normal controls, as well as demonstrating less mature symbolic (object-related) gestures. Like children with autism, these children have linguistic problems, albeit with different aspects of language. However, insufficient research exists with directly comparable groups and measures to evaluate consistency in such findings.

Roy et al.'s (1990) general conclusions were that impairments in the production of gestures and of action sequences are quite common in developmentally-disabled populations. They observed that these deficits are most pronounced when gestures are performed to verbal request, which reinforces the necessity of control for level of language comprehension. Furthermore, the types of errors observed are similar to those seen in apraxic adults, especially the prevalence of perseverative errors in action sequences.

Roy et al. (1990) advocated a more analytic approach to the study of praxis in children, building on the theoretical and methodological advances that have been made in the study of acquired apraxia. Of relevance here are the issues of unreliability in diagnostic criteria and in clinical judgements of praxic performance in adults, recently reviewed by Tate and McDonald (1995). That these issues require resolution in the area of adult neuropsychology suggests that an even greater challenge faces those who study praxis in children.

The work of Dewey with various populations of children (e.g., Dewey, 1993) represents the approach advocated by Roy et al. (1990). Dewey (1993) analyzed developmental trends in representational ability and praxic errors in a group of children with developmental motor deficits, compared with normally-developing controls. Her data for normal children are consistent with those of previous researchers (e.g., Kaplan, 1968; Overton & Jackson,

1973) in indicating a developmental progression in the accuracy of representational gestures over the 6- to 11-year age range. In addition, Dewey's developmental error data (using categories derived from the work of Roy, Square, Adams, & Friesen, 1985) indicate that two error types were linearly related to age (while others were not). In terms of error patterns, children with developmental motor deficits resembled younger, normally-developing children. Thus, delayed rather than deviant development may account for these children's dyspraxic performance.

The relationship between problems of praxis defined in terms of gesture imitation and tool use, and the broader problem of motor incoordination affecting gesture production is unclear (cf. Cermak, 1985; Dewey, 1993). It seems likely that a developmental disorder that interfered with the initial acquisition of an action repertoire would have fewer specific effects than those seen in adult onset apraxia. Acquired neurological dysfunctions interrupt the established skills, whereas developmental neurological disorders prevent the establishment of normal skill patterns, and could thereby result in qualitatively different systems (cf. Snowling's, 1983, discussion of developmental versus acquired dyslexia). Hence there are limitations in defining problems of movement or action in children only with reference to adult models, as Roy et al. (1990) have proposed.

Conclusions

The fundamental issue still to be addressed is the specificity to autism of the deficit in imitating others' movements, when those movements have no symbolic significance. Findings such as those of Cermak (Cermak et al., 1980; Conrad et al., 1983) with learning-disabled children suggest the possibility that the deficit attributed to autism may be associated with a more general category of language-related learning disorder. Alternatively, there may be some aspects of imitation which are impaired in all language-disordered children (e.g., executive, or "how to do it" problems), and others which are characteristic of autism (e.g., conceptual, planning, or "what to do" problems). To complicate the matter further, there may also be disorders of movement associated with varying forms of mental retardation (Roy et al., 1990), so that the profile of praxic impairments seen in any individual with autism might be a joint function of autism, language disorder, and/or intellectual level. To the extent that any of these conditions apply, and that these impairments can be defined more clearly (e.g., as disorders of motor programming versus execution, or as difficulties with timing or force control), praxic deficits may help to further the search for etiologically or prognostically significant subgroups in autism. One hypothesis is that developmental dyspraxia accompanies core autistic social symptoms only when the neurological substrate involved includes kinaesthetic and/or motor systems (Goodman, 1989).

The formulation proposed by Bryson, Wainwright-Sharp, & Smith (1990) is that autism involves a fundamental deficit in the ability to deploy attention to aspects of the internal and external environment (see also Smith & Bryson, 1994, and Bryson, Landry, & Wainwright, in press). Recent studies have focussed on attention in autism, both in terms of basic attentional mechanisms and executive functions. Autistic impairments have been identified in the ability to rapidly shift attention between sensory modalities (Ciesielski, Courchesne, & Elmasian, 1990; Courchesne et al., 1994), and to disengage and redeploy attention within the visual modality (Courchesne et al., 1994; Wainwright-Sharp & Bryson, 1993). Smith and Bryson (1994) suggested that deficient imitative skills are one of the eventual consequences of these problems with attention. This argument has been elaborated by Smith and Moore (in preparation), who propose that a primary disorder of attention could theoretically affect the development of the intermodal perceptual and motoric capabilities required for accurate imitation. Cascading effects of such an attentional disorder would then have an impact on the ability to manipulate representations of self and other, which has been hypothesized to be critically lacking in autism (Barresi & Moore, 1996a; Rogers & Pennington, 1991).

The hypothesis that inadequacy of the body image (i.e., the mental representation of one's physical self) or of the ability to translate representations of others' movements into self movements (an intermodal task) contributes to the imitative deficit appears worthy of consideration, given the evidence from imitation studies (such as the errors described by Ohta, 1987) and the emphasis on theory of mind and social understanding deficits in autism (cf. Barresi & Moore, 1996a; DeMyer et al., 1972; Ohta, 1987; Rogers & Pennington, 1991; Smith & Moore, in preparation). This cognitive hypothesis can be contrasted with (or integrated with!) a more neuropsychological orientation that builds on the current interest in executive dysfunction in individuals with autism (e.g., Bishop, 1993; Hughes, Russell, & Robbins, 1994; Pennington & Ozonoff, 1996). Typically, "executive functions" are defined in terms of such components as the ability to formulate and execute plans (both cognitive and motoric), including the flexible self-monitoring of activity, and the ability to imitiate, maintain and shift activity in order to interact effectively with the environment (Lezak, 1983), perhaps reflecting the operation of a "supervisory attentional system" (Shallice, 1988). Lack of conceptual clarity in how executive functions are defined is particularly problematic, given that dysfunctions in executive control have been reported in a number of other developmental psychopathologies, in addition to autism (Pennington & Ozonoff, 1996). Much of the current work begs the question of how these "top down" planning and control processes become impaired (or why they do not develop) in the autistic population. Input from basic sensory, attentional, and perceptual processes must be integrated in order for a supervisory attentional system such as that proposed by Shallice (1988) to operate. If these basic systems, or the process of integrating inputs across systems, are deficient in autism, as has been suggested (Bryson et al., in press; Courchesne et al., 1994; Smith & Bryson, 1994; Smith & Moore, in preparation), deficits in control processes that are dependent on input from these systems would not be unexpected. Of interest is more detailed information about the specific deficits that characterize autism (as distinct from the many other disorders, such as attention deficit hyperactivity disorder, that share "executive function" deficits; Bailey, Phillips & Rutter, 1996; Pennington & Ozonoff, 1996).

Task dimensions such as the presence or absence of an object, availability of perceptual information (e.g., visual feedback), static postures versus movements (postural sequences), unimanual versus bimanual movements, and symmetrical versus asymmetrical movements may be informative in regard to these alternative interpretive contexts. The goal of these manipulations is to furnish evidence of the mechanisms underlying the putative imitative impairment in autism. Existing literature on developmental dyspraxia in children with nonautistic developmental disorders (in which imitation is the primary skill assessed) underscores the significance of the question of whether (and if so, how) the imitative problem is unique to autism.

The Present Study

The purpose of the study to be described was to clarify some of the major issues raised in the preceding review. Foremost among these issues is the specificity of the imitative deficit to individuals with autism, as opposed to other developmental disorders, especially disorders of language. Therefore, control groups were employed which were matched to the level of language development of the children with autism. One of these groups consisted of normally developing children, the other of children with delayed receptive language abilities.

Variables derived from the literature review on imitation in autism, as well as some parameters which have been manipulated in research on adult apraxia and developmental dyspraxia were investigated. The main dimension of interest was the symbolic/nonsymbolic distinction; previous research has indicated deficits in the imitation of both types of gestures by people with autism, yet few investigators have included both measures within the same study. Therefore, this study incorporated nonsymbolic manual postures and sequences, as well as two types of symbolic actions: actions representing object use and communicative manual gestures. On the basis of most previous literature, it was hypothesized that children with autism would perform poorly relative to controls on all of these tasks. However, the degree and type of deficit in the autistic group was also anticipated to be a function of the degree of cognitive impairment. For example, according to Rogers and McEvoy (1993), production of familiar symbolic gestures is not impaired in high-functioning adolescents and young adults with autism.

Nonsymbolic gestures are restricted in this study to manual (hand and finger) postures and sequences, but both unimanual and bimanual postures were employed, and the symmetry of bimanual postures was manipulated. The rationale for choosing these variables was that spatial and temporal attentional abnormalities in autism may result in fragmentary perception and therefore piecemeal reproduction of a manual display (cf. Ohta's, 1987, "partial" and "incomplete" imitation errors). By including one- and two-handed postures and manipulating symmetry, errors may be observed which would suggest such an effect of spatial attentional abnormalities. On the other hand, temporal attentional difficulties might be anticipated to have an impact on the ability to imitate sequences.

In the case of nonsymbolic postures, the availability of visual feedback while imitating the action was manipulated by screening the child's view of his/her hands. This manipulation was described by Bergès and Lézine (1965) in their study of gesture imitation in normally developing children. Obstructing the child's view of his/her own hands resulted in performance equivalent to that of a child approximately two years younger. However, they also found an age-related increase in the accuracy of imitation in the absence of visual feedback over the six to ten year old age range. Thus, in normal children, manual imitation is facilitated when both visual and kinaesthetic information about hand position is available, but with increasing age, children can compensate better for the lack of visual input. In contrast, previous research using nonimitative perceptual-motor tasks has indicated that visual and kinaesthetic input are not integrated in a normal manner by children with autism (Frith & Hermelin, 1969; Hermelin & O'Connor, 1970). In these studies, the performance of children with autism appeared not to be adversely affected by the lack of visual feedback, as was the case for normally developing and mentally handicapped controls. In previous studies of imitation skills in autism, the availability of visual feedback has either not been analyzed as a variable (e.g., all studies using the Uzgiris-Hunt Scales), or has been confounded with manual versus facial imitation (e.g., Rogers & McEvoy, 1993), in which different processes may be at work (Dawson et al., 1983). Given evidence of atypical relationships between visual and kinaesthetic information in autism, the absence of visual feedback may have less effect on the accuracy of imitation in children with autism than on children with language delay or young normally-developing children.

Sequencing of manual gestures was assessed in a task using very simple gestures; both sequence length and context (location) were varied. The intent was to minimize the demands of reproducing the gestures themselves in order to assess possible group differences in gesture sequencing ability. No specific prediction was made regarding such differences, although claims for sequencing deficits have been made (e.g., Rogers & McEvoy, 1993). "Context" here refers to the location in which the actions were presented; either on a tabletop, or in the air, or on the top of the head. In the first as compared with the second instance, the child received additional tactile feedback from the table surface as the action was performed; in the lattermost condition, no visual feedback was available to the child as he/she imitated the action. Both autism and language disorders have been associated with problems in the sequencing of information in perception and in production (Hermelin, 1976; Tallal, Miller, & Fitch, 1993). The predicted effects of the location manipulation were that the "table" context should facilitate reproduction of the gesture sequences, relative to the "air" context, which in turn should be easier for all groups than "on the head". It was again anticipated that lack of visual feedback ("on the head") would have less negative impact on the performance of children with autism than that of controls. Perseverative movement errors might be expected in the group with autism, given evidence of such errors on the Wisconsin Card Sorting Test (e.g., Ozonoff, Pennington, &

Rogers, 1991), but perhaps also in the language impaired controls given their reported prevalence in that population (Roy et al., 1990).

The other principle dimension explored in the present study was that of the influence of object knowledge and use on the ability of autistic individuals to reproduce symbolic actions. That is, production of two types of representational actions was evaluated: actions involving the use of objects (transitive gestures), and communicative (intransitive) gestures. Although both of these types of actions can be considered as "representational" or "symbolic", they are not be regarded as equivalent in this context, given the different sources of information that must contribute to successful performance on each (cf. Rothi et al., 1991).

Following the pantomime conditions, object knowledge was established by having each child demonstrate the use of each of a set of common household objects. It was expected that all children would be familiar with the use of the particular objects in the set. Imitation of object-action mismatches was assessed by asking children to use each of the objects in an action appropriate to another object in the set (e.g., "eat" with a comb). It was hypothesized that this "unconventional action" condition would result in more errors (i.e., intrusions of the conventional action) in the group with autism than in the controls (Hammes & Langdell, 1981).

In addition to varying the semantic content of actions (i.e., symbolic vs nonsymbolic), the modalities of information input (auditory-verbal, visual-object, or visual-gestural) and response output (verbal, gestural) were manipulated (Bartak et al., 1975; Rothi et al., 1991). That is, transitive gestures were elicited in response to verbal instructions, and to photographs of objects, as well as in imitation of a model. It was hypothesized that children with autism would require more concrete information (i.e., gesture or picture, as opposed to words) in order to produce an appropriate gesture than would language impaired or normal children (Bartak et al., 1975).

For each type of action/gesture, recognition and/or comprehension was assessed prior to testing the child's ability to reproduce the action. As much as possible, parallel conditions for recognition/comprehension and production/imitation were constructed across action types. It was anticipated that children with autism might be less accurate in recognizing and identifying the meaning of gestures, and that this might contribute to deficient imitative performance, especially in younger and lower functioning children. Further, it was expected that for the autistic group an imitative impairment would be observed beyond that which could be accounted for by a recognition problem (Rogers & McEvoy, 1993).

This research provides greater descriptive information regarding the imitative performance of the participants than has been reported previously, with the goal of establishing whether an autism-specific error pattern exists (cf. Jones & Prior, 1985; Ohta, 1987). Videotape records of nonsymbolic postures were rated for accuracy in relation to the modelled gestures, and assessed for error types derived from work on apraxia and developmental dyspraxia (modification of the error categories used by Cermak et al., 1983, and Dewey, 1993). Nonsymbolic sequences were scored for accuracy of sequence reproduction, as well as for errors (e.g., perseveration, context errors). Performance on symbolic gestures with objects was assessed in terms of developmental level, derived from the normal developmental literature (Dewey, 1993; Kaplan, 1968).

Bergès and Lézine (1965) found that more complex hand and arm gestures were more likely to be performed by the dominant limb. The lateralization of praxic processes in autism is an important issue which has received little attention in the literature (with the exception of Dawson et al., 1983). In the present study, the responding hand was not specified to the child in any of the tasks, in order to observe spontaneous performance under the specified range of conditions. It was anticipated that children with autism would show less consistent lateral preferences than either control group. The "object use control condition" was used to determine manual lateral preference for each child. Finally, manual dexterity was assessed using a standardized measure to evaluate the possible contribution of problems of fine motor coordination to task performance.

METHOD

Participants

Twenty children and adolescents with autism spectrum disorders (hereafter "autism"), aged between 7 and 19 years, participated in the research. Selected individual characteristics of the children and adolescents with autism are outlined in Table 2. Seven participants were identified in an epidemiological study in which they met research diagnostic criteria for autism (Bryson et al., 1988). As described by Bryson et al. (1988), these criteria were somewhat more stringent than those for Pervasive Developmental Disorder (PDD) - Autistic Disorder, as defined by DSM III-R (American Psychiatric Association, 1987). The remaining 13 participants were recruited from children known to the investigator or to clinicians at local children's mental health facilities. These children were diagnosed by the referring clinicians as having either high-functioning autism or PDD, and one child (#17 in Table 2) was also diagnosed as having Tourette syndrome. Through the investigator's direct observations of the children, parent interviews (including the Autism Behavior Checklist, Arick, & Almond, 1980a & b), and occasionally, further information from the referral source, it was confirmed that all of the participants with autism spectrum disorders would have met the Bryson et al. (1988) criteria for autism. Autism Behavior Checklist (ABC) scores were not available for two children (#2 and #13), both of whom were from the epidemiological study and clearly met those diagnostic criteria. As shown in Table 2, all others obtained ABC scores above the cutoff of 44 that distinguished autistic from nonautistic children in the epidemiological study (Wadden, Bryson, & Rodger, 1991). (Case #12, whose score is noted in Table 2 as 43, was taken into foster care at the age of 5 years, and his score is therefore almost certainly an underestimate.) Therefore, the 20 participants in this study with autism spectrum disorders, hereafter referred to as the Autistic group, also met criteria for PDD-Autistic Disorder, as defined by DSM III-R. Some of the children would be diagnosed as having Asperger syndrome using the criteria of DSM IV (American Psychiatric Association, 1994), or of ICD-10 (World Health Organization, 1992). This distinction was not made at the time of identification of this sample, and given the controversy over diagnostic criteria for autistic subgroups, additional attempts at classification of this sample have not been pursued.

The general guidelines for subject selection were a nonverbal I.Q. estimate of 65 or more, in addition to receptive language ability at approximately the three-year-old level or greater. These children (17 males and 3 females) thus represented a relatively high-functioning autistic group. Each child was administered the Peabody Picture Vocabulary Test - Revised (PPVT-R, a measure of receptive language level; Dunn & Dunn, 1981). In four cases, the PPVT-R had been recently administered by others, and these scores were

Table 2 Individual characteristics of participants with autism.

Case	Sex	ABC[1] score	CA[2]	PPVT-R[3] standard score	BD[4] scaled score	Dominant Hand
1.	F	83	13 - 11	<40	10	R
2.	M	--	9 - 9	45	5	R*
3.	M	82	7 - 5	54	13	L
4.	M	77	17 - 10	<40	6	R
5.	M	71	14 - 11	<40	5	R
6.	M	84	7 - 8	86	12	R
7.	M	75	8 - 4	82	11	R
8.	F	116	7 - 10	43	--	R
9.	F	80	9 - 6	94	9	R
10.	M	86	14 - 1	120	13	R
11.	M	64	13 - 0	46	5	R
12.	M	43	15 - 4	46	5	L
13.	M	--	18 - 5	92	11	R
14.	M	67	10 - 1	117	10	R
15.	M	52	11 - 2	115	13	R
16.	M	76	8 - 8	50	6	R
17.	M	60	8 - 10	<40	7	R
18.	M	66	10 - 9	41	7	R
19.	M	106	12 - 8	102	8	R
20.	M	44	7 - 0	84	10	L
	M	74.0	11 - 4	68.7	8.7	* see Method
	SD	(18.8)	(41.8)	(30.1)	(3.0)	

[1] Autism Behavior Checklist (past + present score)
[2]Chronological age
[3]Peabody Picture Vocabulary Scale - Revised
[4]Block Design (WISC-R or WAIS-R)

obtained with parental consent. In order to further characterize the functioning of the children with autism, the Block Design (BD) subtest of the Wechsler Intelligence Scale for Children - Revised (WISC-R, Wechsler, 1974; n=16) or the Wechsler Adult Intelligence Scale - Revised (WAIS-R, Wechsler, 1981; n=2) was also administered in most cases. Block Design is a good estimate of nonverbal intelligence for normally developing and language impaired individuals (Sattler, 1992) and is typically a liberal estimate for those with autism (Happé, 1994; Lockyer & Rutter, 1970). For one child with autism, the WISC-III (Wechsler, 1991) had recently been administered at school, and the Block Design score from that test was obtained with parental consent. One additional 7-year-old child with autism was unable to complete testing with the WISC-R Block Design due to attentional and behavioural problems, but was judged clinically by the investigator to have at least borderline nonverbal abilities (subsequent testing by others for clinical purposes has borne this out). The Autistic mean BD score was 8.74 (SD = 2.96; see individual scores in Table 2).

Two control groups were also included. The first was the Language Impaired control group. These 20 children were matched to the group with autism for sex, and as closely as possible on a case-control basis for chronological age and receptive language ability, as measured by standard scores on the PPVT-R (see Table 3). Final matching was based on group mean scores.

Table 3 Chronological ages and receptive language levels, by Group (means, standard deviations, and ranges).

Sample Characteristics

		Autistic (17 M, 3 F)	Language Impaired (17 M, 3 F)	Normal (17 M, 3 F)
Age				
M	(yr-mo)	11-4[a]	11-9[a]	6-6
SD	(mo)	(41.8)	(33.6)	(39.7)
range	(yr-mo)	7-0 to 18-5	6-10 to 17-8	3-4 to 13-7
Receptive Language				
PPVT-R[1] Mental Age	*M*	7-8[b]	8-7[b]	7-5[b]
	SD	(55.7)	(46.5)	(49.3)
	range	2-10 to 19-9	3-0 to 17-10	2-10 to 16-5
PPVT-R Standard Scores	*M*	68.7	75.7	108
	SD	(30.1)	(22.8)	(10.8)
	range	39 to 120	39 to 110	90 to 124

[1]Peabody Picture Vocabulary Scale - Revised

[a]$F(1,38) = .21, p = .65$

[b]$F(2,57) = .45, p = .64$

Diagnoses were based on history (i.e., of significant receptive language delay or severe reading disability), and/or on current relative discrepancy between verbal and nonverbal abilities (i.e., low PPVT-R or verbal IQ relative to nonverbal IQ). The families of six of these children had participated previously in research conducted by the investigator and her colleagues. The remainder were recruited through local clinicians, including school psychologists, speech/language pathologists, and a private school for learning disabled youth.

Although matching on receptive language ability was the primary goal for the present purpose, the clinical groups were also well-matched on the basis of Block Design (BD) scores. For the Language Impaired group, the WISC-R or WAIS-R BD subtest was administered by the investigator in ten cases, and scores from one of these tests administered by others were obtained for five additional children. This measure was not available for five children. For three, the children were judged clinically by the investigator to be functioning in the moderate-to-severe range of mental retardation, with attentional and behavioural difficulties. For the final two language-impaired children, constraints on time and access prevented these scores being obtained. Both of these children were judged clinically by the investigator to be functioning in at least the borderline range of nonverbal ability. Clinical judgements by the investigator were based on information from parents and teachers, as well as her own observations at the time of testing. For the 15 children in the Language Impaired group for whom scores were available, the BD mean score was 9.73 (*SD* = 2.60, range 5 to 14). When generous estimates ("9" for borderline, and "4" for moderate-severe retardation) were substituted for the missing values in the Language Impaired group, a mean BD score of 8.80 (*SD* = 3.05) was obtained.

The second control group consisted of 20 normally-developing children recruited through acquaintances of the investigator. These children were matched by chronological age to the receptive language ages of the children with autism, based on PPVT-R mental age equivalents (see Table 3). They were also matched for sex with the Autistic group. The Normal group was screened (by asking parents) to ensure that there was no history of language delay or disorder, learning disability, or neurological problems. In order that the performance of this group represent that of children functioning in the average range for their chronological ages, children were excluded if they obtained scores two standard deviations or more above or below the mean on the PPVT-R. Three children recruited for this control group were excluded on this basis (two had PPVT-R scores greater than 130, one had a score of 70).

Materials

Picture stimuli used in the nonsymbolic posture tasks were black and white photographs of the hands (right hand for unimanual postures) of the investigator, who acted as the experimenter with all of the children. These can be seen in Appendix A. Each hand posture photograph measured 15.3 by 11.2 cm, with the hands filling most of the area of the picture. Only dark clothing was visible behind the hands, with the exception of photographs of postures used in the sequencing task (Appendix B, and see description of task below), some of which showed the experimenter's hand against a table top or on top of her head.

Another set of tasks required 10 household objects (e.g., hammer, comb), and photographs of six of those objects (see Appendix C for a list of the objects, and for photographs). Objects were photographed against a dark fabric background such that each appeared approximately 12 to 15 cm long in the 12.7 X 17.7 cm print. All photographs were shot in 120 format using TMax 100 black and white film. Each photograph was mounted on heavy 21.2 cm X 15.2 cm card and laminated with plastic.

In the gesture context comprehension test, cartoon line drawings were used (see Appendix F). These were drawn in black ink on heavy 17.5 cm by 13.5 cm card, laminated with plastic. All gesture production tasks were videotaped on VHS cassette using a Panasonic video camera/recorder mounted on a tripod. For the imitation condition in which the child's view of his/her own hands was blocked (see below), a tabletop screen was used. The wooden 36 cm by 67 cm frame had a 21.5 cm by 52 cm aperture. Horizontal rods at the top and bottom of the aperture held gathered black fabric with two slits through which the child placed his or her arms (see Figure 1). Due to the wide age range of children seen in the study, younger (or smaller) children kneeled on a chair (rather than sat) during this experimental condition in order for them to view the experimenter's hands over the top of the screen. Some children found the screen rather awkward. This appeared to be equally true across groups, with the exception of the youngest normally developing children (aged 3-4 years), some of whom were too small to use the screen. This condition was therefore omitted for three of these children in the final sample.

Procedures

Most of the children and adolescents were tested in their own homes/residences (n = 44; 18 Autistic, 8 Language Impaired, and 18 Normal), usually at a kitchen or dining room table. The remainder were tested in a small room in the Department of Psychology, Dalhousie University (1 Autistic, 2 Normal) or at their schools (1 Autistic, 12 Language Impaired).

A schematic outline of the tasks can be found in Table 4. The tasks were administered in two sessions, each lasting approximately 30 to 45 minutes for most children. Typically, in the first session, the PPVT-R and the BD subtest of the WISC-R were administered (for exceptions, see the "Participants" section).

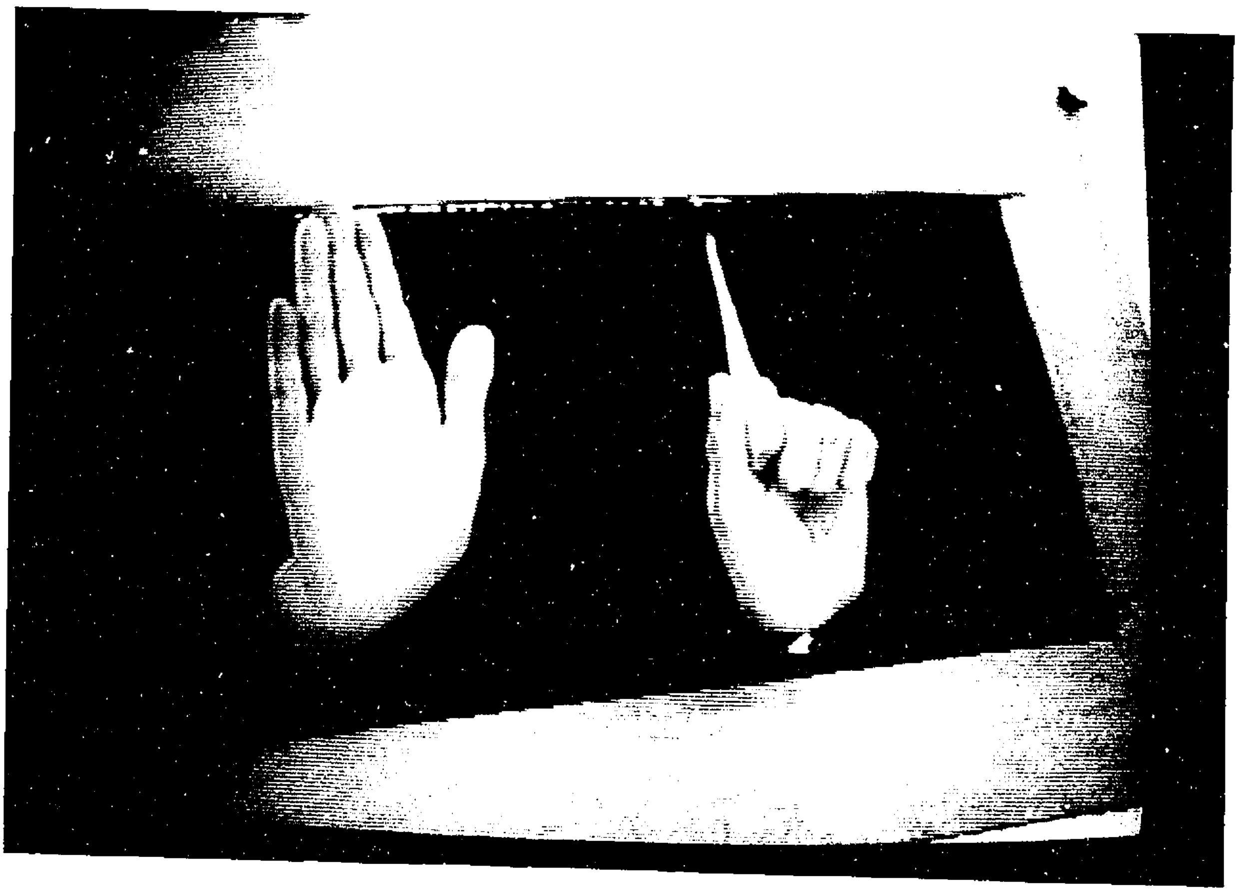


Figure 1 Screening of hands in the No Visual Feedback condition of the Nonsymbolic Postures imitation task.

Table 4 Outline of tasks.

	RECOGNITION / COMPREHENSION	IMITATION/ PRODUCTION
NONSYMBOLIC		
1. Postures:	Photo recognition	Imitation
2. Sequences:	Photo arrangement	Imitation
SYMBOLIC		
3. Actions Using Objects:	Pantomime identification	I. Pantomime production: - verbal request - object photo - imitation
		II. Object use - control
		III. Unconventional object use
4. Communicative Gestures:	Gesture identification	Gesture production: - verbal request - imitation
	Gesture recognition (context)	

The series of tasks that assessed the perception of, memory for, and comprehension of gestures was then administered. For half of the children in each group, nonsymbolic action conditions (Postures and Sequences) were presented first; for the remainder, symbolic actions (Actions Using Objects and Communicative Gestures) were presented first.

Session two consisted of the series requiring the child to produce or imitate gestures. For children who received the nonsymbolic actions first in session one, symbolic actions were presented first in session two, and vice versa. Finally, manual dexterity was evaluated with the Grooved Pegboard (Trites, 1977). In the case of one of the youngest, least verbal children with autism (#8 in Table 2), four sessions were required to complete the series of tasks; one normal three-year-old child was seen over three sessions.

Each child was seated opposite the experimenter, who modelled the gestures for imitation and presented the object and picture stimuli. Modelling and requests for pantomime (with verbal or visual cues) were made a maximum of twice per item. Each modelled gesture was held for approximately five seconds. Children received generous verbal and nonverbal encouragement for their efforts, but no systematic feedback on performance was given.

All unimanual gestures were modelled by the experimenter using her right hand. No instructions regarding hand use were given to the children except in the case of the Grooved Pegboard, which was administered first to the dominant, then to the nondominant hand, as specified in the standard instructions. Hand dominance was determined on the basis of the experimenter's observation of the child's use of a pencil during the "Actions Using Objects" condition (see below). In all but one case (Autistic group, #2 in Table 2), this corresponded with the hand the child actually used for writing. For this one child, later observation and maternal report were inconsistent with the child's actions during the task.

In session two (production tasks), each child's performance was videotaped. The camera was placed beside and slightly behind the experimenter's left or right side, depending on the constraints of the individual setting (room size, available furniture, lighting, etc.). Therefore, the video records were not standardized in terms of angle or distance of recording, lighting conditions, etc.

Gesture Recognition and Comprehension

I. Nonsymbolic Actions

A. Postures

Eight unimanual postures from the deaf alphabet ("a, b, e, f, g, h, v, w") and eight bimanual postures adapted from Bergès and Lézine (1965) were selected (see Appendix A). Two children in the Autistic group (#4 and #20 in

Table 2) had some prior exposure to signed letters, but neither was able to identify reliably the names of the letters used in this study. Of the bimanual postures, the configurations assumed by the two hands were the same in four postures (symmetrical), and different in the other four postures (asymmetrical).

For both unimanual and bimanual actions, recognition was assessed in a multiple choice task, using photographs of the postures (target and two foils, one similar foil and one dissimilar foil). The experimenter modelled the posture, then presented the child with the three choices, and asked "Which one did you see?". The score on this test was the total number of items correct out of the eight unimanual and eight bimanual postures (i.e., total possible score was 16). Whether a similar or dissimilar foil was selected was also recorded and also, for bimanual postures, the number of correctly recognized symmetrical versus asymmetrical bimanual postures.

B. Sequences

Each sequence consisted of a combination of either two or three gestures, selected from three simple components ("fist", "palm", "chop"; see illustrations in Appendix B). Two different sequences were performed for each sequence length in each of three locations (on the table top, in the air directly in front of the modeller, on the top of the modeller's head). The series of six two-action sequences (i.e., two on table, two in air, two on head) was always presented before the three-action series.

The children's ability to recognize the individual components (fist, palm, chop) by pointing to the correct photograph following a demonstration was assessed first. Next, the child's ability to reconstruct the sequence was assessed by placing photographs of the correct individual components in mixed order on the table in front of the child, and asking the child to indicate the order just modelled by pointing to or placing the photographs in order. Photographs were shuffled between trials.

Each trial was scored as correct if the child identified the correct sequence; since there were six two-action sequences, and six three-action sequences, the maximum total score for this task was 12.

II. Symbolic Actions

<u>C. Actions Using Objects</u>

For each of six actions involving the use of objects (see Appendix C), the experimenter pantomimed the use of the object and asked, "What thing do you do this with?". Following ambiguous or reasonable alternative responses (e.g., "axe" for "hammer"), the child was prompted with "Anything else you can do this with?", and given credit if the correct answer was then given. If instead of naming the object, the child named the action (e.g., "pounding", instead of "hammer"), the prompt, "What *thing* (emphasized) do you do this with?" was given. Credit was also given for a correct response at this point.

If the child could not produce a correct verbal response to a given item, even with prompting, that pantomime was repeated after all other items had been administered, and a predetermined choice of verbal responses was provided (e.g., "What do you do this with - a spoon, scissors, or a pencil?").

If again an incorrect or no response was forthcoming, the pantomime was repeated, and the child was asked, "Which of these things do you do this with?", and given the opportunity to select the appropriate object picture from among 2 foils.

Scoring for this task consisted of the numbers of actions correctly identified (out of 6) by each child by (a) naming the object (word label), (b) recognizing the name of the object (word recognition), or (c) recognizing a photograph of the object (photo recognition).

D. Communicative Gestures

The experimenter modelled each of six gestures (e.g., wave goodbye; see Appendix E for a list of the gestures), and asked, "What does this mean?". In the case of ambiguous or reasonable alternative responses (e.g., "hello" for "goodbye"), the child was prompted with "What else does this mean?", and credit was given for a correct response.

If the child could not produce a correct verbal response to a given item, a predetermined choice of verbal responses (e.g., "What does this mean - OK, goodbye, or come here?") was provided following administration of other items in the series.

Scoring for this task consisted of the numbers of gestures correctly identified (out of 6, but see Reliability section) by each child by (a) naming the gesture (word label), or (b) recognizing the name of the gesture (word recognition).

Finally, the child was shown six sets of drawings (see Appendix F), each illustrating (1) one of the six communicative gestures in correct context, (2) another communicative gesture in the same context, and (3) a nonsense gesture in the same context. For each set of three drawings, the child was asked, "Which of these looks right to you?". One point was given for each correct choice for a maximum score of six. Once all sets were shown, each was presented again, and the child was asked to explain why he/she chose the picture that he/she identified as right.

Gesture Production and Imitation

I. Nonsymbolic Actions

A. Postures

Each child was asked to imitate the eight unimanual postures and eight bimanual postures described above (see Appendix A), immediately after each had been modelled by the experimenter (Model Absent). After all unimanual postures were presented, each was modelled a second time and held in view of the child while he/she produced a second attempt (Model Present). The same was then done with the bimanual postures.

Finally, the same sets of unimanual and bimanual postures were modelled, and the child asked to imitate with the view of his/her own hands obscured by a screen through which the child placed his or her hands (see Figure 1). The model remained within view in this condition (No Visual Feedback).

Two types of scoring were carried out for Nonsymbolic Postures. For the first, the videotape record was viewed by the investigator (i.e., non-blind) to locate the still frame which most closely approximated the modelled gesture for each trial of the posture task. This frame was photographed and printed. A blind rater assigned similarity ratings comparing each posture to the model (using the photographs from the recognition task, above, as the standard), without knowledge of group membership or the purposes of the study. Ratings were made on a scale from 1 to 10, with 1 representing minimal similarity to the model and 10 an exact copy of the model.

Reliability. For all tasks, a second blind rater scored 19 out of 60 records (31%) for reliability. These records were selected randomly, but with constraints in order to represent the diagnostic groups evenly (7 autistic, 6 language impaired, 6 normal), and to ensure that both higher- and lower-functioning children were included.

With the exception of the Nonsymbolic Posture data described above, all judgements were made by raters viewing the videotaped records for each participant. The same two raters provided judgements on all of the data reported here. They were trained by providing written descriptions of criteria, by discussion with the investigator, and by provision of feedback after practice scoring of videotapes. Given the heterogeneity of behaviour observed within this sample of children, the primary rater had the opportunity to observe a wider range of performance on these tasks. Thus, it was expected that her blind judgements would be more closely related to those of the investigator. As will be described below, additional reliability information (blind primary rater compared with the investigator as an "expert", nonblind rater) is reported for the two classes of symbolic actions ("Actions Using Objects" and "Communicative Gestures"). All final analyses were conducted using the data from the primary blind rater, who scored data for all participants and whose ratings were reliably correlated with those of the investigator.

For the Nonsymbolic Posture rating data, the reliability measure of interest was the extent to which the ratings of the two blind judges were correlated, regardless of absolute value of the ratings (since the scale was arbitrary). Pearson product-moment correlations were therefore calculated between the ratings assigned by the two raters. The total scores (i.e., summing ratings of all postures and conditions for each individual) were strongly correlated, r=.90; correlations between the subscores across conditions ranged from r=.72 to .92 (mean r=.83). Scores for bimanual postures under all conditions (r=.85) were somewhat less strongly related than for unimanual conditions (r=.92).

The second type of scoring for Nonsymbolic Postures involved enumeration of errors, scored from the still photographs just described. The categories were as follows:

Left-right: Left-right reversal of demonstrated hand use.

Posture: Incorrect form of gesture (e.g., wrong number of fingers, incorrect position of fingers).

Location: Incorrect position of hands relative to each other (e.g., hands at wrong relative heights, too close together or too far apart).

Rotation: At least one hand rotated 45 degrees through the wrist or elbow in any plane. Subclass: Rotation of hand 180 degrees such that the child's view of his/her own hand is an approximation of the child's view of the model's hand (e.g., palmar rather than dorsal surface is presented to the observer).

Symmetry: Any of: (1) "Mirroring" of unimanual posture by other hand, (2) Asymmetrical bimanual posture formed symmetrically, (3) Symmetrical bimanual posture formed asymmetrically, or (4) bimanual posture performed unimanually.

No Response: No recognizable attempt to reproduce the posture.

All error scoring was done by the primary blind rater, with 31% of the records scored by the second blind rater for reliability (19/60 participants, 48 trials each, for a total of 912 judgements). For these data, the question of interest was the extent to which the two raters assigned errors to the same or to different categories. Therefore, kappa coefficients of agreement (Bakeman & Gottman, 1986) were used. A preliminary review of the reliability data indicated that the raters' judgements of the larger class of Rotation errors were unreliable. Therefore, further analyses were restricted to the subclass consisting of 180° Rotations (which constituted 54% of the primary rater's total number of Rotation errors). Kappas were calculated separately for each of the five nonexclusive error types. The obtained kappa of .38 for Location errors was considered inadequate for these analyses (Fleiss, 1981; Landis &

Koch, 1977), and these errors were therefore disregarded. Kappa for Posture errors was .52, considered "fair" (Fleiss, 1981) or "moderate" (Landis & Koch, 1977) agreement, and these errors were retained for subsequent analyses. The remaining errors were retained, and included Symmetry errors, for which kappa was .79 ("excellent", Fleiss, 1981; "substantial", Landis & Koch, 1977). The values of kappa for judgements of Left-Right errors (.95) and for 180° Rotation errors (.82) were considered "excellent" by the criteria of Fleiss (1981) and "almost perfect" according to Landis & Koch (1977).

B. Sequences

Each child was asked to produce each of the six two-action and then the six three-action Nonsymbolic Sequences immediately after a demonstration by the experimenter. Two trials were given for each of the sequences. Each correct reproduction (correct postures and order) of a sequence was given one point, for a maximum of 24 points. Liberal criteria were used in judging the correctness of the postures. Reliability of correct/incorrect judgments was calculated between the two blind judges. Kappa (calculated for 19/60 individuals over 335 trials) was .86 ("excellent", Fleiss, 1981; "almost perfect", Landis & Koch, 1977).

Errors for Sequences (Posture, Location, Addition, Deletion, Substitution, two classes of Perseveration and Sequencing) were enumerated separately:

Posture: A recognizable attempt was made to form one of the three postures, but was distorted in form (e.g., fingers spread vs. together).

Location: The gesture was reproduced in a location other than that which was modelled (e.g., on the table vs. in the air).

Addition: An extra gesture was inserted into the sequence (scored independently of the accuracy of other elements).

Deletion: An element of the sequence was missing.

Substitution: An incorrect element replaced an element of the sequence.

Perseveration I: An immediately preceding sequence was reproduced.

Perseveration II: An element within a sequence was repeated.

Sequencing: The correct elements were produced in an incorrect order.

Due to the infrequent occurrence of several types of error, some categories were dropped (Posture and Location), and others collapsed for analyses. A single kappa was calculated reflecting the agreement between the two blind raters on the distribution of errors across the following mutually exclusive categories: Perseveration (two types combined); Substitution, Addition, and Deletion (combined); Sequencing; and No Error. Overall, kappa was .70 for these judgments ("good", Fleiss, 1981; "moderate", Landis & Koch, 1977).

II. Symbolic Actions

C. Actions Using Objects

Pantomime of each of the six Actions Using Objects (transitive actions) was requested by asking each child to "Show me what you do with a " ____ ". Each child was then asked to generate a pantomime in response to pictures of the objects, with the request, "Show me what you do with this". The experimenter then modelled each pantomime, and asked the child to imitate what she did ("Do this."). These transitive actions were scored for developmental level as follows (after Kaplan, 1968, and Dewey, 1993):

0 pts: No response, or incorrect gesture

1 pt: Pointing or undifferentiated movement in appropriate vicinity for gesture

2 pts: Body part used as object, or major inaccuracies in gesture

3 pts: Object represented in gesture, minor inaccuracies in gesture

4 pts: Correct gesture, object fully represented

These data were considered to represent scores on an ordinal (developmentally-based) scale, rather than categories, as was the case with error data. Reliabilities were therefore calculated using intraclass correlation coefficients (ICC's), a measure of the variance accountable to raters, as opposed to subjects (Shrout & Fleiss, 1979). For the three conditions (gesture to Command, gesture to Photo, gesture to Imitation), ICC's calculated between the two blind raters for 19 individual participants scored from videotape were .93, .84, and .75, respectively. A second set of reliability calculations were made for the same individuals between the scores of the original blind rater, and scores assigned by the investigator (as an "expert" nonblind judge). These ICC's were .84, .94, .88 for the Command, Photo, and Imitation conditions, respectively.

As a control condition, the objects named in the above conditions, plus four novel objects (see Appendix C), were then handed in turn to the child, who was asked to "Show me what you do with this". Scoring consisted of judgments as to whether the child used the object in the conventional way. All children demonstrated understanding of the use of each object. Objects were presented at the midline to permit judgements about each child's manual lateral preferences. One object (screwdriver) was dropped from the calculation of handedness, as many of the younger children used the object bimanually.

Finally, the experimenter modelled the use of each of the ten objects in an unconventional action (e.g., "writing" with the hammer, "brushing teeth" with the spoon; see Appendix D), then gave each object to the child, saying

"Now you do it". This condition was scored by having raters render categorical judgements as to whether the child was (1) imitating the unconventional use of the object; (2) using the object conventionally (i.e., as intended); (3) some combination of (1) and (2), either (a) initially using the object conventionally then imitating, or vice versa, or (b) blending the two actions into one; or (4) not using the object in any recognizable action. The value of kappa for agreement between the two blind raters for these judgments was .65 ("good" (Fleiss, 1981; "substantial", Landis & Koch, 1977). For the original rater and the investigator ("expert" judge), a kappa of .91 was obtained ("excellent", Fleiss, 1981; "almost perfect", Landis & Koch, 1977).

D. Communicative Gestures

For the six Communicative Gestures (see Appendix E), the experimenter asked the child to "Show me with your hands how to say " _____ ". The child's own label from the first session (recognition/comprehension) was used to elicit the gesture. The experimenter then modelled each of the gestures, and asked the child to do the same.

Scoring of the Communicative Gestures was intended to parallel the scheme adopted for the Actions Using Objects. Gestures were assigned a rating from 0 to 4, reflecting the "goodness" of the gesture as a conventional means of conveying the requested meaning. A score of "0" was assigned for no response, or for an incorrect gesture. Preliminary analyses indicated that inclusion of the "clapping" gesture was not warranted, as many children did not reliably produce the gesture even when cued with the label they had provided in the recognition/comprehension session (such as "hurray", "good", "bravo"). Frequently, the children instead produced gestures such as "thumbs up", "OK", or raised their arms above their heads. "Clapping" was therefore eliminated from the set of Communicative Gestures for the production/imitation analyses, reducing the number of gestures to five.

Reliability between the two blind raters was again determined using ICC's, which were .91 and .84 for the gesture to Command and gesture to Imitation conditions, respectively. As with the other category of representational actions ("Actions Using Objects"), reliability was also examined between the blind rater and the investigator, an "expert" judge. For gesture to Command, and gesture to Imitation scores, ICC's = .96 and .94, respectively.

RESULTS

All analyses were conducted using the SPSS-X statistical package (SPSS Inc., 1988). As described in the Method, the three diagnostic groups (Autistic, Language Impaired, and Normal) did not differ significantly in their receptive language mental age scores, as measured by the Peabody Picture Vocabulary Test - Revised (PPVT-R). However, because of the wide variability in PPVT-R mental ages within groups, and the difficulty of matching on a case-by-case basis, given the sample sizes available, analyses of covariance were conducted using PPVT-R mental age as a covariate.

Results of screening procedures indicated that missing values were infrequent and nonsystematic. Missing data were not replaced; all analyses were conducted with listwise deletion of cases with missing data. Most missing data were attributable to nonoptimal camera angles that interfered with accurate coding of gestures. One child in the Autistic group would not permit videotaping in which his face was visible; this resulted in loss of so many data in the Nonsymbolic Posture task that this case was excluded from those analyses. As described in the Method, three of the youngest children in the Normal group did not contribute data to the No Visual Feedback condition of the Posture task. The maximum amount of missing data in any analysis was 5 out of 60 cases (3 Autistic, 2 Normal) in the Actions Using

Objects production task. All of these instances were attributable to data lost to camera view as the child moved the objects.

The results of evaluations of assumptions for the various analyses were satisfactory, with the exception of error data for the Nonsymbolic Posture imitation tasks. Logarithmic transformations were applied to these data to correct positive skewness, and to minimize the effects of one outlying score for 180° Rotation errors in the Posture task.

SPSS-X MANOVA provides multivariate procedures for repeated measures analyses of covariance. For most of the repeated measures analyses reported here, compound symmetry assumptions (as evaluated by Mauchly's sphericity test) were not met. Therefore, multivariate F, rather than averaged F, results are reported for the repeated-measures effects (SPSS, Inc, 1988; Tabachnick & Fidell, 1989). Pillai's criterion was used to evaluate the significance of multivariate F's. All between-groups and between-conditions contrasts reported are univariate F statistics for single-degree-of-freedom comparisons (i.e., equivalent to t-tests).

It is important to note that, given that the present design does not provide counterbalanced orders of presentation for conditions within tasks (see Method), the results of interest in most instances are the main effects of Group and the Group X Condition interactions.

Handedness and Dexterity

Manual preference was compared across groups in two ways. First, observations of each child's hand use during the "Actions Using Objects" tasks resulted in a Handedness score ranging from 0 to 9, representing the number of objects for which the right hand was used. Since the children in the Normal group were considerably younger than those in the Autistic and Language Impaired groups (chronological ages of approximately 6 years versus 11 years), and degree of handedness develops until approximately the age of 9 years (McManus et al., 1988), handedness scores were analyzed in a univariate analysis of covariance, with chronological age as the covariate. There was no significant effect of Group, $F(2,56) = .33$, $p = .72$; Autistic $M = 6.9$, $SD = 3.2$; Language Impaired $M = 7.2$, $SD = 3.1$; Normal $M = 7.3$, $SD = 2.8$.

Second, categorical scores were constructed, such that individuals with Handedness scores of 9 were considered exclusive right-handers, those with Handedness scores of 0 were considered exclusive left-handers, and those with scores of 1 to 8 were considered to show mixed handedness. The frequencies of individuals in each Handedness category by groups are presented in Table 5, in which it is readily apparent that the proportions of children displaying right-, left-, or mixed-handedness did not differ between groups.

Table 5 Numbers of individuals displaying right-, mixed-, or left-handedness, determined by the number of right-handed uses (out of 9) of objects in the Actions Using Objects control task.

Handedness

	Autistic	Language Impaired	Normal
Right (9)	10	10	9
Mixed (1-8)	8	8	9
Left (0)	2	2	2

Analyses of manual dexterity (i.e., Grooved Pegboard) were restricted to those children in the Autistic and Language Impaired groups. Grooved Pegboard times were available for only 14 children in the Normal group because the remainder were too young to complete the task. However, data for all 20 children in the Autistic group and for 19 in the Language Impaired group were available. Analyses were conducted on a "time per peg" measure, rather than on the total time to complete the task, as children below 8 years of age were administered the shorter (10 peg) form of the task (Trites, 1977).

The Grooved Pegboard "times per peg" were analyzed in a repeated measures analysis of covariance, with Hand (Dominant, Nondominant) as the repeated measure, and PPVT-R mental age as the covariate. The means are displayed in Table 6.

Table 6 Times, per peg, for completion of the Grooved Pegboard, by Group and Hand (means and standard deviations).

Dexterity

	Autistic	Language Impaired
Dominant	4.9 (1.9)	3.5 (1.2)
Nondominant	5.5 (1.7)	3.9 (1.6)

There was a significant main effect of Group, $F(1,36) = 7.45$, $p = .01$. Children in the Autistic group were significantly slower to place pegs than were those in the Language Impaired group. As expected, there was also a significant main effect of Hand, with the dominant hand being faster than the nondominant hand, $F(1,37) = 14.57$, $p < .001$. The Group X Hand interaction was not significant, $F(1,37) = 1.25$, $p = .27$. Thus, children in the Autistic group were bilaterally slower than children in the Language Impaired group, and both groups showed a significant dominant hand advantage.

Gesture Recognition and Comprehension

I. Recognition of Nonsymbolic Actions

A. Postures

A univariate analysis of covariance was conducted on total Posture recognition scores (maximum score = 16) across the three diagnostic groups, with receptive language level (PPVT-R mental age) as a covariate. There were no significant Group differences in Posture recognition scores, $F(2,55) = 1.35$, $p = .27$; Autistic $M = 12.90$ ($SD = 2.0$), Language Impaired $M = 13.95$ ($SD = 2.3$), and Normal $M = 12.63$ ($SD = 2.6$).

Recognition errors across groups were examined by looking at whether children erred by choosing foils similar to, or dissimilar from, the target posture. The proportions of similar foils chosen relative to the total number of errors made by each child were subjected to a univariate analysis of covariance. There were no significant Group differences on this measure, $F(2,55) = 1.05$, $p = .36$ (Autistic $M = .87$ ($SD = .27$), Language Impaired $M = .89$

($SD = .28$), Normal $M = .75$ ($SD = .38$). When recognition errors occurred, all groups tended to err by choosing similar, rather than dissimilar foils.

Whether recognition errors differed across groups with respect to symmetrical versus asymmetrical bimanual postures was then examined. A measure was constructed that represented the proportion of errors on symmetrical vs asymmetrical postures, consisting of the ratio of the number of errors made on symmetrical bimanual postures to the total number of errors (on symmetrical and asymmetrical postures combined). An analysis of covariance performed on these proportional scores revealed significant Group differences, $F(2,55) = 3.57$, $p = .04$; Autistic $M = .48$, $SD = .39$; Language Impaired $M = .25$, $SD = .41$; Normal $M = .16$, $SD = .33$. Planned contrasts indicated that means for the Language Impaired and Normal groups did not differ, $F(1,55) = .66$, $p = .42$, but that children in the Autistic group made more errors in recognizing symmetrical postures, $F(1,55) = 6.47$, $p = .01$. That is, children in the Autistic group erred approximately equally often on symmetrical and on asymmetrical postures, while the Language Impaired and Normal groups recognized asymmetrical postures less often. Overall, however, recognition performance did not differ across groups.

B. Sequences

Posture Sequences recognition data consisted of the numbers of sequences correctly recreated by arrangement of photographs of the postures, and are displayed in Table 7. The data were analyzed in a repeated measures

Table 7 Numbers of sequences correctly identified (maximum = 2), by Group, Sequence Length, and Location (means and standard deviations).

Nonsymbolic Sequences - Recognition

		Autistic	Language Impaired	Normal
	Table	1.6 (.5)	1.5 (.7)	1.6 (.7)
2-posture sequences	Air	1.5 (.7)	1.6 (.7)	1.4 (.7)
	Head	1.4 (.7)	1.4 (.8)	1.5 (.6)
	Table	0.5 (.7)	0.9 (.8)	0.7 (.8)
3-posture sequences	Air	0.7 (.9)	0.5 (.7)	0.6 (.7)
	Head	0.9 (.9)	0.8 (.9)	0.9 (.8)
Total (maximum = 12)		6.4 (2.8)	6.7 (2.7)	6.5 (3.1)

analysis of covariance, with Sequence Length (two or three postures) and Location (table, air, head) as the repeated measures, and Group as the between-subjects measure. There was no significant main effect of Group, $F(2,56) = .28$, $p = .76$, and no significant main effect due to Location, multivariate $F(2,56) = .77$, $p = .47$. There was a significant main effect of Sequence Length, $F(1,57) = 163.73$, $p < .001$. That is, for children in all three groups, sequences of two postures were correctly recognized more frequently than were sequences of three postures. There were no significant 2-way or 3-way inyeractions (Group X Sequence Length X Location, multivariate $F(4,114) = 1.27$, $p = .29$; Group X Sequence Length, $F(2,57) = .03$, $p = .98$; Group X Location, multivariate $F(4,114) = .59$, $p = .67$). Therefore, the effects of manipulations of Sequence Length and Location were the same on the Autistic group as on controls.

Summary: Recognition of Nonsymbolic Actions

Children with autism were as accurate in recognizing nonsymbolic manual postures as were children in the two language-matched control groups, although their recognition error patterns differed somewhat from those of controls. Specifically, they erred equally often on symmetrical and asymmetrical postures, whereas the latter were recognized proportionately less often by controls. Children with autism did not differ from either age- and language-level matched, or from younger language-level matched groups of children in their ability to match simple sequences of postures to their corresponding pictures, regardless of sequence length or location.

II. Recognition/Comprehension of Symbolic Actions

A. Actions Using Objects

Recognition data for the Actions Using Objects task are illustrated in Figure 2, consisting of numbers of actions correctly identified by (1) generating a verbal label for the object associated with the action (Word), by (2) recognizing the correct object word from among three choices (Word Recognition), or by (3) indicating a picture of the object from among three choices (Photo Recognition). As described in the Method, the latter two options were provided when the child had failed to provide the label in response to the preceding cue. A repeated measures analysis of covariance was conducted on the numbers of objects correctly identified by children in each Group in each of the three Cue conditions, Word, Word Recognition (subsuming Word), and Photo Recognition (subsuming Word and Word Recognition). The main effect of Group was not significant, $F(2,56) = 3.08$, $p = .054$, although a trend toward fewer pantomimes being recognized by the Autistic group was apparent.

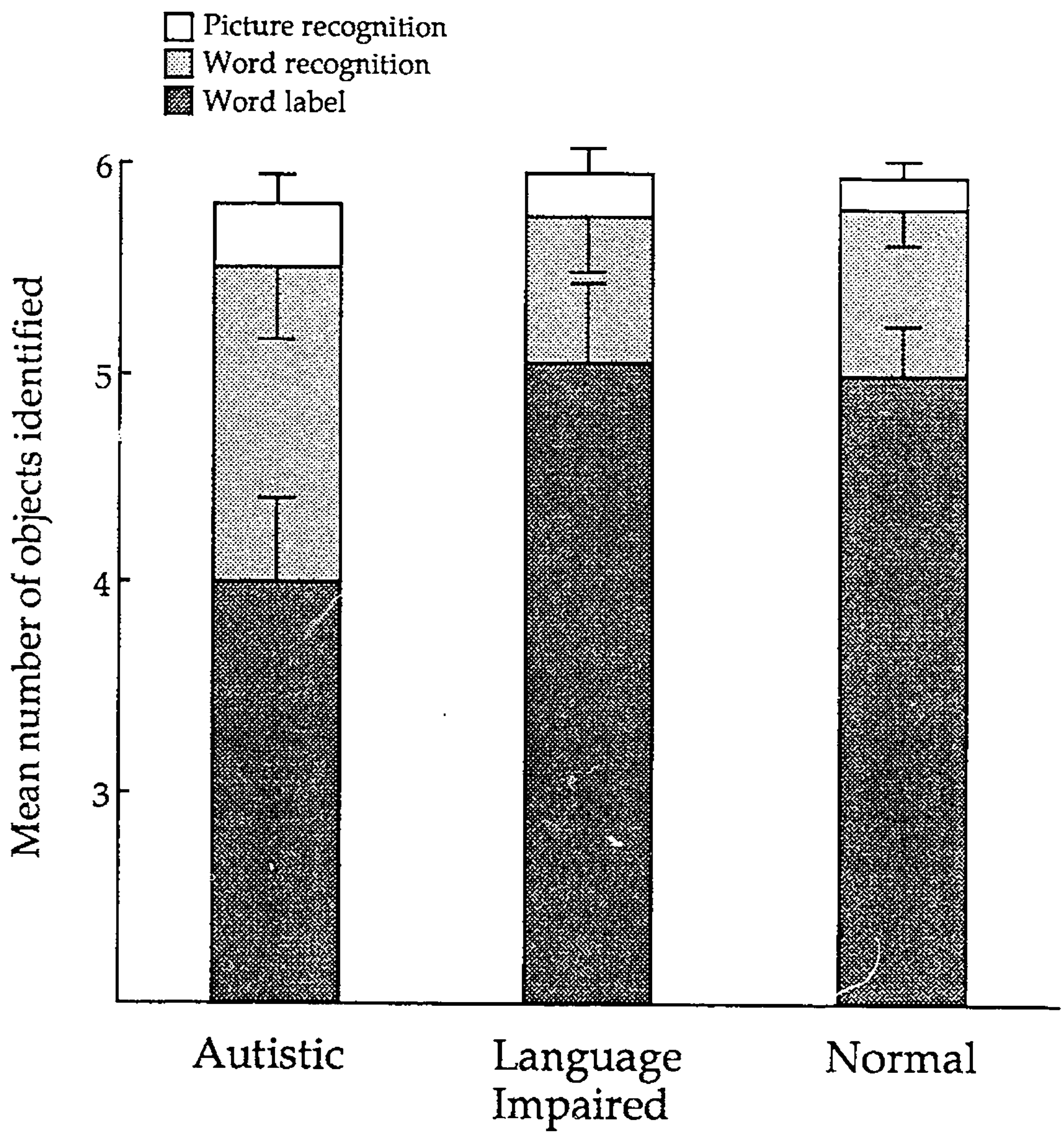


Figure 2. Numbers of action-appropriate objects identified in each cue condition, by Group (means and standard errors).

As would be expected, there was a significant main effect of Cue, multivariate $F(2,56) = 23.18$, $p < .001$, such that each additional cue resulted in an increment in the number of object-related actions recognized.

The Group X Cue interaction was not significant, multivariate $F(4,114) = 1.39$, $p = .24$. However, visual examination of Figure 2 suggests that the Autistic group provided fewer verbal labels than either of the control groups.

B. Communicative Gestures

Analysis of the data for recognition of Communicative Gestures parallels that described above for Actions Using Objects. Numbers of gestures correctly identified by (1) generating a verbal label (Word), or by (2) recognizing the correct gesture word from among three choices (Word Recognition) are illustrated in Figure 3. The latter option was provided when the child had failed to provide the label in response to the preceding cue. Five Communicative Gestures were retained for scoring (see Reliability section of Method). A repeated measures analysis of covariance was conducted on the numbers of gestures correctly identified by children in each Group in each of the two Cue conditions, Word and Word Recognition (subsuming Word). There was no significant main effect of Group, $F(2,55) = 2.04$, $p = .14$.

The main effect of Cue condition was significant, $F(1,56) = 56.97$, $p < .001$, indicating that more gestures were identified by Word Recognition than

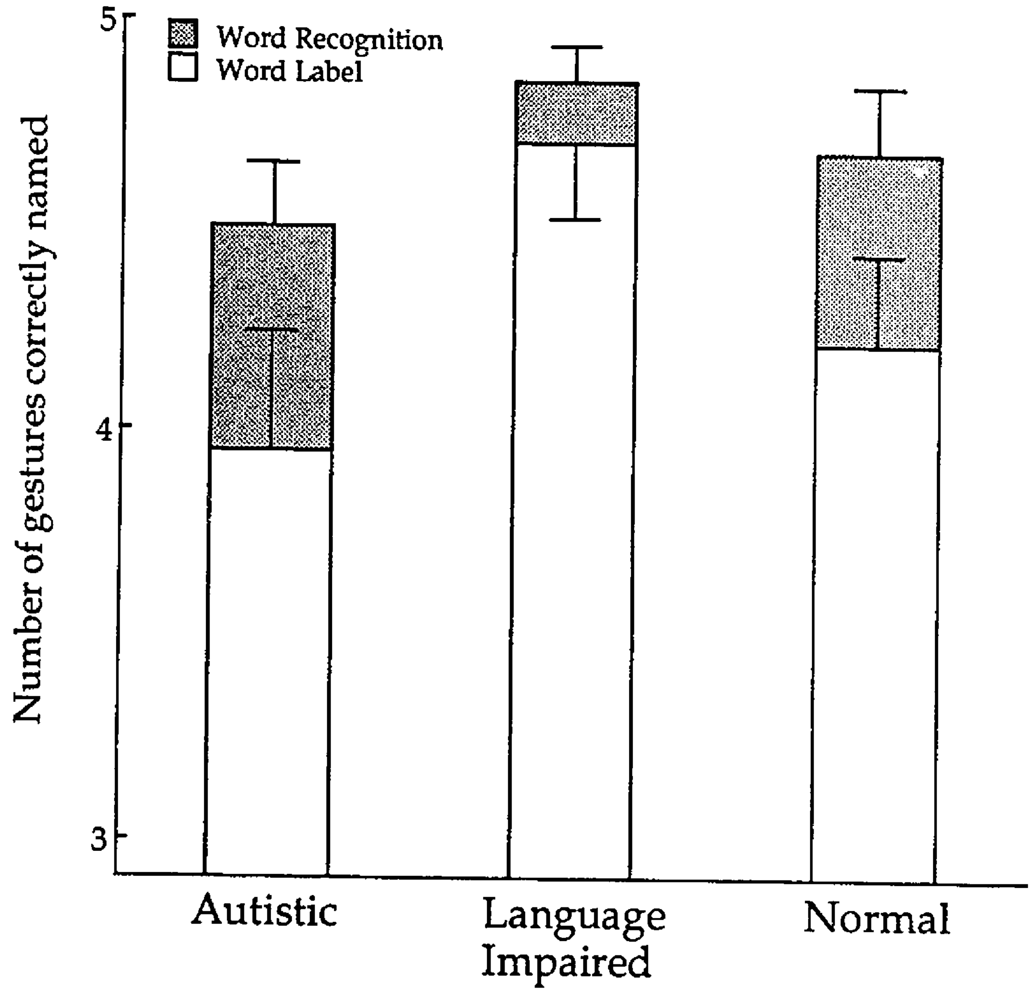


Figure 3. Numbers of communicative gestures correctly named in each cue condition, by Group (means and standard errors).

by Word. The Group X Cue interaction was not significant, $F(2,56) = 2.49$, $p = .092$. Again, however, examination of the data (Figure 3) suggests that there may be a tendency for the Autistic group (versus both control groups) to identify fewer gestures by spontaneously providing a verbal label.

The second measure of Communicative Gesture comprehension was the Gesture in Context task, in which children indicated the drawing in which each gesture appeared in an appropriate context. These scores (number of correct picture choices) were analyzed in a one-way analysis of covariance, which revealed no significant Group differences, $F(2,52) = 1.83$, $p = .17$; Autistic $M = 4.6$, $SD = 1.6$; Language Impaired $M = 5.0$, $SD = 1.5$; Normal $M = 4.0$, $SD = 1.7$.

Summary: Recognition/Comprehension of Symbolic Actions

Children with autism were able to identify actions associated with common objects, when those actions were pantomimed by the experimenter. There were no significant differences between groups in the numbers of actions identified by recognition of appropriate verbal labels (i.e., object names), or choice of photographs of the action-appropriate objects, although there was a nonsignificant trend toward fewer correct spontaneous verbal responses (i.e., naming the object) by the Autistic group. The same pattern was seen for Communicative Gestures. Children with autism tended to have more difficulty than controls in generating appropriate labels for Communicative gestures, and to rely more often on recognition of the words when provided choices. However, overall, children in the Autistic group were just as able as those in the Language Impaired and Normal groups to indicate recognition of Communicative Gestures. Furthermore, their ability to identify the appropriate pictorial contexts for the same social gestures for which they had some difficulty generating names was not impaired.

For symbolic actions, then, recognition and comprehension appeared to be intact in the children with autism. However, although overall performance was normal, the means by which this performance was accomplished may have differed. For example, verbal access to descriptive labels for these actions appeared to a source of difficulty for at least some children in the Autistic group.

Gesture Production and Imitation

I. Imitation of Nonsymbolic Actions

A. Postures - Global ratings

The data for Nonsymbolic Posture imitation represent global ratings of the similarity of the gestures to the modelled standard (see Method). These ratings are presented in Figure 4 by Group and Condition (Model Absent, Model Present, No Visual Feedback). The data were analyzed in a repeated

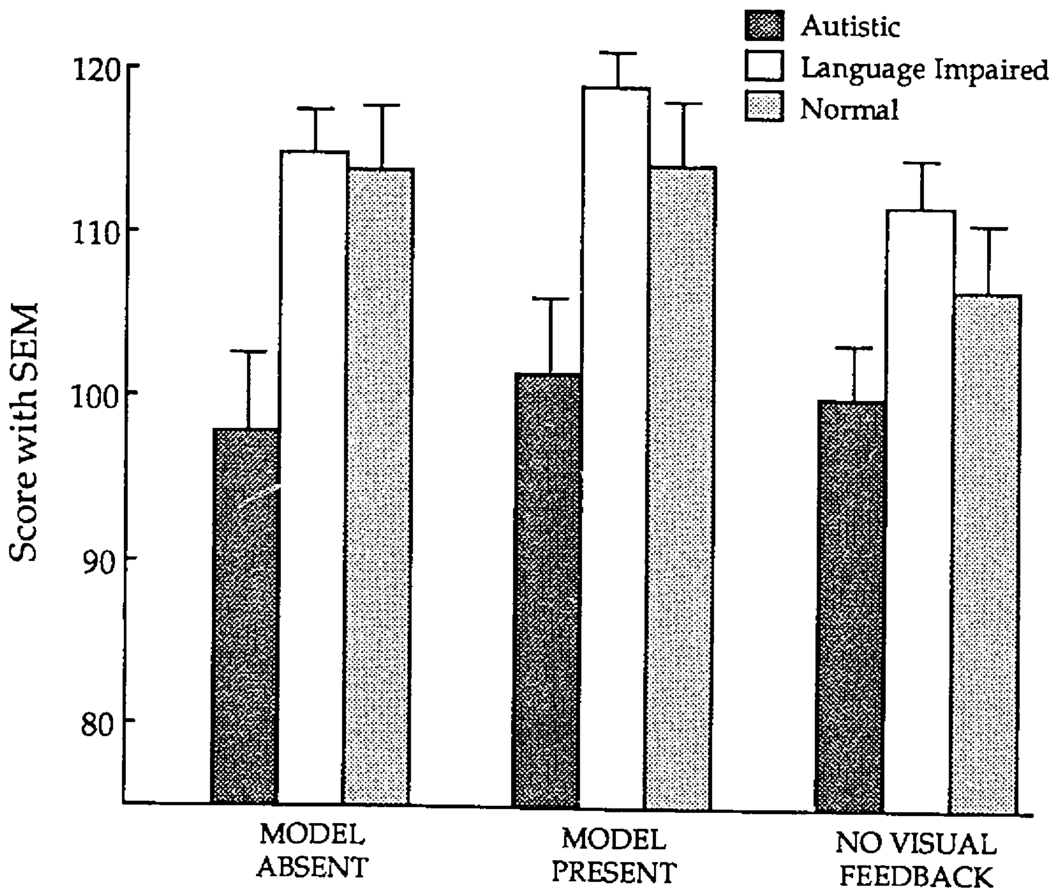


Figure 4. Global ratings of nonsymbolic posture imitation, by Group and Condition (means and standard errors of the means).

measures Group X Condition analysis of covariance, with Condition as the repeated measure. There were significant main effects of both Group, $F(2,52) = 5.88$, $p = .005$, and Condition, multivariate $F(2,52) = 6.44$, $p = .003$. Planned contrasts indicated that the effect of Group was due to significantly lower overall Posture scores for the Autistic than for the two control groups, $F(1,52) = 11.1$, $p = .002$, whose scores did not differ, $F(1,52) = .66$, $p = .42$. The main effect of Condition was attributable to (1) lower scores obtained in the Model Absent condition, compared to the Model Present condition, $F(1,53) = 6.06$, $p = .02$, and (2) to lower scores in the No Visual Feedback condition, compared to the Model Present condition, $F(1,53) = 6.35$, $p = .02$. The Group X Condition interaction was not statistically significant, multivariate $F(4,106) = 1.44$, $p = .22$.

As described previously, the Nonsymbolic Posture recognition data indicated that the Autistic group erred equally frequently in recognizing symmetrical and asymmetrical bimanual postures, while the controls erred more frequently on asymmetrical postures. Production data were therefore examined for corresponding differences in the imitation of bimanual postures. Global ratings of Posture imitation by children in the three Groups for the bimanual symmetrical and asymmetrical postures (collapsed across Model Absent, Model Present, and No Visual feedback conditions) are presented in Table 8. A repeated measures Group X Symmetry Condition (Symmetrical versus Asymmetrical) analysis of covariance revealed that,

Table 8 Global ratings of nonsymbolic posture imitation for bimanual postures, by Group and Symmetry condition (means and standard deviations).

Nonsymbolic Postures - Imitation

	Autistic	Language Impaired	Normal
Symmetrical	81.1 (12.9)	92.8 (7.7)	91.3 (9.7)
Asymmetrical	73.5 (13.4)	82.5 (7.4)	80.7 (10.1)

consistent with the analysis reported above for the imitation rating data, there was a significant main effect of Group, $F(2,43) = 4.95$, $p = .01$ (and that the Autistic group had lower scores than did either of the control groups, $F(1,43) = 9.78$, $p = .003$, whose scores did not differ, $F(1,43) = .13$, $p = .72$). There was also a main effect of Symmetry Condition, $F(1,44) = 144.42$, $p < .001$, indicating that symmetrical postures were rated as being more accurately imitated than asymmetrical postures. However, there was no significant Group X Symmetry Condition interaction, $F(2,44) = 1.33$, $p = .28$, indicating that neither type of bimanual posture was relatively more difficult for the Autistic (or any other) group. Thus, although the Autistic group's recognition of nonsymbolic postures did not differ from that of controls, they made relatively more recognition errors on symmetric postures, whereas in production, their overall performance was poorer than that of controls, yet not more so for symmetric postures,

Postures - Errors

Posture imitation data were also analyzed with respect to the presence of the four error types determined to be sufficiently reliable for analysis (see Method): Posture errors, Left-Right Reversal errors, Symmetry errors, and 180° Rotation errors. (These errors were not mutually exclusive.) Mean numbers of errors produced by children in each of the Groups for each Condition are presented in Tables 9 through 12. Examination of the distributions of these errors indicated marked positive skewness for all but Posture errors, as well as an outlier for 180° Rotation errors. Therefore, logarithmic transformations were applied to the error data before analyses. Each error type was analyzed in a repeated measures analysis of covariance, with Condition (Model Absent, Model Present, No Visual Feedback) as the repeated measure.

Analysis of log Posture errors (see Table 9 for untransformed means) revealed no main effects of Group, $F(2,56) = 1.75$, $p = .18$, or Condition, multivariate $F(2,56) = .08$, $p = .92$., nor any significant significant Group X Condition interaction, multivariate $F(4,114) = 1.03$, $p = .39$.

Table 9 Numbers of Posture Errors, by Group and Condition (means and standard deviations).

Nonsymbolic Postures - Imitation: Posture Errors

	Autistic	Language Impaired	Normal
Model Absent	10.0 (3.3)	9.1 (3.2)	8.7 (3.7)
Model Present	9.4 (4.1)	9.2 (2.6)	8.6 (3.2)
No Visual Feedback	10.9 (3.5)	10.4 (3.4)	9.0 (5.3)
Total	31.8 (7.1)	28.7 (7.5)	26.3 (9.6)

The untransformed mean numbers of Left-Right Reversal errors are displayed in Table 10. Analysis of log Left-Right Reversal errors revealed that

Table 10 Numbers of Left-Right Reversal Errors, by Group and Condition (means and standard deviations).

Nonsymbolic Postures - Imitation: Reversal Errors

	Autistic	Language Impaired	Normal
Model Absent	6.7 (3.4)	5.8 (3.2)	5.7 (3.6)
Model Present	7.2 (4.0)	5.5 (3.1)	5.2 (4.0)
No Visual Feedback	8.4 (3.1)	8.9 (3.8)	7.0 (5.0)
Total	22.3 (8.3)	20.2 (8.3)	17.9 (10.9)

there was no significant main effect of Group, $F(2,55) = 2.08$, $p = .14$. There was a significant main effect of Condition, multivariate $F(2,55) = 3.87$, $p = .03$. Planned contrasts indicated that the Model Absent and Model Present conditions did not differ, $F(1,56) = .93$, $p = .34$, while the No Visual Feedback condition differed significantly from both of these, $F(1,56) = 7.69$, $p = .008$.

That is, as indicated by the means shown in Table 10, significantly more Left-Right Reversal errors were made by children in all groups when they could not see their hands. The Group X Condition interaction was not significant, multivariate $F(4,112) = .85$, $p = .50$.

Mean numbers of Symmetry errors are displayed in Table 11; note that

Table 11 Numbers of Symmetry Errors, by Group and Condition (means and standard deviations).

Nonsymbolic Postures - Imitation: Symmetry Errors

	Autistic	Language Impaired	Normal
Model Absent	.35 (.81)	.10 (.31)	.35 (.75)
Model Present	.60 (1.40)	.05 (.22)	.60 (1.82)
No Visual Feedback	.80 (2.14)	.40 (1.79)	.30 (.92)
Total	1.84 (3.39)	.55 (1.79)	1.25 (2.43)

these were very infrequent errors. Analysis of log Symmetry errors yielded no significant main effects of Group, $F(2,56) = 1.23$, $p = .3$, or Condition, multivariate $F(2,56) = .18$, $p = .84$, nor any significant Group X Condition interaction, multivariate $F(4,114) = .37$, $p = .83$.

Table 12 presents mean numbers of 180° Rotation errors. Analysis of

Table 12 Numbers of 180° Rotation Errors, by Group and Condition (means and standard deviations).

Nonsymbolic Postures - Imitation: 180° Rotation Errors

	Autistic	Language Impaired	Normal
Model Absent	1.20 (2.38)	.40 (.82)	.50 (1.05)
Model Present	1.50 (2.74)	.20 (.52)	.50 (1.28)
No Visual Feedback	1.05 (2.33)	.00 (0.00)	.25 (.55)
Total	3.9 (7.1)	0.6 (1.1)	1.3 (2.3)

log 180° Rotation errors revealed that there was a significant main effect of Group, $F(2,56) = 4.11$, $p = .02$. Planned contrasts indicated that 180° Rotation errors were more common for the Autistic group than for the two control groups, $F(1,56) = 8.11$, $p = .006$, for whom there was no difference, $F(1,56) = .13$, $p = .72$. There was no significant main effect of Condition, multivariate $F(2,56) = 2.32$, $p = .11$, and no significant Group X Condition interaction, multivariate $F(4,114) = .50$, $p = .74$.

Although all types of errors were made more frequently by the Autistic group, when tested separately, only 180° Rotations appeared to distinguish their nonsymbolic posture imitation performance from that of the Language Impaired and Normal controls.

B. Sequences - Correct/Incorrect

Numbers of correctly imitated Nonsymbolic Sequences consisting of either two or three postures (Sequence Length) in each of three Locations are presented by Group in Table 13. These data were analyzed in a repeated measures analysis of covariance with Sequence Length and Location as the repeated measures. For this analysis, in order for a sequence to be scored as correct, both the sequence and the location had to be correctly reproduced. There was a significant main effect of Sequence Length, $F(1,56) = 64.09$, $p < .001$, indicating that for all groups, fewer three-element sequences were correctly produced than two-element sequences. There was no significant main effect of Group, $F(2,55) = 2.29$, $p = .11$. There was no significant Group X Sequence Length interaction, $F(2,56) = .29$, $p = .75$. There was a significant main effect of Location, multivariate $F(2,55) = 13.66$, $p < .001$. Planned contrasts indicated that sequences modelled on the table were more often correctly reproduced than those modelled in the air or on the head, $F(1,56) = 25.85$, $p < .001$, and that there was a trend toward fewer correctly imitated sequences when modelled on the head than in the air, $F(1,56) = 3.92$, $p = .053$. There was no significant Group X Location interaction, multivariate $F(4,112) = .77$, $p = .55$. The three-way Group X Sequence Length X Location interaction was also nonsignificant, multivariate $F(4,112) = 1.36$, $p = .25$.

No differences were apparent between the abilities of children with autism and those of controls to imitate simple sequences of nonsymbolic postures. The effects of sequence length and location manipulations were the same on all groups.

Sequences - Errors

Sequence imitation was also examined with respect to errors. As described in the Method, three types of errors were reliably identified in the sequencing task: Perseveration (of individual postures or of sequences) errors, Posture Change errors (i.e., Substitution, Addition, or Deletion of postures),

Table 13 Numbers of sequences correctly imitated (maximum = 4), by Group, Sequence Length, and Location (means and standard deviations).

Nonsymbolic Sequences - Imitation

		Autistic	Language Impaired	Normal
2-posture sequences	Table	3.5 (.9)	3.7 (.9)	3.2 (1.2)
	Air	3.7 (.7)	3.1 (1.3)	3.0 (1.4)
	Head	3.0 (1.2)	3.0 (1.3)	2.3 (1.6)
3-posture sequences	Table	2.7 (1.2)	2.8 (1.0)	1.8 (1.7)
	Air	2.3 (1.6)	2.1 (1.3)	1.5 (1.6)
	Head	2.0 (1.3)	1.9 (1.2)	1.7 (1.8)
Total (maximum = 24)		16.8 (5.2)	16.5 (5.2)	13.4 (7.3)

and Sequencing errors. As the sequencing task was discontinued for several younger and/or lower-functioning children without completion of all trials, numbers of errors were prorated by dividing the actual numbers of errors of each type by the number of trials completed for each child. These figures were then multiplied by the maximum number of trials (24), in order to convey an indication of the actual frequencies with which these errors occurred.

Separate univariate analyses of covariance were conducted on the numbers of Perseverative, Posture Change, and Sequencing errors for each Group, collapsed over Sequence Length and Location. There were no significant Group differences on any error type. For Perseverative errors, there was no main effect of Group, $F(2,54) = .19$, $p = .83$; Autistic $M = 2.8$, $SD = 3.2$; Language Impaired $M = 3.1$, $SD = 5.0$; Normal $M = 3.5$, $SD = 3.8$. There were also no significant Group differences for Posture Change errors, $F(2,54) = .50$, $p = .61$; Autistic $M = 2.9$, $SD = 2.6$; Language Impaired $M = 2.6$, $SD = 1.7$; Normal $M = 3.5$, $SD = 2.8$. Lastly, no significant Group differences were seen for Sequencing errors, $F(2,54) = 1.82$, $p = .17$; Autistic $M = 1.6$, $SD = 1.2$; Language Impaired $M = 1.9$, $SD = 1.9$; Normal $M = 1.1$, $SD = 1.3$.

Thus, it does not appear that the occurrence of any of these errors in the Sequences tasks distinguishes among the Autistic, Language, Impaired, and Normal groups.

Summary: Imitation of Nonsymbolic Actions

Children with autism produced poorer reproductions of nonsymbolic manual postures than did children in either of the two control groups. One type of error involving rotation of the hand by 180 degrees (e.g., palm toward, rather than away from, the viewer) was more common for the Autistic than for other children. For all children, posture imitation was better in the presence than in the absence of the model, and better when they could see their own hands during the task than when their view of their hands was blocked. When no visual feedback was available, left-right reversals of the hands increased in frequency for all groups.

There were no differences among groups in the ability to reproduce simple sequences of postures. For all children, sequences of three postures were more difficult to imitate than were sequences of two postures. Also for all participants, posture sequences were most easily imitated when modelled on a tabletop, as contrasted with in the air or on the top of the head. Sequences modelled on top of the head tended to be most difficult to imitate.

II. Production/Imitation of Symbolic Actions

A. Actions Using Objects - (1) Developmental ratings

Table 14 presents ratings of developmental level (see Method) for pantomimed Actions Using Objects produced by children in each Group under each of three conditions, (1) on verbal request (Command), (2) in

Table 14 Ratings of developmental level (0-4; see Method) of actions using objects, by Group and Request Condition (means and standard deviations).

Actions Using Objects - Production

	Autistic	Language Impaired	Normal
Command	2.3 (.9)	3.0 (.6)	2.8 (.7)
Photo	2.3 (.8)	3.1 (.6)	2.8 (.7)
Imitation	2.7 (.6)	3.4 (.5)	3.2 (.5)
Total	2.5 (.7)	3.2 (.5)	2.9 (.6)

response to a photograph of the object (Photo), and (3) in response to the experimenter's modelling (Imitation). The data were analyzed in a repeated measures analysis of covariance, with Request Condition (Command, Photo, Imitation) as the repeated measure. There was a significant main effect of Request Condition, multivariate $F(2,51) = 18.1$, $p < .001$. This effect was due to scores for the Imitation condition being significantly greater than those for the Command or Photo conditions, $F(1,52) = 36.9$, $p < .001$, which did not differ, $F(1,52) = .35$, $p = .56$. There was also a significant main effect of Group, $F(2,51) = 10.08$, $p < .001$, indicating that, overall, children in the Autistic group were less successful in producing these actions than were those in the other two groups, $F(1,51) = 18.93$, $p < .001$, whose scores did not differ, $F(1,51) = 1.21$, $p = .28$. There was no significant Group X Request Condition interaction, multivariate $F(4,104) = .44$, $p = .78$.

(2) Unconventional Actions Using Objects

Imitation of Actions Using Objects was also examined in the Unconventional Actions task, data from which are illustrated in Table 15. Recall that each child could make one of four possible responses following modelling of an unconventional action using an object in this task: (1) imitating the unconventional action, (2) producing the conventional action associated with the object, (3) combining the conventional and unconventional actions, and (4) producing an unrecognizable action. Each child completed 10 trials, each of which involved a different object.

As seen in Table 15, Panel A, there were significant Group differences in the mean numbers of imitations of unconventional actions, $F(2,56) = 3.32$, $p = .04$. children with autism produced fewer imitative responses than those in either control group, $F(1,56) = 6.02$, $p = .02$, who did not differ, $F(1,56) = .63$, $p = .43$.

There were no significant differences among Groups in the mean numbers of conventioanl actions produced with the objects, $F(2,56) = 1.06$, $p = .35$, although it appears in Panel B of Table 15 that the performances of the Autistic and Normal groups more closely resemble each other's than either resembles that of the Language Impaired group.

There was an nonsignificant trend toward differences among Groups in the mean numbers of "blended" actions, $F(2,56) = 2.80$, $p = .07$, with an apparent tendency toward greater numbers of such responses by the Autistic group (see Table 15, Panel C).

Similarly, although it appears from the means in Table 15, Panel D, that more "unrecognizable" actions were produced by the Autistic group, this difference was not statistically significant, $F(2,56) = 2.48$, $p = .09$.

The results for this task were explored further using nonparametric methods. Children were classified as "always" imitators if their responses on

Table 15 Numbers of responses in each of 4 categories in the Unconven tional Actions Using Objects task, by Group (means and standard deviations).

Unconventional Actions Using Objects

	Autistic	Language Impaired	Normal
A. IMITATION:			
	8.3 (2.5)	9.8 (.6)	9.1 (1.8)
B. CONVENTIONAL ACTION:			
	.7 (1.4)	.1 (.3)	.6 (1.3)
C. BLENDED ACTION:			
	.8 (1.5)	.1 (.2)	.3 (.6)
D. UNRECOGNIZABLE ACTION:			
	.4 (.6)	.1 (.3)	.1 (.3)

all 10 trials were judged to be imitations of the unconventional actions. The data were then cast into a 2 X 3 contingency table for the three diagnostic groups (Table 16), and analyzed by the method of Rodger (1969) using his error-rate $E\alpha = .05$, which uses the critical value ($\chi^2(2) = 4.78$) provided by Rodger (1975). The results indicated that the incidence of children classified as always imitators in the Autistic group (50%) was lower than that in the two control groups, χ^2 (2) = 5.71. The incidence of always imitators did not differ between the Language Impaired (85%) and Normal (75%) groups, χ^2 (2) = .48.

Additional analyses of data presented in Table 16 indicated that there were no significant differences across Groups in the proportions of children who produced no conventional responses in the Unconventional Actions task, versus those who produced at least one (Autistic, 35%; Language Impaired, 10%; Normal, 20%; χ^2 (2) = 3.73). When conventional responses were collapsed with blended conventional/imitative responses and the analysis repeated, again no significant Group differences were observed (Autistic 35%; Language Impaired, 15%; Normal, 25%; χ^2 (2) = 2.13).

B. Communicative Gestures

Ratings for the quality of Communicative Gestures (0 to 4; see Method) under two conditions: verbal request (Command), and in response to the

Table 16 Numbers of individuals by response category and Group, in the Unconventional Actions Using Objects task.

Unconventional Actions Using Objects

	Autistic	Language Impaired	Normal
IMITATION:			
Always	10	17	15
Sometimes	10	3	5
CONVENTIONAL ACTION:			
Never	13	18	16
Sometimes	7	2	4
CONVENTIONAL *or* BLENDED ACTION:			
Never	13	17	15
Sometimes	7	3	5

experimenter's modelling (Imitation) are seen in Table 17. These ratings were analyzed in a repeated measures analysis of covariance, with Request Condition (Command, Imitation) as the repeated measure. There was a significant Group X Request Condition interaction, $F(2,54) = 4.83$, $p = .01$.

Table 17 Ratings of gesture quality (0-4; see Method) for communicative gestures by Group and Request Condition (means and standard deviations).

Communicative Gestures - Production

	Autistic	Language Impaired	Normal
Command	2.3 (1.0)	3.4 (.8)	2.8 (.9)
Imitation	3.3 (.7)	3.7 (.4)	3.4 (.6)
Total	2.8 (.8)	3.6 (.6)	3.1 (.7)

Within the Command condition, there was a significant Group effect, $F(1,53)$

$= 69.5$, $p < .001$. The mean score of the Autistic group was significantly low relative to both control groups in this condition, $F(1,53) = 13.31$, $p = .001$; the scores of the control groups did not differ significantly, although there was a trend toward lower scores for the Normal versus the Language Impaired group, $F(1,53) = 3.64$, $p = .06$.

Within the Imitation condition, although there was a marginally significant Group effect, $F(1,53) = 3.17$, $p = .05$, planned contrasts indicated no significant differences between scores for the Autistic group versus both controls, $F(1,53) = 3.35$, $p = .07$, nor between the Normal and Language Impaired groups, $F(1,53 = 2.98$, $p = .09$ (see Table 17).

Within-groups contrasts indicated that performance in the Imitation condition was significantly enhanced compared with that in the Command condition, for all groups: Autistic, $F(1,53) = 113.3$, $p < .001$; Language Impaired, $F(1,53) = 183.8$, $p < .001$; and Normal, $F(1,53) = 154.2$, $p < .001$.

Summary: Production/Imitation of Symbolic Actions

Children with autism had more difficulty than controls in generating and imitating symbolic actions, both those involving objects and social communicative gestures. Fewer children in the Autistic group consistently imitated unconventional uses of objects, relative to both control groups.

Production of Communicative Gestures in response to a verbal request but not to imitation was particularly weak for the children with autism.

Manual Dexterity and Imitation

As described above, the Autistic group differed significantly from chronological- and mental-age matched Language Impaired controls in their manual dexterity, as measured by performance on the Grooved Pegboard. In addition, there were significant differences between these groups in their ability to imitate Nonsymbolic Postures, as measured by the ratings of overall gesture quality. Therefore, in order to establish the extent to which differences between the groups in imitation performance might be accounted for by differences in motor skill, between-groups differences in imitation were examined using the dexterity measure as a covariate. First, an analysis of covariance was conducted on mean total posture imitation ratings (i.e., collapsed over Model Absent, Model Present, and No Visual Feedback conditions), between the Autistic and Language Impaired groups, with receptive language level (PPVT-R mental age) as the covariate. As expected, there was a significant Group difference, $F(1,36) = 4.54$, $p = .003$; Autistic $M = 299.5$, $SD = 51.1$; Language Impaired $M = 345.3$, $SD = 32.2$. Receptive language level accounted for 11% of the variance associated with the imitation ratings scores, $F(1,36) = 4.60$, $p = .04$. The posture imitation rating data were then reanalyzed, with both the receptive language mental age (PPVT-R mental age) and dexterity (Grooved Pegboard dominant hand "time per peg") measures as covariates. Regression analysis indicated that an additional 37% of the variance was accounted for by the inclusion of the dexterity measure, $F(2,35) = 16.44$, $p < .001$. With both of these effects covaried, significant Group differences in Nonsymbolic Posture imitation scores remained, $F(1,34) = 4.81$, $p = .04$. Thus, the Autistic group continued to show lower imitation scores once the significant amounts of variance due to both receptive language level and manual motor skill had been removed.

DISCUSSION

The purpose of this dissertation was to integrate and extend the findings of a number of studies of gesture imitation in autism conducted over the past 25 years. During this period, claims have been made about the praxic disabilities of individuals with autism, but differences in aims, methodologies, and samples have precluded direct comparisons. A major goal of this investigation was to replicate the reported deficits with a single sample of children and adolescents with autism, and to clarify the nature of the findings with reference to the current relevant literature.

Before proceeding with the discussion of results, four methodological issues will be addressed briefly: the choice of comparison groups, the assessment of gesture recognition and comprehension, order effects, and coding. Next, the results of tasks assessing nonsymbolic imitation, including sequencing of nonsymbolic postures, will be discussed. Following this, the focus of the discussion will shift to the findings for the symbolic tasks involving object-related actions and social gestures. The implications of the present results for the understanding of how actions are represented in autism will then be addressed, in the context of current views of autism. A number of avenues for further investigation will be suggested throughout this discussion, which will conclude with comments regarding the importance of the study of imitation in autism.

Methodological Considerations

Comparison groups. In many early studies that reported deficits in gesture imitation, the specificity of the impairment to autism was in question. Therefore, a major concern for this investigation was that of appropriately controlling for the level of functioning in the group with autism. Based on the preceding literature review, it appeared that matching for language level was a critical factor, and this was one goal of the present study. Due to the uneven cognitive profile that is typical of autism, finding individual language-level matches was extremely challenging. In this study, a concerted effort was made to locate clinical controls whose language skills were discrepant from their nonverbal abilities, and whose receptive language abilities were as closely matched as possible to those of the participants with autism. Young typically-developing children, also matched to the Autistic group for language level, were a second essential control group. Covarying receptive language scores from the data analyses where possible was an additional attempt to rule out group differences attributable to level of functioning, rather than diagnostic status. That the pattern of results observed was consistent with most findings suggests that the previously reported imitative impairment in autism was not an artifact of differences in either general or language ability between groups. Indeed, it appears to be quite a robust finding. Given the replicability of the general phenomenon, one can look more confidently to the specific results for clues as to the nature of the problem in autism. Is the performance of children with autism qualitatively different than that of controls? What variables influence the ability of individuals with autism to reproduce gestures?

Recognition and comprehension of gestures. Another control issue that was central to the design of this investigation was that of establishing the ability of individuals with autism to recognize and/or to comprehend the gestures that were used in the imitation tasks. Only one other study, not yet in the published literature, has acknowledged the need for this essential information (Rogers & McEvoy, 1993).

The impairments observed in the present study for the group with autism cannot be dismissed as resulting from inability to encode the gestures, as differences were not seen on measures of gesture recognition or comprehension. In the only previous study to have assessed recognition of gestures prior to assessing the imitation of those gestures, Rogers and McEvoy (1993) also reported that autistic imitation deficits were not attributable to encoding problems. Their sample was somewhat older and considerably higher functioning than that in the present study. Thus, the present study extends the finding that imitation deficits exist in the absence of gross encoding deficits to a younger and relatively more impaired group. The tendency for all groups to choose similar foils when making recognition errors in the Nonsymbolic Postures task suggests that responses based on inattention and impulsivity were equally distributed across groups. The possibility of more subtle receptive problems is discussed below with reference to specific aspects of the data.

Order effects. The significant "conditions" effects found in the analyses of the present data must be interpreted in light of the constant order in which all participants were exposed to the conditions. The only counterbalanced order was whether the set of symbolic or nonsymbolic tasks was presented first to the individual in each session. Pragmatic constraints necessitated these design decisions. Firstly, the sample was not large, and a within-subjects design was necessary. Beyond this, many tasks demanded a logical order in which, for example, increasingly informative cues were provided in order to elicit a response. Consequently, the group by condition interactions, rather than the main effects of conditions, are of primary interest, the latter being susceptible to practice and transfer effects. These issues will be discussed with respect to specific results, as relevant.

Coding of data. Reliability of judging the quality of gesture production has been identified as an area of concern for studies of adults with acquired apraxia (Tate & McDonald, 1995). It follows that this would also be an issue for those who study the development of gestural abilities and its disruption. Due to the wide ranges of chronological age and level of functioning represented by the participants in this research, reliable coding of responses was particularly challenging. As described in the Method, collapsing of some error categories was necessary in order to establish reliable scoring, and some categories were dropped from further analyses. For the remaining data, however, the obtained reliability statistics are not inconsistent with those reported, for example, by Dewey (1993), in her study of children with developmental motor problems and normally-developing controls. It is likely that both changes in the definitions of some error types and more intensive training of observers could render other aspects of the data amenable to analysis.

Nonsymbolic Imitation

Manual motor skills and gesture production. The present results indicate that the ability of children with autistic spectrum disorders to produce nonsymbolic manual gestures was impaired, relative to that of children with nonautistic language delays or disorders, and of young typically-developing children. These difficulties were accounted for in part, but not entirely, by deficits in motor coordination, as elaborated below.

Manual dexterity was significantly impaired in this sample of children and adolescents with autistic spectrum disorders. That is, they completed the Grooved Pegboard more slowly than did controls, both with the dominant and nondominant hands. This finding is consistent with those of Szatmari et al. (1990). The population of individuals who present clinically with autistic spectrum disorders is extremely variable with respect to performance on tasks assessing manual motor skill (Manjiviona & Prior, 1995). However, it appears that performance for the overall category of autistic spectrum disorders tends to be poorer than predicted by language mental age. Where results are not consistent with this conclusion, perhaps both sample and task differences may be factors. The more important issue is the extent to which the heterogeneity in motor skills within autistic spectrum disorders may mask subgroup differences.

Manjiviona and Prior (1995) reported that scores on a standardized motor assessment did not reliably distinguish high-functioning autistic (HFA) from Asperger syndrome (AS) individuals. In contrast, Szatmari et al. (1990) found that motor skill was among the significant neuropsychological variables in a discriminant function analysis predicting HFA versus AS diagnoses, with HFA individuals performing better (i.e., faster) on the pegboard task than did those in the AS group (especially with the nondominant hand). However, classification based on the obtained discriminant function was poor (about 67% overall). It is clear that the relationships among manual motor skills, handedness, and diagnoses of autistic spectrum disorders are complex, and that this remains an area for further inquiry. Perhaps clarification awaits a consensus regarding the other variables that define putative autistic subgroups (Manjiviona & Prior, 1995; Ozonoff, Rogers, & Pennington, 1991). In particular, the present results suggests that the inclusion of tests of praxic ability as well as simple motor skills might be informative.

Postures. It must be noted that the assessment of nonsymbolic posture recognition by picture choices was a relatively crude assay for the accuracy of the representation of the gesture. One could argue more conservatively that what was controlled was attention to and memory for the gesture stimulus, rather than for the accuracy of encoding. Only three picture choices were used in the recognition task in the present study, in order not to tax too greatly the attentional capacities of the younger and lower functioning participants. However, the results of the manipulation of the similarity of foils to target postures indicated that the children with autism were attentive to the features of the target gesture. That is, there was no indication of more impulsive responding by the children with autism, in that when errors were committed, the foils were not chosen randomly. Rogers and McEvoy (1993) reported that they used six foils in their gesture recognition condition, but did not describe the degree of similarity between target and foils, or report any analysis of errors.

The children with autism in this study performed overall as well as controls in their recognition of nonsymbolic postures. Children in both control groups, however, erred more often in recognizing asymmetrical bimanual postures, while the errors of children with autism were evenly divided between symmetrical and asymmetrical postures. While this result might suggest some difference between the autistic and non-autistic groups in the encoding of these two types of gestures, it is difficult to interpret what that effect might be. For example, it did not appear to have implications for the production of the gestures. Although imitation was rated as being more accurate (for symmetrical as opposed to asymmetrical postures) for all children in this study, there were no differential effects on imitation across groups. Neither did symmetry errors in posture imitation as coded in this study (e.g., mis-reproduction of an asymmetrical posture as symmetrical), differentiate the autistic group from controls. More detailed exploration of relationships between recognition and production errors, perhaps on an individual basis, might be warranted.

Support for this suggestion comes from Rincover, Feldman, and Eason (1986), who reported a case in which a child with autism was unable to learn bimanual signs when the model's hands were far apart (20 cm), but was able to when they were closer together (5 cm). This result was interpreted as an example of "tunnel vision", or overly selective spatial attention. Similarly, Bryson et al. (1990) have suggested that a form of spatial neglect may be manifested in autism (cf. Townsend & Courchesne, 1994). Perhaps, for some children in the Autistic group, the symmetry relationships of the bimanual gestures were not evident, due to the effects of such neglect on integrating the perception of the more spatially distributed gestures. However, one is again left to speculate as to why such an effect would not be apparent in the imitation data. It may be that neither the coding of quality of imitation nor of symmetry errors was sufficiently sensitive to detect a difference if it existed. A parametric approach to the manipulation of gesture characteristics might reveal effects such as these.

Although converging evidence suggests that imitation problems remain demonstrable in the absence of gross perceptual difficulties, this does not preclude the possibility that some aspects of the model to be imitated are not accurately encoded, at least by some people with autism. Manipulation of more subtle aspects of the gesture in the picture foils than was used in the present study would be possible, permitting one to explore specific hypotheses regarding encoding difficulties. For example, the occurrence of 180° Rotation errors in posture imitation suggests that using photographs of rotated versus veridical postures would be an informative manipulation in a recognition task. The implications of the present findings for our understanding of gesture representation in autism will be addressed in the concluding section of this discussion.

The general finding that imitation of nonsymbolic gestures by children with autism was less accurate than that by controls confirms the findings of DeMyer et al. (1972), Jones & Prior (1985), Ohta (1987), and Rogers and McEvoy (1993). In the present study, static postures and posture sequences were tested separately, in order to assess whether a deficit existed even for shaping the hand to match a single posture. Overall ratings of the accuracy of posture imitation by a blind judge were significantly lower for the Autistic group. These differences were not reflected in the numbers of posture errors; instead, these errors were frequent and equal across the groups of Autistic, Language Impaired, and young Normal children. This finding confirms previous observations of praxic difficulties for children with a variety of language and learning impairments (Roy et al., 1990), and developmental trends in praxic abilities (Dewey, 1993). It is, of course, possible that an alternative definition of posture errors might reveal that some aspect of posture formation might differentiate children with autism, and these data afford the opportunity to pursue additional investigations of this kind. However, the present results suggest that other error types, which may be of more theoretical significance, should be the focus of future study.

Role of visual information. Additional information about the nature of the fundamental nonsymbolic imitative deficit in autism comes from the examination of the effects of manipulation of stimulus conditions and the analysis of errors. Specifically, the role of visual information in the guidance of imitative movements was investigated by including the Model Absent, Model Present and No Visual Feedback conditions in the nonsymbolic posture imitation task. That there was no significant interaction between these conditions and groups for either global ratings or errors argues against the prediction that the use of visual information in gesture imitation by children with autism would differ from that by the control groups. However, there are hints of differences in the data that will be elaborated in theis section of this discussion.

All three groups did show improved imitation in the second (Model Present) condition, presumably as a joint function of practice and the availability of a model. Although definitive conclusions are precluded by the confound of order here, it does not appear that visual memory differences could account for the poorer gesture imitation by the Autistic group.

Similarly, all three groups' imitation scores were lower when the model remained present but no view of the performing hand was available to the child (No Visual Feedback). It had been hypothesized that the effects of lack of visual feedback during imitation tasks would be reduced for children with autism compared with controls, based on analogous findings that have been reported for nonimitative visual-motor tasks (Frith & Hermelin, 1969; Hermelin & O'Connor, 1970; Masterton & Biederman, 1983).

As noted above, previous imitation studies confounded visibility of the gesture (i.e., to the subject) with the body parts involved (e.g., facial versus manual imitation; e.g., Rogers & McEvoy, 1993), or with the locus of the gesture (e.g., on the head, versus in front of the body; studies using Uzgiris-Hunt scales). Dawson et al.'s (1982) study suggested that facial and manual imitation by individuals with autism may be dissociable on neurological grounds. Similarly, Raade, Rothi, and Heilman (1991) have argued, based on evidence from adults, that acquired facial and limb apraxias are determined by somewhat independent mechanisms.

The "locus of gesture" variable was included in the sequencing task of the present study, in which (unlike earlier studies with the Uzgiris-Hunt scales) the specific postures used in each of three locations were controlled. No differences were observed between groups in the Sequencing task when sequences were performed out of sight (on the head) versus in front of the body. Instead, these sequences tended to be more difficult for all children, not differentially so for those with autism.

Even when visibility was manipulated directly by screening the hands in the nonsymbolic posture imitation task, group differences were not obtained. It is possible that this effect would have been apparent had not the No Visual Feedback condition constituted the third repetition of the same series of postures. Practice may have "washed out" an effect that might otherwise have been observable. Inspection of the means in Figure 4 suggests that this might have been the case, as the Language Impaired control group appears have been more adversely affected by being unable to see their hands than was the Autistic group (intermediate scores were obtained for the Normal group). Additional qualitative evidence was sought from the error data.

The 180° Rotation errors observed in the present study appear similar in kind to those described by Ohta (1987). Those errors were used by Barresi and Moore (1996a) as indirect support for their hypothesis that individuals with autism show a general failure to integrate information specifying first and third person perspectives, on the levels of action, affect, and cognition. They speculated that this might be attributable to an early developmental failure by infants with autism to process the intermodal information that is available in social interchanges, or perhaps an even more general failure of intermodal integration (see also Smith & Moore, in preparation).

Certainly, the finding that children in the Autistic group made significantly more of these rotational errors poses a challenge for any account based on diminished use of visual feedback by this group. Indeed, it appears more consistent with the contrary position, that the children with autism are responding on the basis of what is directly accessible to perception, that is, to their view of their own hands. This would imply increased, rather than decreased, dependence on visual feedback.

Perhaps these alternatives may be reconciled with reference to the suggestion, alluded to in the Introduction, that it is the integration of information in perception, rather than the predominance of one modality over another, that is abnormal in autism (Hermelin (1976; Hermelin & O'Connor, 1970), and that this may be fundamentally an attentional problem (Smith & Moore, in preparation). In the present study, the imitation performance of the Autistic may have been poor across all of the conditions relative to controls because of their diminished ability to integrate these two sources of information. Removal of visual feedback in the third imitation condition would thus have been irrelevant to their performance, which would already reflect poor integration of the dual sources of information (as opposed to lack of dependence on vision). In brief, eliminating visual monitoring of the hand may have had some differential effects on the Autistic group. However, in order to resolve this issue, it would be necessary to correct the confounding effects of practice. In addition, perhaps other simpler tasks could address this issue more directly than in the context of praxis.

The significant decline in the quality of imitation in the No Visual Feedback condition for all participants was an expected finding (Bergès & Lézine, 1965). What was unexpected, however, was the significant increase in Left-Right Reversal errors that occurred in this condition. It is suggested that this effect is a result of the children reverting under challenging conditions to a less mature imitation strategy, as though they were facing a mirror. "Mirror" responses were found by Bergès and Lézine (1965) to constitute the majority of responses in normally-developing children up until the age of six years, and non-mirror responses predominated only in children over ten years of age.

Mirror responses might be interpreted as a form of more visually-driven matching, with the gesture reproduced relative to an external, rather than an egocentric (body-based) frame of reference. A similar argument for 180° Rotation errors would attribute their more frequent occurrence in the Autistic group and in young typically-developing children to a failure to encode the gestures of others accurately within a self-referenced framework.

One would then expect an increased frequency of mirror (Left-Right Reversal) errors in the Autistic group. Although no significant preponderance was observed, the trend was consistent with somewhat more mirror (Left-Right Reversal) errors being produced by the children with autism when their hands were visible to them (see Table 10).

Anecdotally, the present author has noted that typically-developing infants go through a stage at which they reverse the orientation of person-directed gestures such as waving "bye-bye", although no reference to this has been encountered in the literature. Instances of 180° rotations were also observed in the present study when some children produced a beckoning "come here" gesture with their index finger pointing away from, rather than toward themselves. These types of errors were observed among the youngest normally-developing children, but also in much older and higher-functioning children and adolescents with autism. Most striking was the case of a 14-year-old boy with autism whose PPVT-R standard score was 120, yet who, when imitating, rotated several meaningless postures and the "come here" gesture. Perhaps the 180° Rotations by the children with autism in the present study stand out because, given the age range of the sample, they are so developmentally inappropriate, whereas the mirror responses are still relatively common in the other groups. One might expect that in an older, higher-functioning autistic group, left-right reversals might persist.

Future more hypothesis-driven studies of imitative behaviour can build on the information provided by the present research. For example, it would now be possible to construct a gesture series and tests of recognition that would maximize the likelihood of errors that could increase our understanding of the processes at work. Exploration of the sources of rotational errors should include studies of their occurrence in normal development, and their relationship to other aspects of the infant's developing understanding of interactions between people. Parallel studies of younger children with autism would be instructive with respect to whether a delayed or a deviant developmental pattern would be observed. The results of further nonimitative tasks addressing the integration of visual and kinaesthetic information by people with autism (for example, using the task of Klein & Posner, 1974) would be informative. Of particular interest is the issue of whether concomitant failures of intermodal integration would be observed on tasks that do and do not tap an interpersonal dimension (Smith & Moore, in preparation; see recent work by Haviland et al., 1996, and Loveland et al., 1995).

Sequences. One somewhat surprising aspect of the present findings was the unimpaired performance of the children with autism on the tasks assessing the recognition and imitation of posture sequences. Group differences were seen in the imitation of static postures but not in simple sequencing when the demands for postural accuracy were minimized. The failure to observe an increased number of perseverative responses is perhaps particularly surprising, given evidence of perseveration for individuals with autism on tasks such as the Wisconsin Card Sorting Test (Ozonoff, Pennington, & Rogers, 1991; Rumsey, 1985; Szatmari et al., 1990), and others (Hughes and Russell, 1993; McEvoy, Rogers, & Pennington, 1993). However, increased perseverative responding is not a universal finding (Minshew, Goldstein, Muenz, & Payton, 1992). The range of language functioning in the present study was great, with some children obtaining mental age equivalents below three years. Multiple instances and forms of perseveration (e.g., of postures, of sequences) were observed for some children in all three groups, especially those with lower verbal mental ages. Categories of perseverative responding were collapsed to improve the reliability of scoring these errors, but this practice may have obscured some effects. It is possible that some alternative parsing of the data might reveal group differences that were masked in the present analyses. In particular, there may be justification for predicting that greater perseveration to a location (e.g., table) would be seen in the Autistic group, based on the evidence that disengaging from a spatially determined strategy appears particularly difficult for children with autism (Hughes & Russell, 1993; McEvoy et al., 1993; Russell & Jarrold, 1995), even at the level of spatial attention (Townsend & Courchesne, 1994; Wainwright-Sharp & Bryson, 1993). Bryson et al. (in press) have proposed that this form of perseveration (that is, to a spatial location) may be particularly prominent in autism, and may account for the very poor performance observed on many "executive function" measures (e.g., the Tower of Hanoi).

The present result (that is, no relative difficulty with gesture sequences) is not inconsistent with the sequencing deficit claimed by Rogers and McEvoy (1993), as those investigators did not include a comparison of single and sequential nonsymbolic postures. Instead, among their tasks were sequential nonsymbolic hand and arm movements, and both single and sequential facial movements. Their claim of a deficit for facial movement sequences is contaminated by the fact that the autistic group also showed lower performance than controls in the *single* facial movement condition. When single gestures cannot be accurately imitated, as has been demonstrated, failure to imitate complex sequences cannot be attributed parsimoniously to a sequencing deficit.

The assertion that "sequencing" is deficient in autism dates at least from the work of Hermelin and O'Connor (1970). It is the case that on a variety of auditory tasks (both linguistic and nonlinguistic), these investigators demonstrated atypical patterns of recall and production of ordered information. However, two visual-spatial ordering tasks were reported by

Hermelin and O'Connor (1970). In the first, a seriation task, children with autism were unable to place five squares in descending order of size (cf. Yurmiya, Sigman, & Zacks, 1994). However, in the second, these children were able to reproduce the order of a series of four pictures that had just been shown to them, and to use semantic associations between the pictures to guide their performance. They were reported to make "somewhat" more errors than normal controls, who were matched to the autistic group for verbal digit span (and were probably higher-functioning in terms of language). This picture task resembles the sequence "recognition" task in the present study, in that both perception and reproduction of a visually-presented series is required.

The Autistic group in this study did not differ from controls, either in the "posture picture arrangement" task or when they actually reproduced the sequences of postures in the imitation task. This latter finding is challenging, given that Hermelin (1976) summarized years of careful studies by concluding that children with autism can deal effectively with information presented in a spatial framework, but that their processing of temporal sequences is impaired. Furthermore, she hypothesized that the autistic tendency is to process information in the modality in which it is presented, rather than recoding it to a more abstract (amodal) form. Nonetheless, the pictures in the picture arrangement task alluded to above and the gestures of the present study, were reproduced spatially (in the case of the "recognition" task) and temporally (in the case of the imitation task). Perhaps these tasks were merely simple enough (both in terms of the simplicity of the postures and the brevity of the sequences) to be accommodated by the strategies available to the participants with autism. In any case, it is clear from the present results that it could not be merely the sequencing aspect of gesture production that under-lies the pronounced difficulties in this domain consistently reported for people with autism. It would be of interest to document the performance of individuals with autism on other action sequencing tasks such as those employed by Kimura (1977) or Roy (1981) in their studies of adults with acquired apraxia. In addition, it may be important to examine the relation-ships between the elements of sequences, whether these are semantic relationships, or whether the sequences of movements share "directedness" toward a goal.

In a recent report, Hughes (1996b) described clear motor planning impairments for a group of children with autism. The task was adapted from Rosenbaum et al. (1990), and required a series of movements to place a rod into a holder. The ends of the rods, and the holders, were colour-coded, so that the children could be instructed which end of the rod to grasp and where to place it. The starting position of the rod was manipulated to influence the probability of each child using an overhand (typically preferred) or an underhand grip, resulting in either a comfortable or an awkward starting position. The ability to plan the movements required to complete the task efficiently was then assessed by analyzing the numbers of comfortable transfers of the rod made in the non-preferred grip condition. The rationale for this measure was that evidence of planning was strongest when a non-preferred strategy was used to accomplish a goal. Compared with groups of mentally handicapped and normally developing children, children with autism were significantly less successful at this task.

Hughes (1996b) considered several possible interpretations of this finding. One potential interpretation invoked a sequencing deficit. Hughes (1996b) advocated additional work to tease apart sequencing versus prediction deficits in autism. The present study makes a contribution to this effort. The sequencing task used here reduced the demands for posture imitation by using very simple discrete postures. Short sequences were also used, but more importantly, a manipulation of sequence length was introduced. When children with autism have been described as having deficits in the sequencing of movements (e.g., Hughes, 1996b; Rogers & McEvoy, 1993), the length of the movement sequences have not been manipulated. Therefore, there was no opportunity for any interaction to arise between sequence length and diagnostic group. Such an interaction would be observed if groups were differentially affected by increasing sequence length, as predicted for a genuine sequencing deficit.

The present results indicate clearly that the performance of the children with autism was not affected disproportionately by the requirement to imitate longer sequences. A simple sequencing account of their failure to execute more complex series of movements is therefore rejected. The distinction between the necessity for serial ordering (simple sequencing, as in the present task) versus planning (movements directed toward a goal, as in Hughes, 1996b) appears to be important[1].

Symbolic Gestures

Consistent with the Piagetian view of imitation, the early literature on imitation in autism focussed on apparent deficiencies in symbolic gestures, but primarily with respect to production or imitation, rather than to the receptive aspects of gesture representation. Presumably, if failure to imitate

[1] It is noteworthy that efficient completion of the Grooved Pegboard entails taking account of the orientation of each slot as one approaches with a small key-like metal peg, and matching the orientation of the peg to the slot during the movement. Even the very high-functioning men with autism in the Rumsey and Hamburger (1988) study showed a trend toward slower performance on the Grooved Pegboard, especially with the nondominant hand. When motor skill differences were not observed for children with autism (McManus et al., 1992), the task was the Annett pegboard, in which much larger wooden pegs are removed from one row of holes and fitted into another (Annett, 1970). Consistent with this, McEvoy et al. (1993) included the Wallin pegboards A (round pegs) and B (square pegs) from the Merrill-Palmer Scale of Mental Tests as discriminant tasks in their study of executive functions in preschool-aged children with autism. There were no differences in speed to complete these (combined score) between the children with autism and either nonverbal mental-age matched or verbal mental-age matched

were a consequence of an inability to represent the event mentally, there would also be a general failure to recognize the actions in question. As noted in the Introduction, one element of evidence against such a position is the sensitivity shown by children with autism to being imitated (e.g., Dawson, 1991). Evidence of intact recognition and comprehension of the gestures used in an imitation study would be another (Smith & Bryson, 1994).

As has been demonstrated, overall recognition of neither nonsymbolic nor symbolic gestures differentiated the Autistic group from controls in the present study. However, as with the possibility of subtle effects on the recognition of nonsymbolic postures, there was some indication that the receptive symbolic gesture tasks were affected by task variables. In this study, when understanding of symbolic gestures was elicited by requiring the child to produce a verbal label, the performance of some children with autism appeared somewhat weaker (although nonsignificantly so). This was the case whether the symbolic gestures were object-related pantomimes or conventional communicative gestures. However, under recognition conditions involving word or picture choices, there was no indication that the children with autism were disadvantaged relative to controls. This raises the issue of whether the autistic difficulty with symbolic gesture production resides with the semantic representation of the gesture, or perhaps with some other

---

normally-developing children. The visual-motor integration requirements of these other motor tasks are considerably reduced, relative to those of the Grooved Pegboard.

process necessary for linking a semantic representation with different output options.

The results of this study confirm previous research indicating that children with autism have relative difficulty imitating the actions of others, whether or not those actions have symbolic content, and whether or not they are communicative in nature. Therefore, any impairment observed in the imitative learning of symbolic gestures must be at least in part attributable to a basic nonsymbolic dysfunction (which is itself apparently partly due to problems with motor planning). Is there an additional impact on the production or imitation of these gestures attributable to processing the meaning of symbolic actions?

Rogers and McEvoy (1993) reported that the high-functioning adolescents and young adults with autism in their study were able to recognize object pantomimes and conventional social gestures in pictures as well as controls. However, information as to how recognition was indicated, and whether any assessment of comprehension was involved was not available in their preliminary report. These investigators reported no differences between their autistic and control groups in the production of simple meaningful hand or facial gestures. Therefore, it is clear that high-functioning individuals with autism can learn to produce conventional gestures, as has also been demonstrated in naturally-occurring contexts by

Attwood et al. (1988). However, the quality of those gestures was not the focus of either the Attwood et al. (1988) or Rogers and McEvoy (1993) investigations.

For the children in the present study, the quality of production of even simple, familiar gestures and pantomimes was lower than that of controls, especially when communicative gesture production was cued by a verbal request. Thus, it was not the novelty of the gestures that accounted for the difficulty in producing them (as one might argue for the meaningless postures and sequences). Even when the meaning of a gesture was known, the quality of gesture production was discernably less mature than that seen in matched controls.

The finding that meaning may fail to facilitate autistic performance has been demonstrated in other contexts. For example, Hermelin and O'Connor (1970) reported studies of verbal recall in which children with autism did not benefit from the semantic relationships among words in sentences or in lists of related words, whereas normally-developing and mentally handicapped children showed better recall of these compared with random word lists. Later studies have shown that word meanings are represented by children with autism such that they are accessible in experimental paradigms like the Stroop test (Bryson, 1983; Eskes, Bryson, & McCormick, 1990), and others (Tager-Flusberg, 1985a & b). However, this semantic knowledge appears not to be applied in a typical manner (Hermelin & O'Connor, 1970). Thus, research on linguistic representation in autism indicates that the flexible *use* of knowledge, rather than the intactness of the concepts themselves, may be impaired (Eskes et al., 1990). This hypothesis of a dissociation between conceptual knowledge and its application has relevance for the interpretation of autistic performance in symbolic gestural tasks.

Object-related actions. The literature on object-related symbolic representation in children with autism has tended to emphasize either imitation or imaginative play (and occasionally both). Pantomime, which was the focus of several studies described in the present literature review, has been addressed in both contexts. It is instructive to analyze the results of the Actions Using Objects tasks reported here, first with respect to the findings reviewed earlier, and then in the context of recent ideas about pretend play in children with autism.

The results of the pantomime task in the present study replicate those of Bartak et al. (1975) and of Curcio and Piserchia (1978). Both of these studies indicated that children with autism had some ability to comprehend and to produce object pantomimes. However, Curcio and Piserchia (1978) noted the immaturity of these productions, as was observed for this sample of children with autism. Bartak et al. (1975) demonstrated that both the receptive and expressive abilities of their autistic group in this domain were less well-developed than those of a matched control group of children with developmental receptive language disorders. Furthermore, the performance of the children in the Bartak et al. (1975) study was particularly impaired relative to that of controls when language was used to elicit pantomime from the child, or when the child had to name the action modelled by the experimenter. These effects are paralleled for the communicative gestures in the present study. However, for object-related pantomimes, responses by the Autistic group in this study to verbal request were not weaker than to object photographs or to imitation, as compared with controls (although there was a trend toward an autistic deficit for naming a pantomime). Instead, the Autistic group's performance was weaker overall. This finding supports the contention that not all tasks that could be considered "symbolic" are equal (in the sense of necessarily reflecting the operation of the same mechanisms), a point that is often overlooked in the imitation literature. In particular, the social dimension associated with communicative gestures might reasonably be expected to influence their acquisition for children with autism (Attwood et al., 1988; Lord, 1985).

It is important to note that relative effects for the two types of symbolic tasks across studies presumably would be sensitive to variables such as the language skills of the particular samples of individuals with autism, as well as to their chronological ages and their experience with the specific objects and gestures in question. Indeed, as will be discussed below with reference to the Unconventional Actions task, the choice of objects might have substantial effects on the outcome of such studies.

It is also worth reiterating the point made by Bartak et al. (1978) that even though the children with autism in their study showed some capability for conventional gesture use in the test situation, only 2 out of 16 of these children were reported by their parents ever to have employed gestures spontaneously at home (cf. Attwood et al., 1988), other than pointing (cf. Baron-Cohen, 1989b). This contrast between competence and performance is a recurrent theme in this discussion.

In the Unconventional Actions task, derived from the work of Hammes and Langdell (1981), children in the Autistic group were significantly less likely to imitate the unconventional use of an object, the conventional function of which was familiar to them. When they did not imitate the unconventional action, their predominant response was to use the object for its conventional function. Indeed, some children appeared almost "driven" to do so. Others began to imitate the unconventional use, then appeared overcome by the urge to use the object conventionally, or vice versa. A few children (all either with autism, or young normals) produced "chimeric" responses; for example, the model "ate" with a comb, which the child then used in a conventional "combing" motion but in front of her mouth. The results of this task indicated that the substitution of one object for the function of another was more difficult for the children with autism. This effect was attributed by Hammes and Langdell (1981) to the fact that, although able to form "internal images", the child with autism might be unable to manipulate these mental images in as flexible a manner as other children. Whether these operations are conceptually distinct (much less empirically separable) will be raised later.

It has been well-documented that children with autism show markedly reduced pretend play, a domain that subsumes activities such as the use of imagined objects, the substitution of one object for another, and the assumption by the child and attribution to others of alternate roles and identities. This deficit has been revealed both by a decreased tendency to engage in pretence, and by the use of a limited number of forms of imaginative play even when present (see review by Jarrold, Boucher, & Smith, 1993). Lewis and Boucher (1988) demonstrated that spontaneous pretend play was very limited in a group of children with autism. However, their study revealed that with prompting, simple forms of pretend play could be elicited. This result has been complemented by a study by Jarrold, Smith, Boucher, and Harris (1994), who failed to find evidence that children with autism were impaired in the comprehension of pretence. They argued on the basis of this finding that the relative lack of spontaneous pretend play in autism was a problem of performance, rather than competence. They proposed that the search for generative deficits in pretend play would be more profitable.

A recent formulation by Harris (1993), building on these and related findings, hypothesized that the autistic deficit in the production of pretend play can best be accounted for by impairment in the ability to plan actions. Specifically, he proposed that the behaviour of individuals with autism is guided by the external context, and that the ability to plan actions requiring guidance by internally-generated plans is particularly impaired for these people. Pretend play requires that an imagined state of affairs be held in memory to guide behaviour for the duration of the play episode. This conceptualization led Harris (1993) to interpret the difficulty with pretend play in autism as another example of a failure of executive control. The substance of this argument (although not the "executive function" terminology) was foreshadowed by Hammes and Langdell (1981) when they wrote of the lack of a tendency by people with autism "to use elements of their perceptions that might allow prediction of future events" (p. 331). This is related to the idea that one aspect of executive control is the use of "working memory" to maintain a representation of current reality, while simultaneously entertaining alternate representations (Goldman-Rakic, 1994).

Jarrold, Boucher, and Smith (1994) attempted a direct test of Harris' executive function account of pretend play deficits in autism. They employed a task from the normal developmental literature, designed by Golumb (1979). This task examined children's substitutions of objects in a situation requiring pretence. For a given action (e.g., brushing teeth), there was a demonstration, using human figures, with an appropriate object (e.g., yellow toothbrush). The child was then requested to repeat the action, with the appropriate object removed, and given a choice of another, inappropriate but functional object (e.g., a yellow pencil of similar size), or several nonfunctional, but perceptually similar objects (4 yellow dowels of varying lengths). It was hypothesized that children with autism would resist choosing the "counter-functional" object (i.e., the pencil in the above example), due to their inability to override the functional associations of that object. This hypothesis was not supported by Jarrold et al.'s data. There were no differences observed between the choice behaviours of the children with autism, two mentally handicapped control groups (one verbal-mental-age-matched, and one nonverbal-mental-age-matched), and normally developing children matched for verbal mental age. Jarrold et al. (1994) interpreted their results as evidence that the "failure to inhibit salient reference" could not explain the problem of pretence in autism, as predicted by Harris (1993). The role of other executive dysfunctions in contributing to the problem was not ruled out, however.

The data from the present study are relevant to this debate. Both in this study and that of Hammes and Langdell (1981), the difficulties of the children with autism were apparent when they were required to use the objects in an unconventional way. In contrast, Jarrold et al. (1994) reported that the hierarchy of object choices did not differ between the autistic and control groups, but no indication was given of the children's actual behaviour with the objects. In the present study, there was a clear difficulty for many of the children with autism, as well as a number of the younger typically-developing children. However, this became apparent only when the object was in the hands of the child. Again, this suggests that the locus of the difficulty lies more with the representation of the action (or the links between the object and the action representation and/or its motor translation) than with the object itself. According to this interpretation, choice behaviour (merely indicating the object, verbally or by pointing) might be less likely to show an impairment than would use of the object. This is a testable hypothesis that differs from that derived by Jarrold et al. (1994) from the work of Harris (1993).

Another recent report is relevant to the discussion of object use in autism. Fox and Tallis (1994) tested adults with autism and a mentally handicapped control group in a situation in which a variety of objects (e.g., pen, comb, mug, tea bag) were displayed within reach, but were not referred to (verbally or otherwise) by the tester during the session. The measure of interest was the frequency with which individuals in the two groups engaged in "utilization behaviour". This term has been used to describe the behaviour of people with frontal lobe lesions who, when presented with an object, grasp and use it (Lhermitte, 1983; Shallice, Burgess, Schon, & Baxter, 1989). Fox and Tallis (1994) reported that half of the group with autism in their study showed at least one instance of utilization behaviour, while only one control patient did so. They proposed that this phenomenon, associated with the executive function deficits observed in frontal lobe damage, might provide a framework within which to understand better the repetitive and stereotypic behaviour seen in autism (e.g., flicking lights on and off).

It is suggested that this behaviour might also illuminate the apparent inconsistencies between the findings reported by Jarrold et al. (1994) on the one hand, and those of Hammes and Langdell (1981) and the present study on the other. If the sight of an object with well-established functional associations is sufficient to induce an individual with autism to use that object (as suggested by the "utilization behaviour" account), then what the children in the Jarrold et al. (1994) study did with the "counter-functional" objects once selected becomes especially critical. The children's choices of those objects might, in terms of this framework, have resulted from a tendency to select an object with a function (any function), rather than the nonfunctional foils.

Thus, it is possible that the choices made by the autistic and control groups, although similar, were made for different reasons.

A final aspect of the procedure used by Jarrold et al. (1994) bears consideration. Data from the present study suggested that some objects were more likely to elicit their conventional uses than were others: three out of ten objects accounted for 54% of the "conventional responses" recorded. These objects (toothbrush, spoon, and hammer) seem to be among those with which this population might have had most experience, either in activities of daily living or in play. It could be argued that these objects (unlike, for example, the key or screwdriver) had very strong associations with specific actions for these children, although the uses of all of the objects were clearly familiar. Jarrold et al. (1994) reported significant differences in their effects due to the object sets employed. Of the functional and counter-functional objects used by Jarrold et al. (1994), only a few seem likely to have strong associations with specific actions for young children (i.e., a toothbrush and a pencil, versus a die and an eraser). (This might also be related to the "prototypicality" of the objects themselves, cf. Hughes, 1996a.) The point is that objects differ in their tendency to elicit particular actions from individuals, reinforcing the idea that characteristics of the objects and the degree of association with specific actions might be critical variables in studies of autism.

Implications for Gesture Representation in Autism

The present data from both nonsymbolic and symbolic imitation tasks can be used to address the issue of how gestures are represented by people with autism. Specifically, the prevalence of rotational errors, the tendency to not imitate unconventional uses of objects, and the difficulty naming modelled actions and producing gestures on verbal command provide the strongest evidence consistent with the hypothesis that actions are represented in an overly-specific form that limits flexible access under varying conditions.

As previously mentioned, Hermelin (1976) described an autistic tendency to encode information rigidly with respect to the modality in which it was presented, rather than in a more abstract, amodal form. Frith (1989; Frith & Baron-Cohen, 1987; Frith & Happé, 1994) has argued instead that autism entails a lack of "central coherence", that is, of the tendency in normal information processing for experiences to be bound together by meaning. Thus, on one hand, the problem in autism has been conceived as one of representations being tied too tightly to sensory/perceptual experience (a "bottom up" deficit), and on the other, of being bound too loosely by meaning (a "top down" deficit). The present contention is that these claims are two sides of one coin, and thus a framework is required that can accommodate both.

Vaina (1983) emphasized that objects and actions must be represented with respect to their functions in the real world. That is, her view of an information processing system entails the efficient encapsulation of world knowledge about not only the perceptual attributes of objects, but about their uses as well. She proposes that these two types of knowledge are contained in modules that are somewhat independent, although normally they operate together. Vaina (1983) conceived of a hierarchically-organized system, in which objects and actions are represented at the most basic level by their sensory attributes, in modality-specific forms. At the next level, that of the functional representation, possible object functions are represented in a categorical manner. The functional representation contains information about objects and actions aggregated across modalities, incorporating information about the actions in which an object can participate. Vaina (1983) noted that this necessarily entails multiple categorizations for any given object (e.g., a spoon can be used for eating, throwing, or playing a xylophone). For the present argument, a critical feature of Vaina's hypothesized system is that efficient access to the functional representations of objects is organized from the general (more abstract, categorical level) to the particular (more specific level). For example, if one is looking for an object to throw, the analysis of objects available in the environment need only be at the functional/categorical level of "objects that can be thrown", as opposed to the specific (e.g., "spoons" versus "small rocks"). From this viewpoint, an overly specific form of representation, in which functional/categorical information is not accessed preferentially when required, would be disadvantageous for many interactions with the environment[2].

The present hypothesis is that in autism functional representations are constructed abnormally, such that the representations of objects and movements remain tied concretely to the sensory modalities and to the environmental contexts in which they were experienced. The result is inefficient access by the information processing system to information encapsulated by that representation. In the example above, the object "spoon" would be readily accessed with respect to its conventional function, "eating". However, using the object in an unconventional action (e.g., playing a xylophone) would require over-riding that strongly-associated function. According to the rules governing Vaina's (1983) notion of a functional representation, flexibility in action requires that the most general categorical information be accessed preferentially. Yet, it may be that for the person with autism, the general information is not readily available, experiences having been encoded more strongly as discrete objects, actions, and events than as exemplars of catego-

---

[2] One of Frith's contributions has been to identify instances in which the abnormality of autistic information processing results in performance peaks, rather than deficits. For example, performance on an "embedded figures" task was better for an autistic group than for controls (Shah & Frith, 1983). Frith (1989; Frith & Happé, 1994) invokes "lack of central coherence" as an explanation of this and other autistic phenomena, but this example can be accommodated by the hypothesis that overly-specific encoding, at the expense of higher-order relationships,

ries. This is not to say that categories are not eventually constructed in autism, only that the process is atypical and inefficient (Ricks & Wing, 1975; see also Klinger & Dawson, 1995). Similarly, in the resulting representational system, categorical or functional relationships, including those that require integration of information across modalities, may be abnormal. Therefore, in situations in which performance would normally be facilitated by crossmodal integration (e.g., the visual-motor tracking experiment of Frith & Hermelin, 1969) or by semantic associations between stimuli (e.g., recall of related and unrelated words, Hermelin & O'Connor, 1970), these results were not obtained for autistic groups.

With respect to the present data, the children with autism appeared to have represented the modelled gestures in forms adequate to support recognition through direct visual correspondence (in the case of the nonsymbolic postures and sequences), or in response to word or picture cues (in the case of symbolic gestures), but direct access through an auditory/verbal route (i.e., naming a gesture, or producing a gesture on verbal request) appeared particularly difficult. The latter finding (i.e., for symbolic gestures) was also reported by Bartak et al. (1975), and may be an example of a modality-specific deficiency in autism. People with autism are generally described as processing information preferentially through the visual, rather than the auditory modality (Hermelin & O'Connor, 1970). Thus, in addition to modality

---

characterizes autistic perception (see Brian & Bryson, in press, for a test of Frith's account).

specificity, there appears to be the potential for imbalance in the strength of inputs between modalities, perhaps explicable in terms of attentional factors (cf. Posner et al., 1976).

The frequency of rotational errors by children with autism may be interpreted as resulting from attempts to reproduce the modelled gesture directly as observed, again suggesting a representation of the action based primarily on visual information. The more abstract visual-kinaesthetic representation that would enable the efficient transformation from "action by other" to "action by self" appears to be less readily accessible, perhaps as a consequence of difficulty integrating information across modalities, and/or of computing the necessary spatial transformation.

In the case of the unconventional actions with objects task, the difficulty appears to lie with the ability to over-ride the conventional functional relationships between particular objects and actions. Again, it is as though the sight and feel of the object provoke very specific associations that "trigger" the conventional action when the object is in the hand. This behaviour merits more detailed exploration. Of interest is whether comparable mechanisms can account for the behaviour of children with autism and typically-developing preschoolers on this task, and for the "utilization behaviour" of adults with frontal lobe injury. In particular, is there a distinction between the tendency to engage in an action when the cues associated with that action are present, and a failure to *inhibit* an action in the presence of cues for that action?

One issue that requires clarification is whether there might be two related types of difficulty in autism - one involving the selection of sensory information required to construct functional representations (input), and the other affecting the selection and execution of actions suited to current environmental demands (output). Such input and output dysfunctions would implicate a complex interplay of attentional and inhibitory mechanisms, such as those known to develop with the maturation of executive ("frontal") functions (Diamond, 1995a & b). Recent work has attempted to clarify the mechanisms involved in the normal development of executive control. For example, Zelazo, Reznick, and Piñon (1995) have demonstrated, using a simple analogue of the Wisconsin Card Sorting Test designed for preschoolers, that children younger than approximately 4 years, although able to verbalize a selection rule, appear unable to over-ride an established response set to apply that rule. The phenomenon, also found in adults with acquired frontal dysfunction (Stuss & Benson, 1986), appears to parallel that observed here in the unconventional actions with objects task. As yet, the developmental mechanisms are poorly understood, but the further exploration of these functions for typically developing children is necessary to inform the analysis of the deficits in autism.

These results all suggest an inflexibility in the use of information concerning objects and actions by people with autism. That is, the representation appears accessible under some circumstances (e.g., when only within-modality correspondence is required), yet is inefficiently accessed when the task requires that very salient associations be ignored, or when there is a change of context within which the information must be applied.

Related issues were raised in earlier research on language in autism, in which particular difficulty was identified with the acquisition of relational terms, pronouns, and prepositions. It has been suggested that autistic delay or deviance in the use of these linguistic features reflects the lack of stable concrete referents (Kanner, 1943/1973; Menyuk & Quill, 1985). In addition, a limited ability to generalize has long been noted to be a pervasive characteristic of autistic language learning (Harris, 1975; Lord, 1985).

Role of Anomalous Attention?

An obvious issue is, what mechanism could be proposed to underlie the tendency to form rigid and idiosyncratic representations of experience? Attention has been conceived as a set of processes that map perceptual inputs in the service of action (Allport, 1987), and could perhaps be considered as linking Vaina's modality-specific representations and the amodal functional representation. Attentional processes would then be critical in the construction of functional representations, by directing and perhaps determining the strength of perceptual inputs. Bryson et al. (in press) have reviewed the evidence of abnormalities in the deployment of spatial attention by people with autism, and argued that there are impairments in disengagement of attention from attended locations, and/or in orienting and shifting attention. The possible role of dysfunctional inhibitory mechanisms in spatial information processing has also been questioned (Bryson, 1995). Bryson et al. (in press) have argued that dysfunction of basic attentional processes in autism could contribute to impairment of the supervisory attentional system (Shallice, 1988) and thereby to purported executive dysfunctions in the disorder. As argued by a number of authors (e.g., Bailey et al., 1996; Bryson et al., in press; Hughes et al., 1993), the concept of executive dysfunction has questionable specificity and little explanatory power in accounting for the characteristics of autism. Dysfunction in basic attentional mechanisms, however, could conceivably produce the kinds of aberrant representations alluded to in this discussion, as well as contributing to impairment of higher-order attentional systems.

Although the present data cannot address this issue directly, the evidence provided here is consistent with subtle abnormalities in the representation of actions. Direct evidence of anomalous spatial attention for people with autism (Bryson et al., in press) provides one of the strongest candidates for a basic impairment capable of disrupting the crossmodal integration of sensory information, a function presumed to be required for accurate imitation (cf. Grandin, 1996; Smith & Moore, in preparation). A greater understanding of the operation of these fundamental processes in autism should precede the attribution of autistic symptoms to higher-order cognitive operations. Issues such as the coordination of sensory information and the role of attention in the control of action for people with autism should be examined in more detail, independently of the context of gesture use (see Klein & Posner, 1975, and Tipper, Lortie, & Baylis, 1992, for examples of relevant paradigms).

Praxic Development

These data also require interpretation within a developmental context, as the behaviour of the Autistic group on the present tasks often resembles that of the youngest normally-developing children (cf. Hughes, 1996b). It is as though some aspects of information processing remain "stuck" in a developmentally early mode (although the mechanisms responsible in the case of autism probably differ from those in normal development). Another approach to defining the imitative problem in autism would be to analyze the successes and failures on praxic tasks in relation to a model of the normal development of these functions.

Existing models of praxis (e.g., Rothi et al., 1991) have been designed to accommodate disruptions following brain injury, such as the ability to pantomime actions without being able to name the associated objects, or to name tools but not to use them appropriately, consistent with the existence of modality-specific routes to action. In addition, the evidence from acquired apraxia reveals dissociations consistent with a dual system in which gestures are normally represented both with respect to their physical parameters and to their functional ("semantic") associations. Normal praxis has been conceived as the product of an hierarchically-organized action system incorporating both modality-specific and amodal representations, and both conceptual and production components (MacKay, 1985; Roy, 1983; Roy & Square, 1985). Cognitive neuropsychological models have the advantage of addressing the possibility of disruptions to both input and output selection processes, as well as specific conceptual and/or representational issues. However, in order to provide an adequate account of what is missing in the representation of gestures in autism, a normal developmental model is required. Although the acquisition of object and gestural knowledge and the development of gesture use are active research domains (e.g., Boyatzis & Watson, 1993; von Hofsten, 1989; Pick, 1989), there is no well-articulated neuropsychological account of the development of praxic abilities (Cermak, 1985; Dewey, 1995; Roy et al., 1990). Perhaps further empirical evidence of the disruption of praxis in autism could, in turn, assist the effort of constructing useful developmental models.

Future studies of praxic abilities in autism will benefit from the information provided by the present study. As noted in the literature review, some studies have treated imitation as an all-or-nothing phenomenon, scoring imitation as "present" or "absent". On the contrary, it is obvious that even people with autism can imitate, but the evidence as to what actions they imitate and how they do so suggests that imitation appears late and under atypical conditions. For this reason, the present study focussed not on whether children with autism could imitate others, but on the nature of their imitative difficulties. Building on the results of the present study, tasks can now be designed which maximize the probability of occurrence of informative errors in gesture production and imitation.

If both methodological and sampling issues were addressed systematically, subtle indications of differences in the encoding of gesture information in the present recognition data might also be more pronounced. For example, manipulation of the features of gestures used as recognition foils might reveal evidence of recognition errors that parallel the errors seen in imitation (e.g., rotational errors) for at least some individuals with autism. Perhaps evidence of impaired recognition or comprehension might be revealed for individuals with autism who are younger, intellectually lower-functioning, or more severely autistic.

It should be emphasized here that the youngest participants with autism in this study were seven years of age, and all appeared to understand that their task was to imitate the investigator. It seems likely that some younger and/or lower-functioning children with autism would lack such understanding. Indeed, the promotion of imitation is an initial focus of most current early intervention programs for autism (Harris & Handleman, 1994). The fact that many children with autism need to be taught explicitly to imitate other people underscores what a departure from the natural developmental course is seen in this disorder. More analytic studies of the acquisition of imitative skills by children with autism would be invaluable (for a recent example, see Young, Krantz, McClannahan, & Poulson, 1994). Such research could potentially benefit clinical practice, as better understanding of the reasons for autistic delays and differences in imitation might result in more efficient teaching techniques.

Conclusions

The major issues addressed in this dissertation were the specificity of deficient gesture imitation to autism, and the analysis of the nature of the deficiency. Consistent with previous research, the children and adolescents with autism in this study performed relatively poorly on tasks assessing gesture production and imitation. This study extended prior findings by clearly demonstrating that neither delayed receptive language skills nor gesture recognition or comprehension deficits accounted for the autistic imitative impairment. It was also shown that significantly reduced fine motor skills for the participants with autism contributed to, but did not account for, their relative praxic deficits.

It is important to note that some measures of gesture production (e.g., posture errors, sequencing) revealed no more impairment for children with autism than for controls. Thus some praxic problems appear to be common to individuals functioning at lower language levels (Roy et al., 1990). A major contribution of this study was the demonstration of a distinctive pattern of deficits within the autistic group, consisting of rotational errors, difficulty imitating unconventional actions with objects, and problems accessing gestural information with verbal labels. Most importantly, the present data provide support for a common deficit underlying imitation of both symbolic and nonsymbolic actions by individuals with autism. It was hypothesized that both symbolic and nonsymbolic gestures are represented in a more modality-specific and context-dependent manner in autism, preventing the more flexible use that was apparent in the performance of language-matched controls. Particular difficulty previously associated with the use of symbolic gestures by people with autism appeared to be due to specific weakness in using an auditory-verbal route to access the functional representation of objects and actions.

It bears emphasizing that the pattern of praxic deficits was apparent here even in the production of very simple gestures, and was observed among some of the oldest and highest-functioning of the participants with autism. The possibility that differences in praxic abilities, especially in association with attentional and social symptomatology, might contribute to the description of autistic subgroups merits investigation.

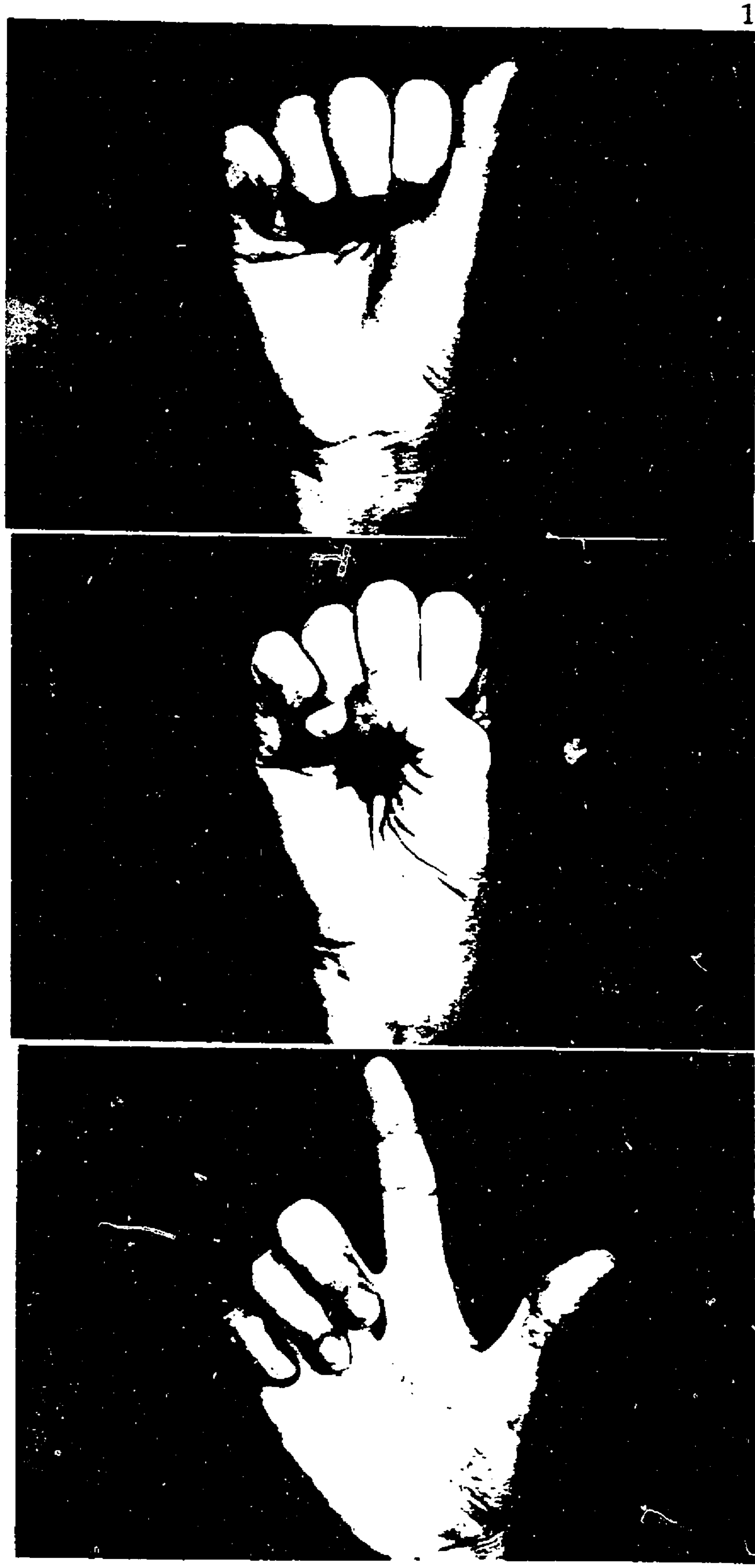
This dissertation has contributed to the understanding of the problem of imitation in autism by shifting the focus of study to the quality, not only the quantity, of imitative behaviour. Research in this area should now attempt to establish underlying mechanisms for praxis dysfunctions, to use information about the nature of these impairments to assist in the treatment of autism, and to examine relationships between patterns of praxic deficits and other social, communicative, and cognitive characteristics of people with autistic disorders.

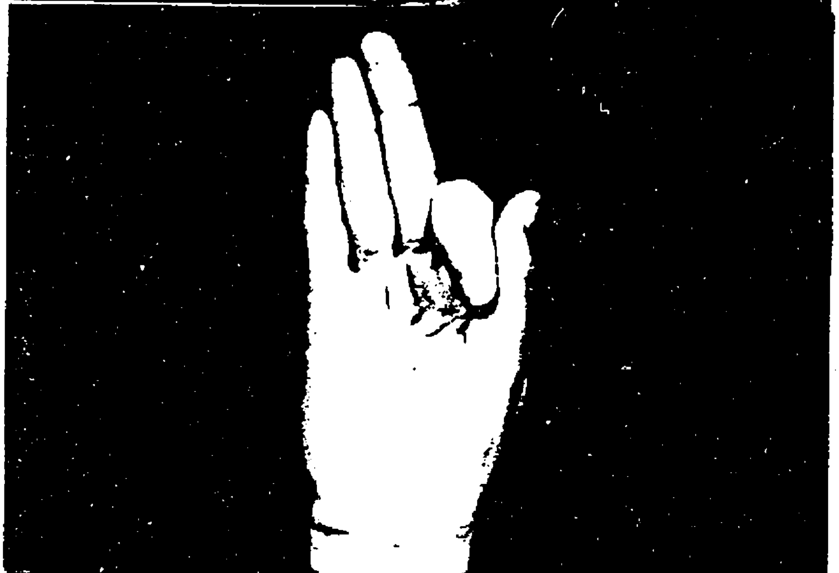
While this study has emphasized the ability of individuals with autism to recognize, understand, produce and imitate gestures in an artificial context, the study of imitative behaviour in natural contexts is also important. The need to teach some children with autism to attend to and imitate the behaviour of others highlights the very early differences in affective and social responsiveness that may be fundamental to understanding the disorder (Hobson, 1993; cf. Kanner, 1943/1973). Imitation has been conceived as a mechanism for the development of shared understanding (e.g., Barresi & Moore, 1996a; Meltzoff & Gopnik, 1993) and nonverbal communication, and as a means of discovering new aspects of the environment and learning new skills (Uzgiris, 1981). One can readily imagine the cascade of implications of imitative deficits such as those described here, if indeed they are present from early in life.

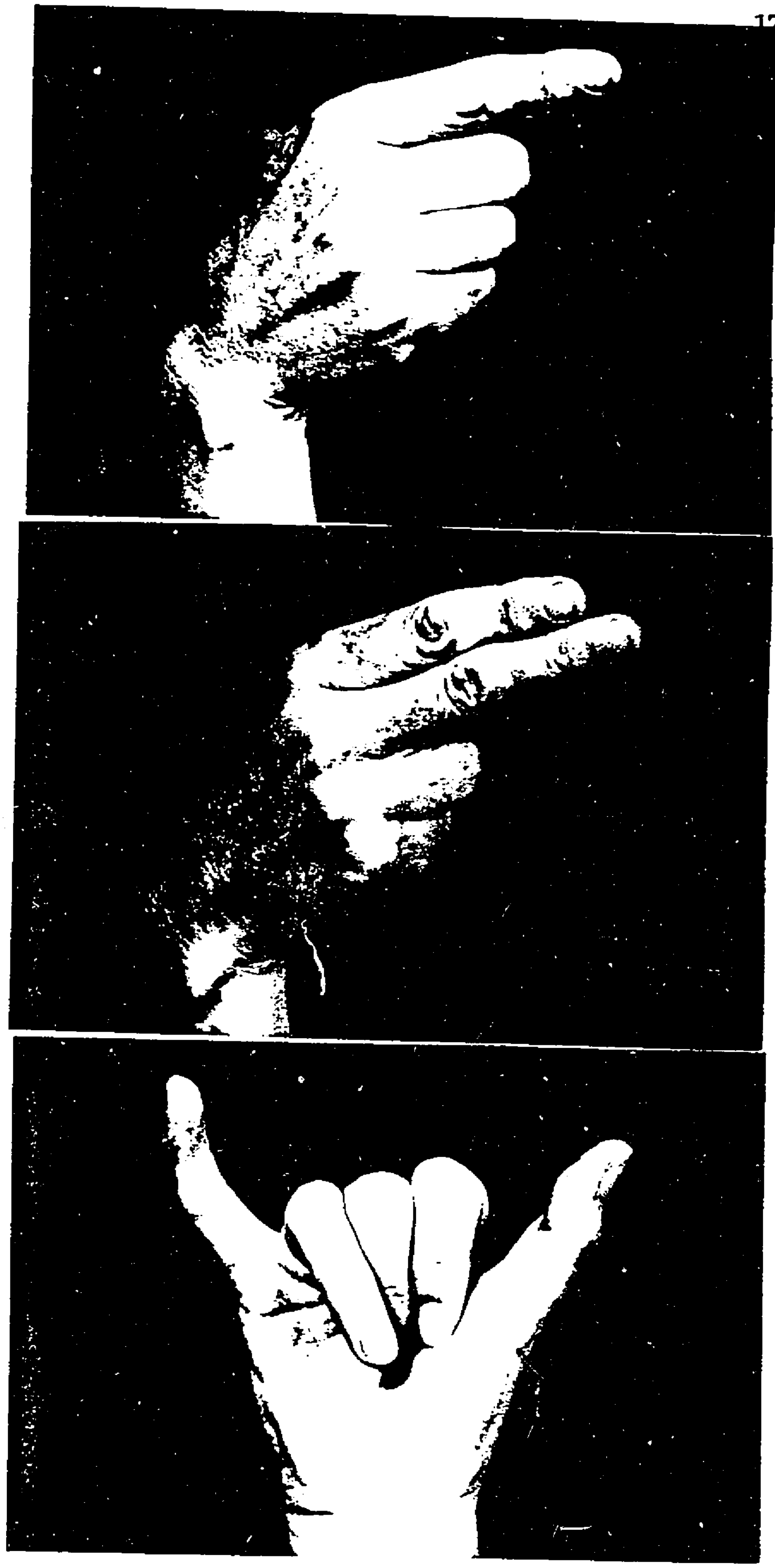
Appendix A

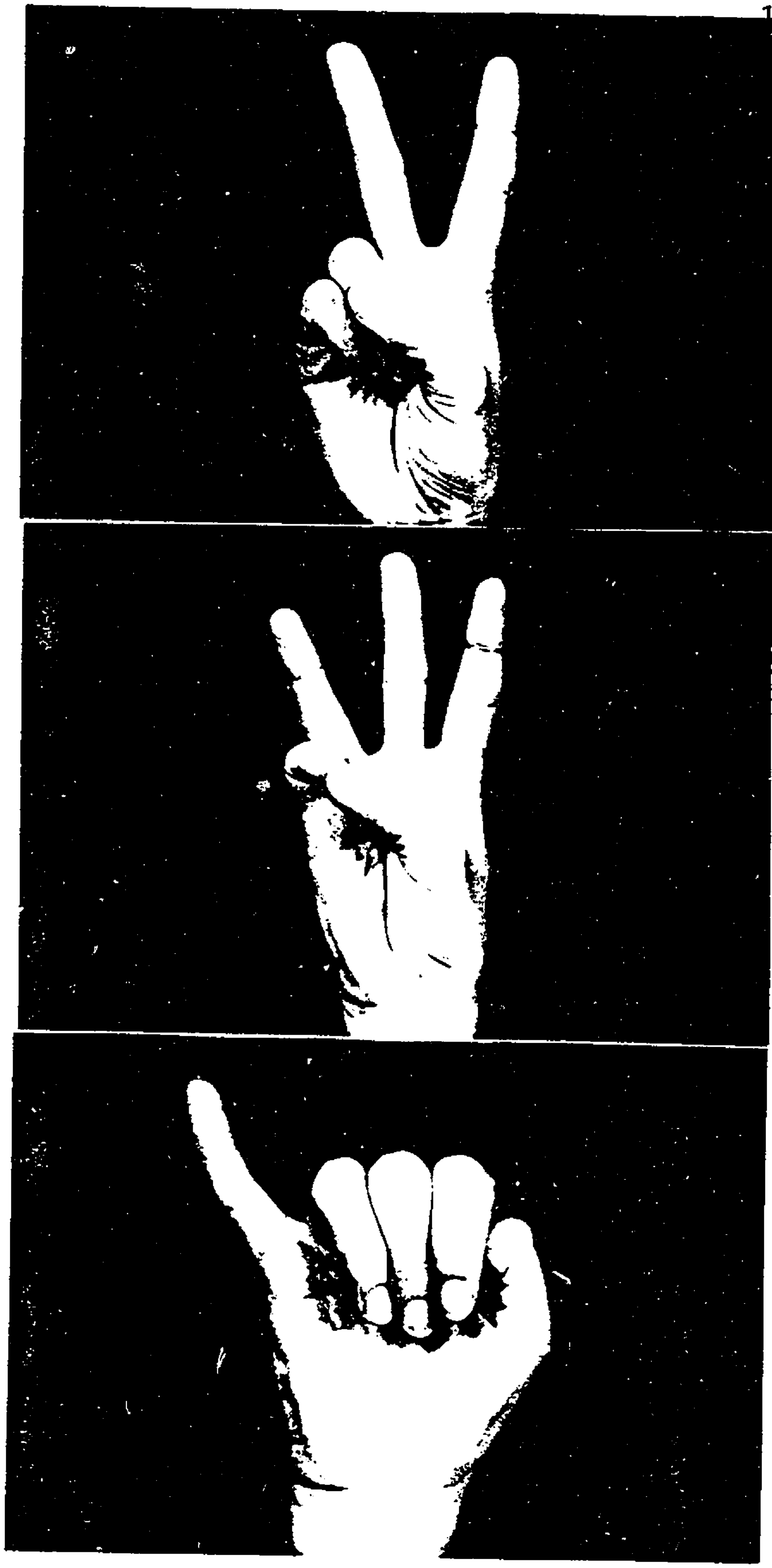
Nonsymbolic Actions

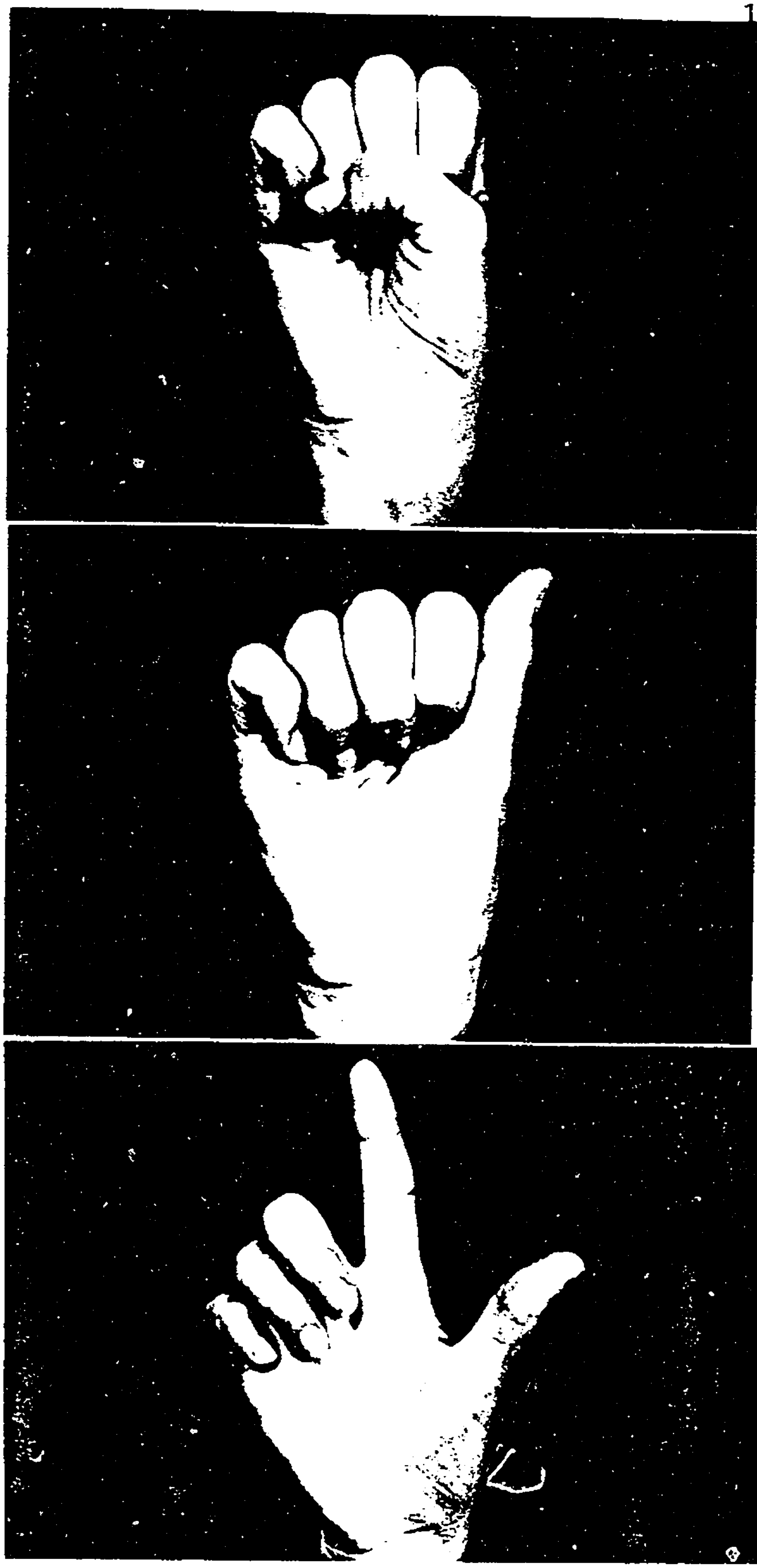
Photographs of unimanual and bimanual Nonsymbolic Postures, and foils used in posture recognition task: (top) target posture, (middle) similar foil, (bottom) dissimilar foil.

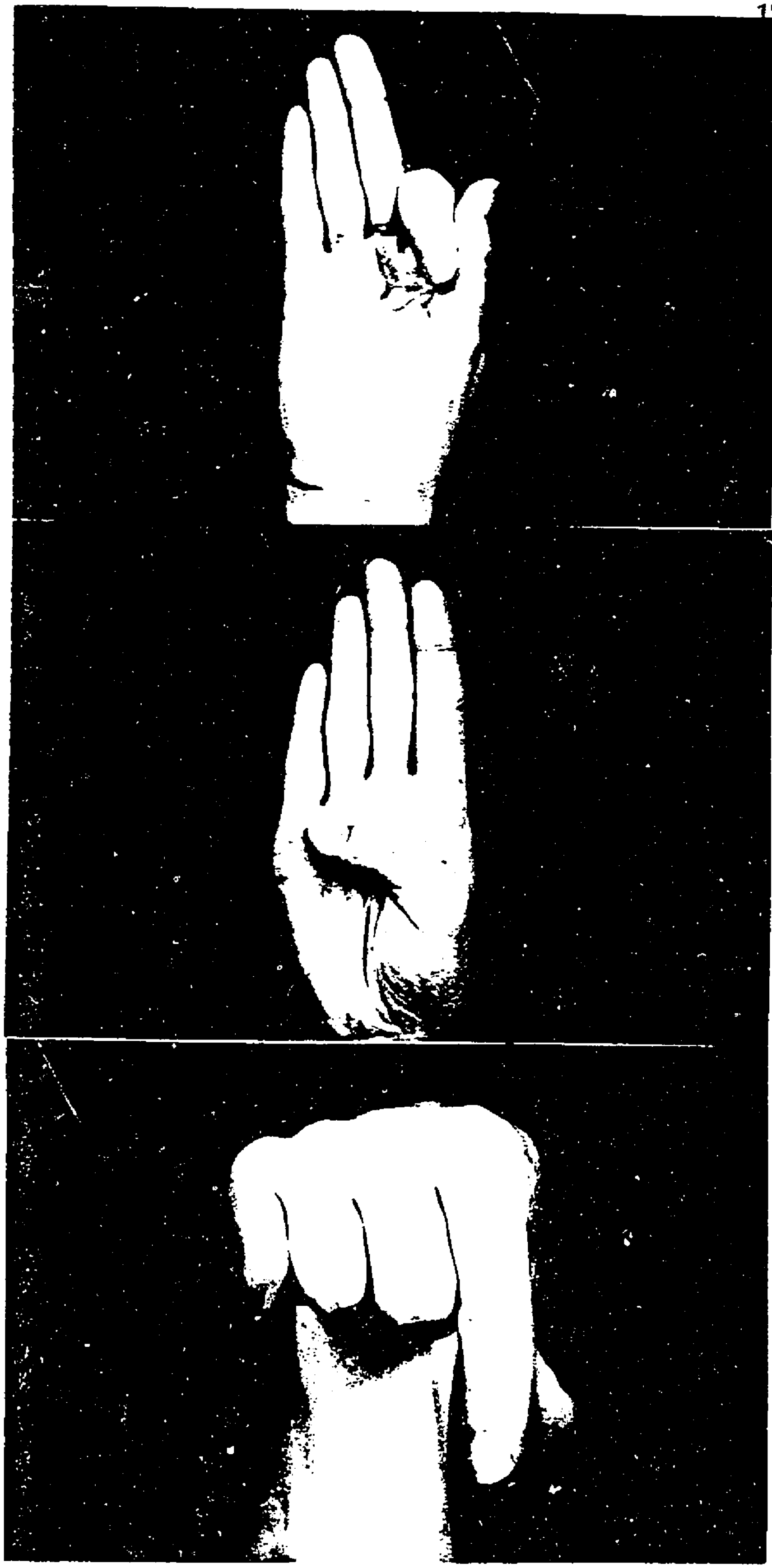


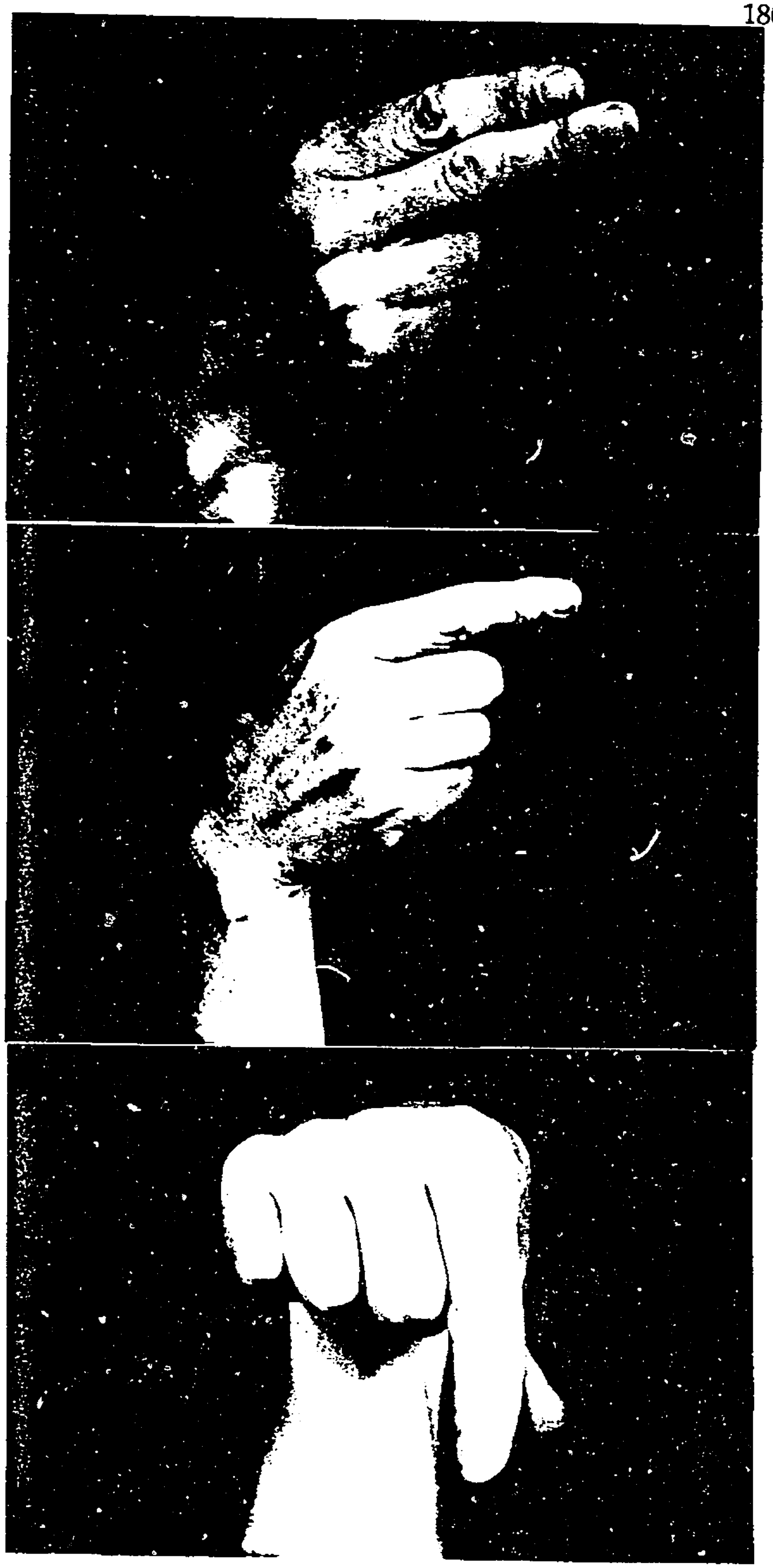


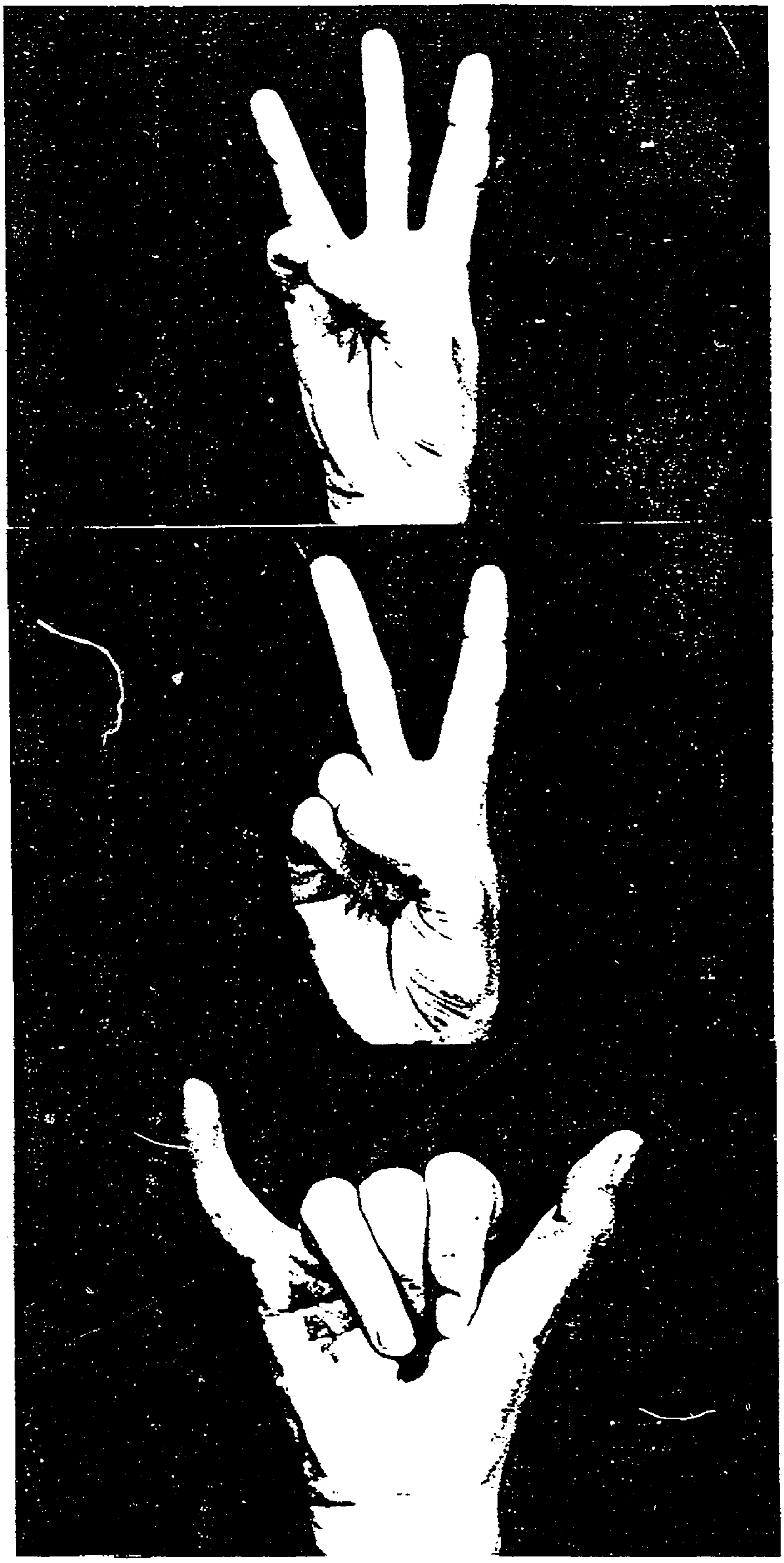


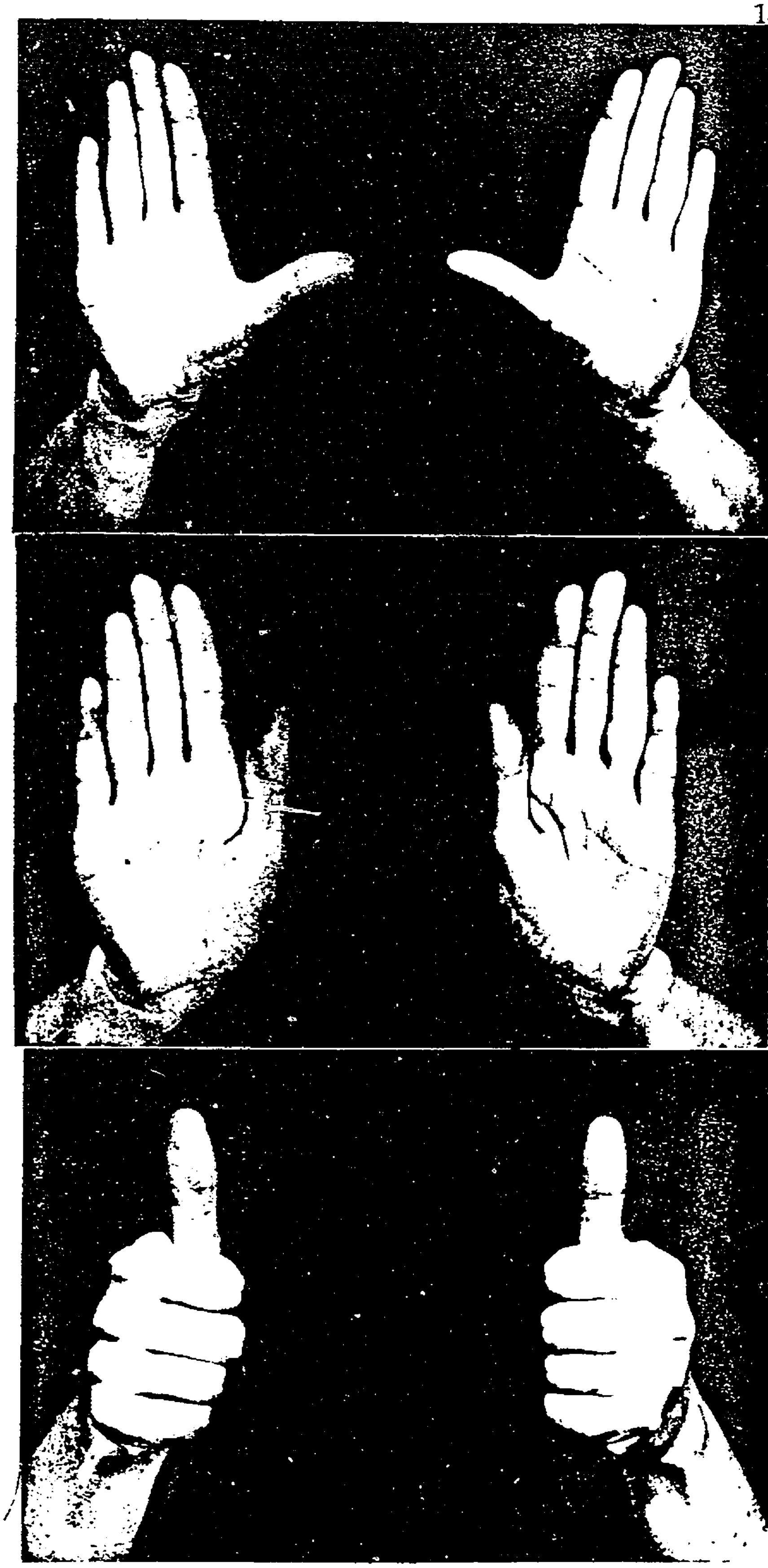


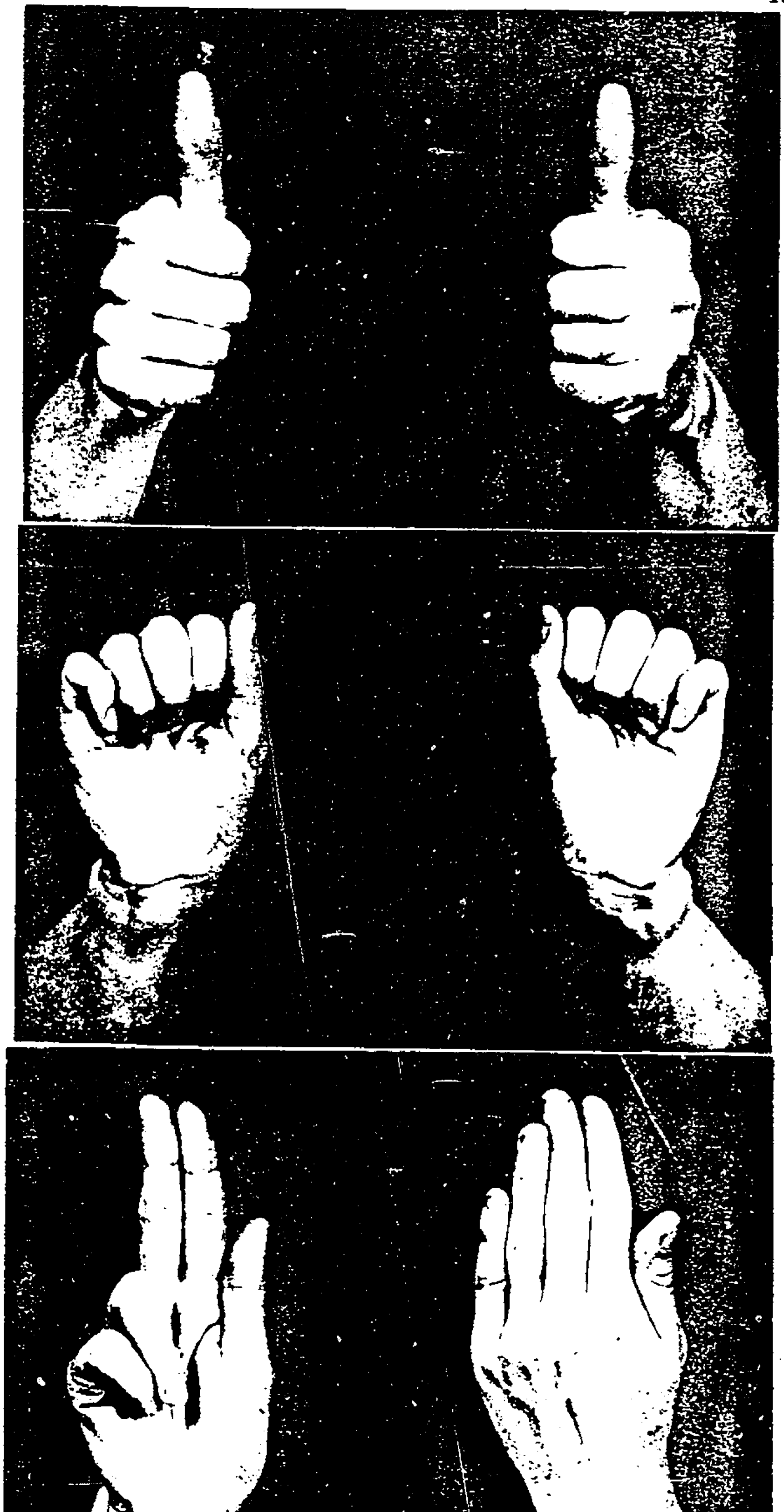


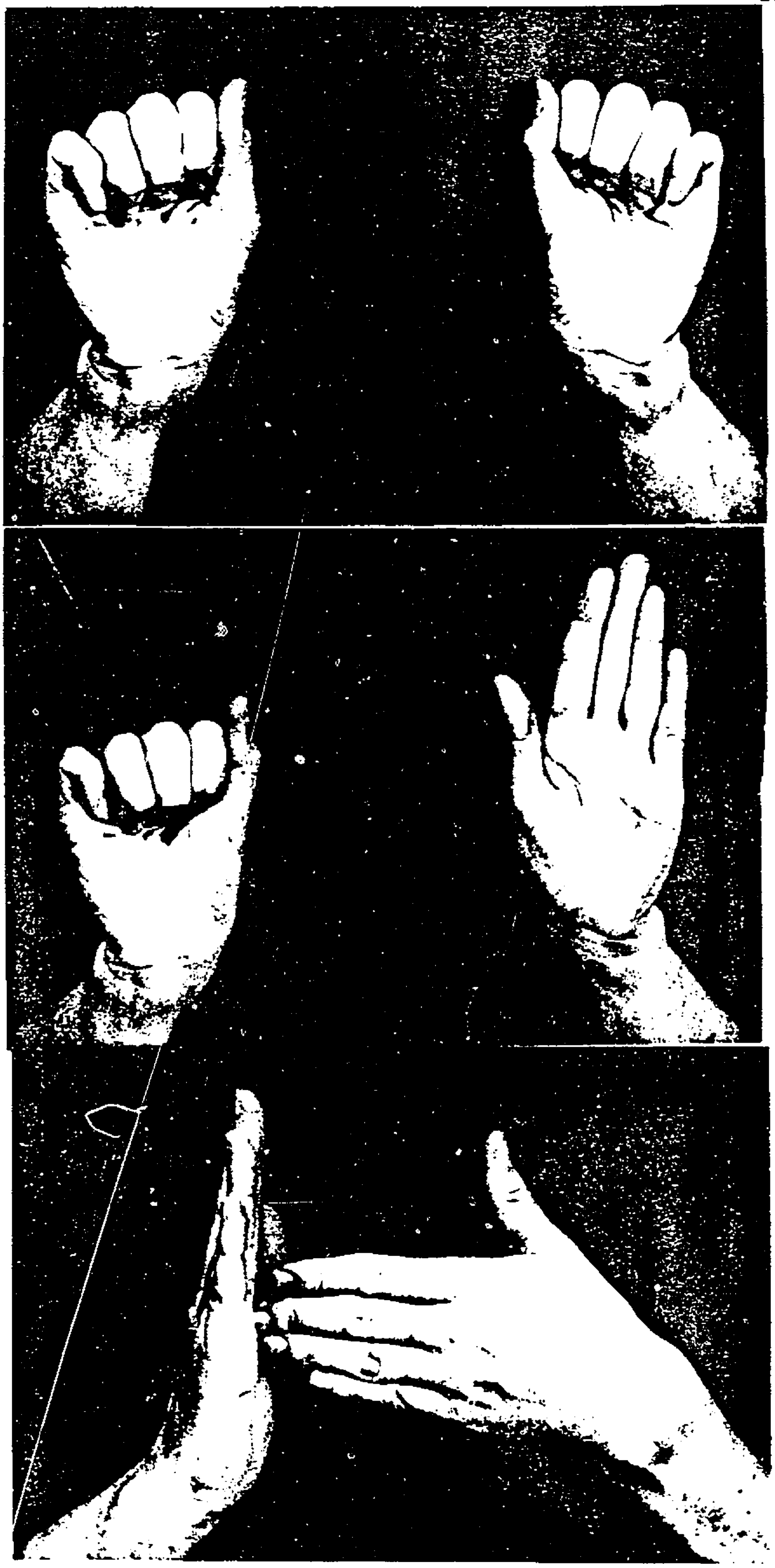


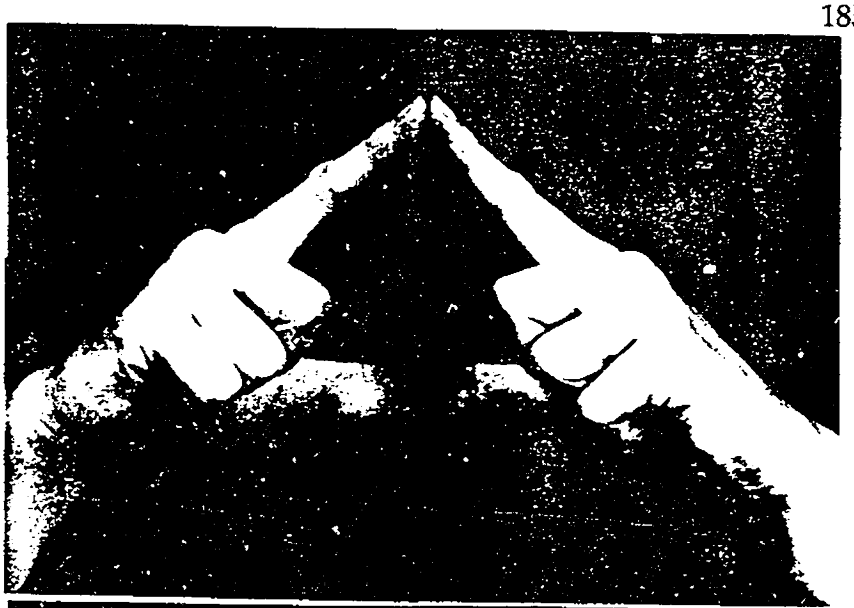


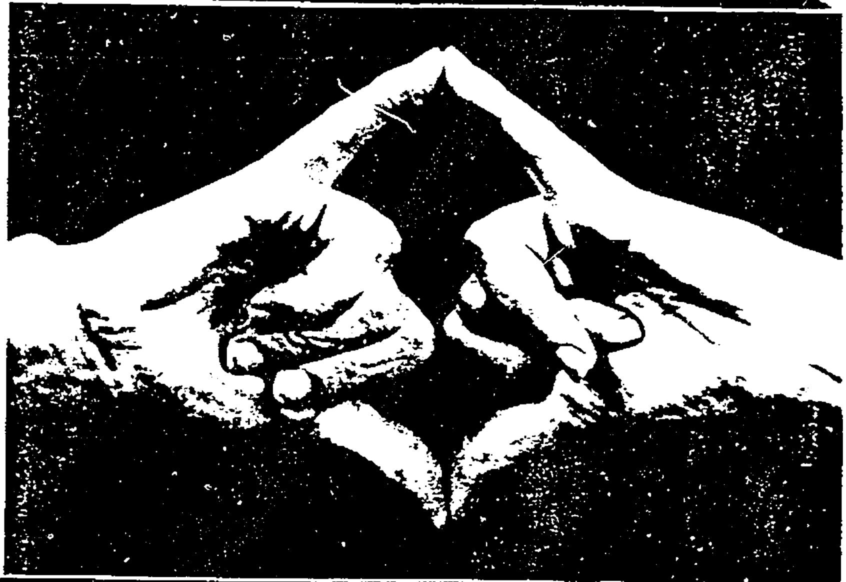


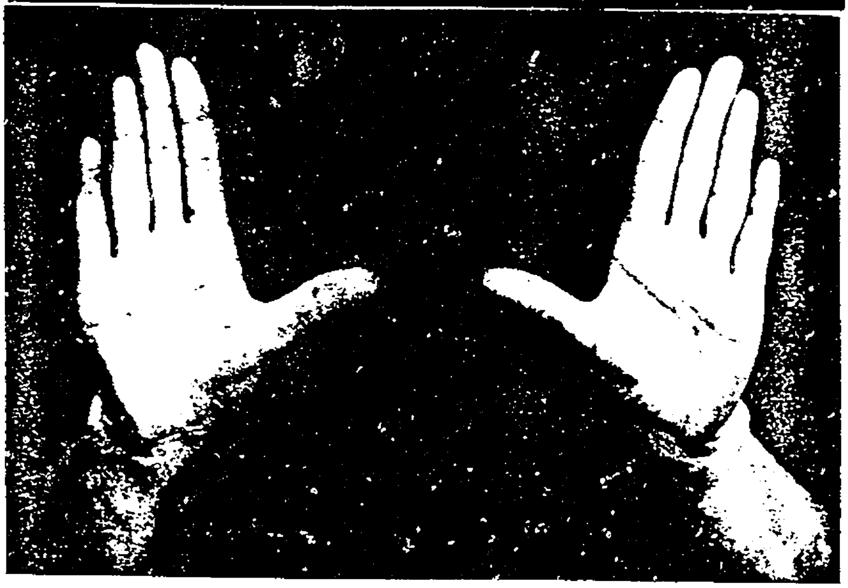


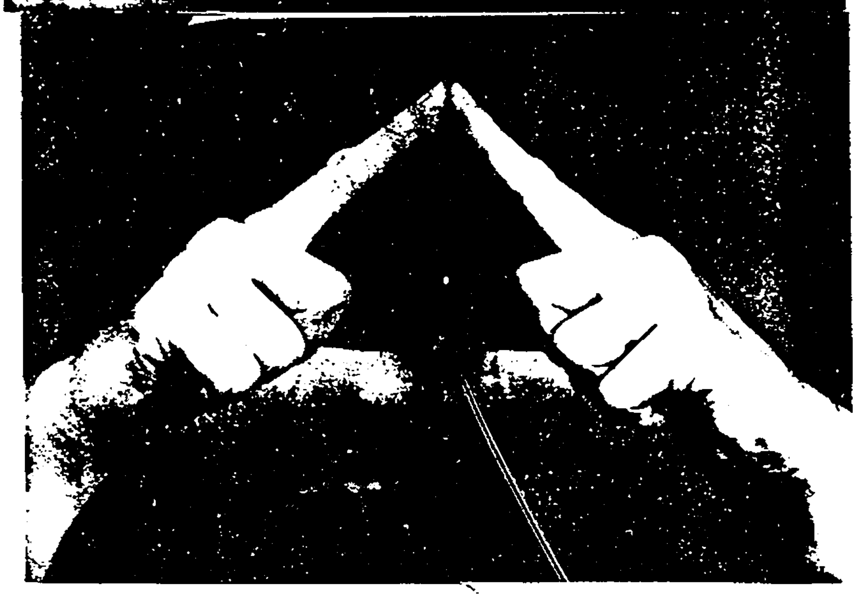


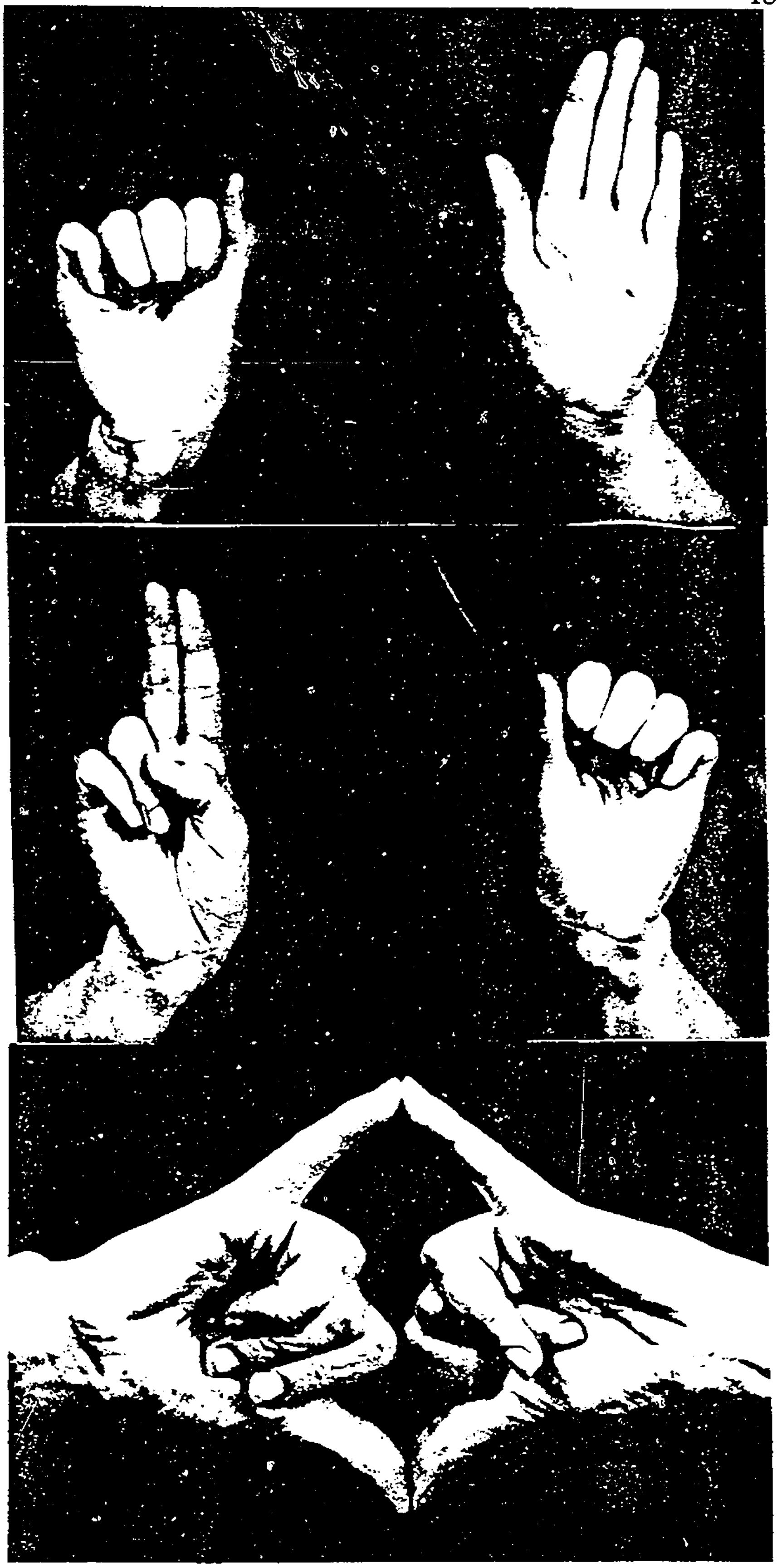


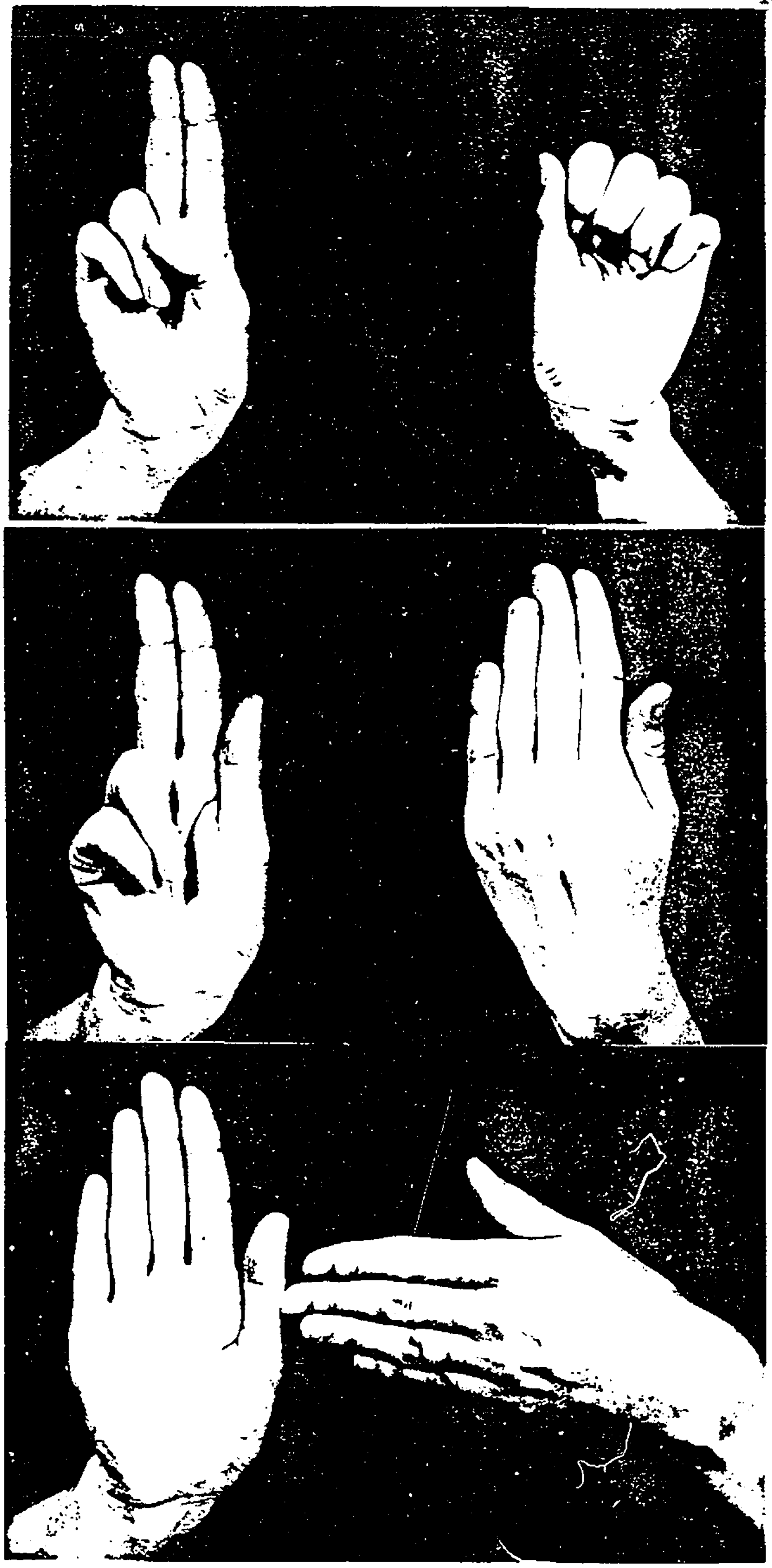


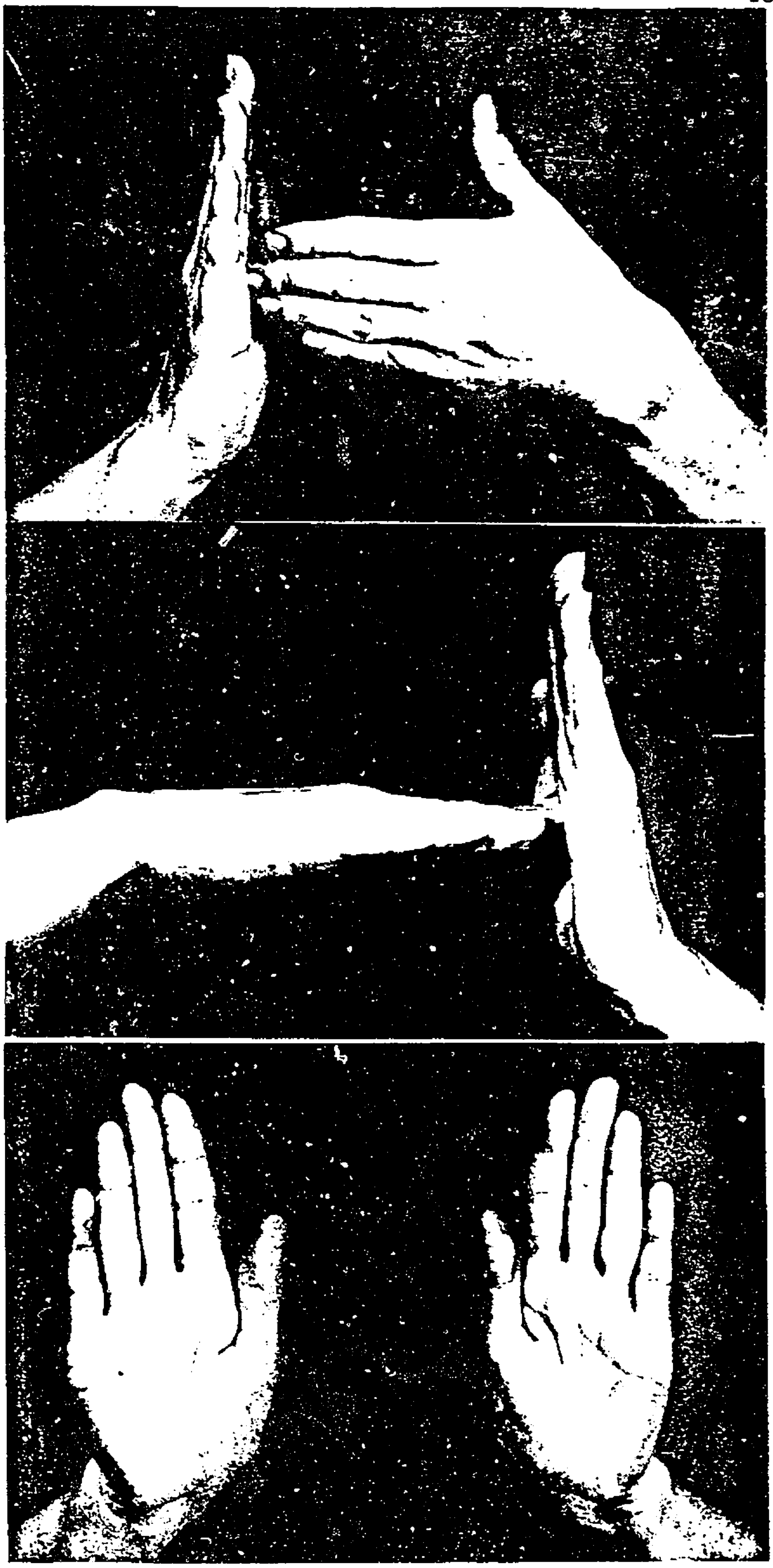








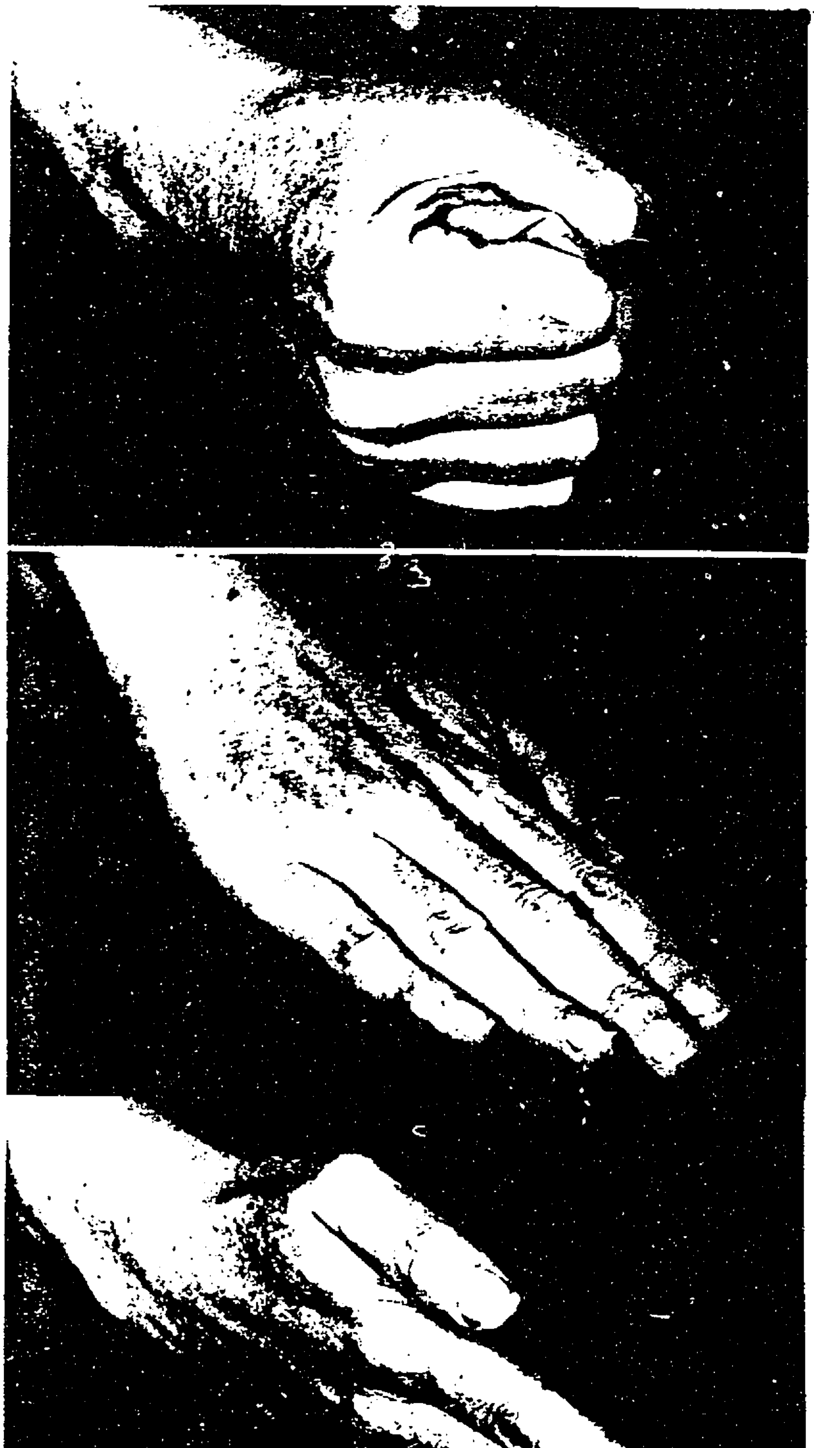


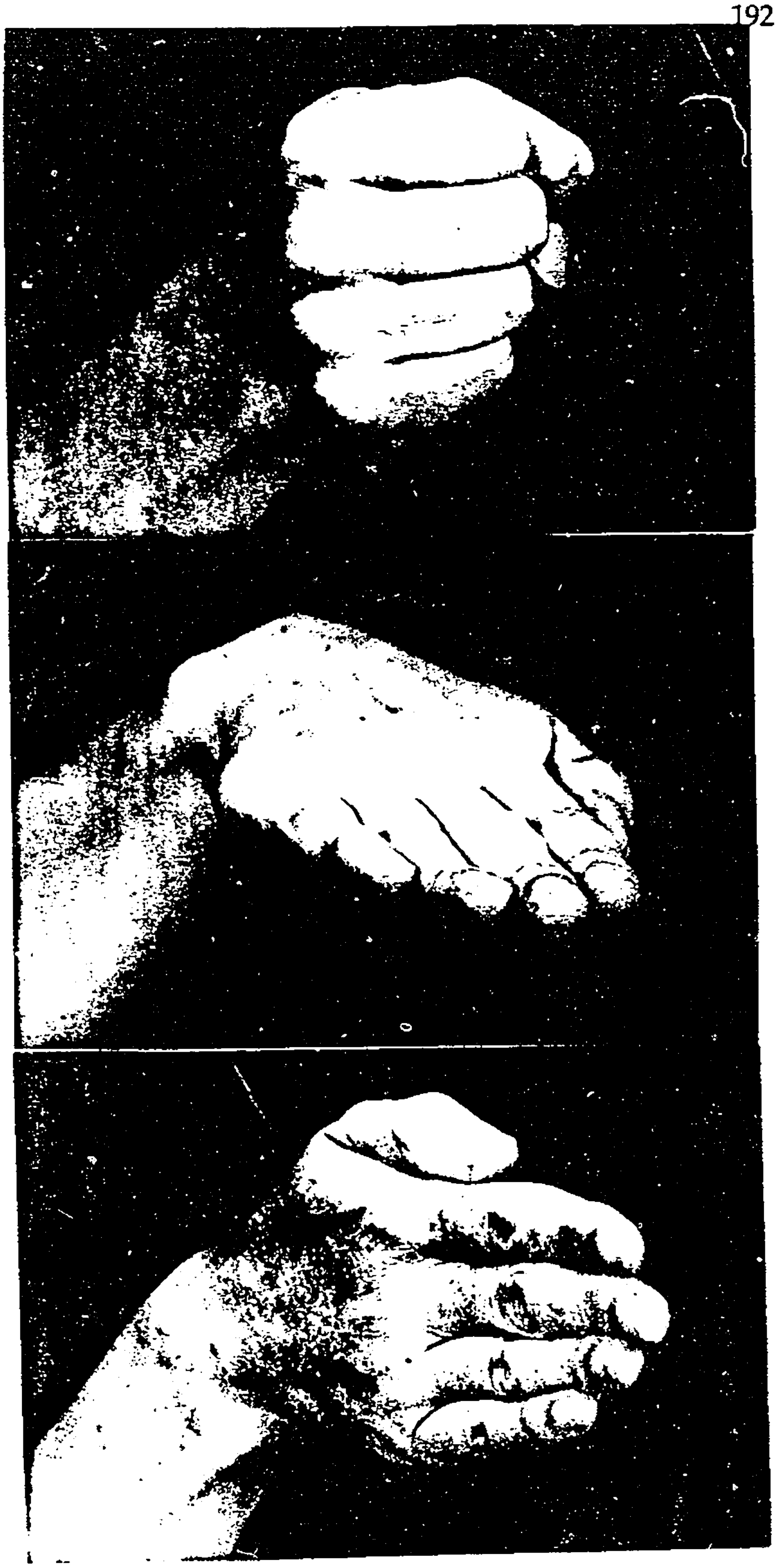


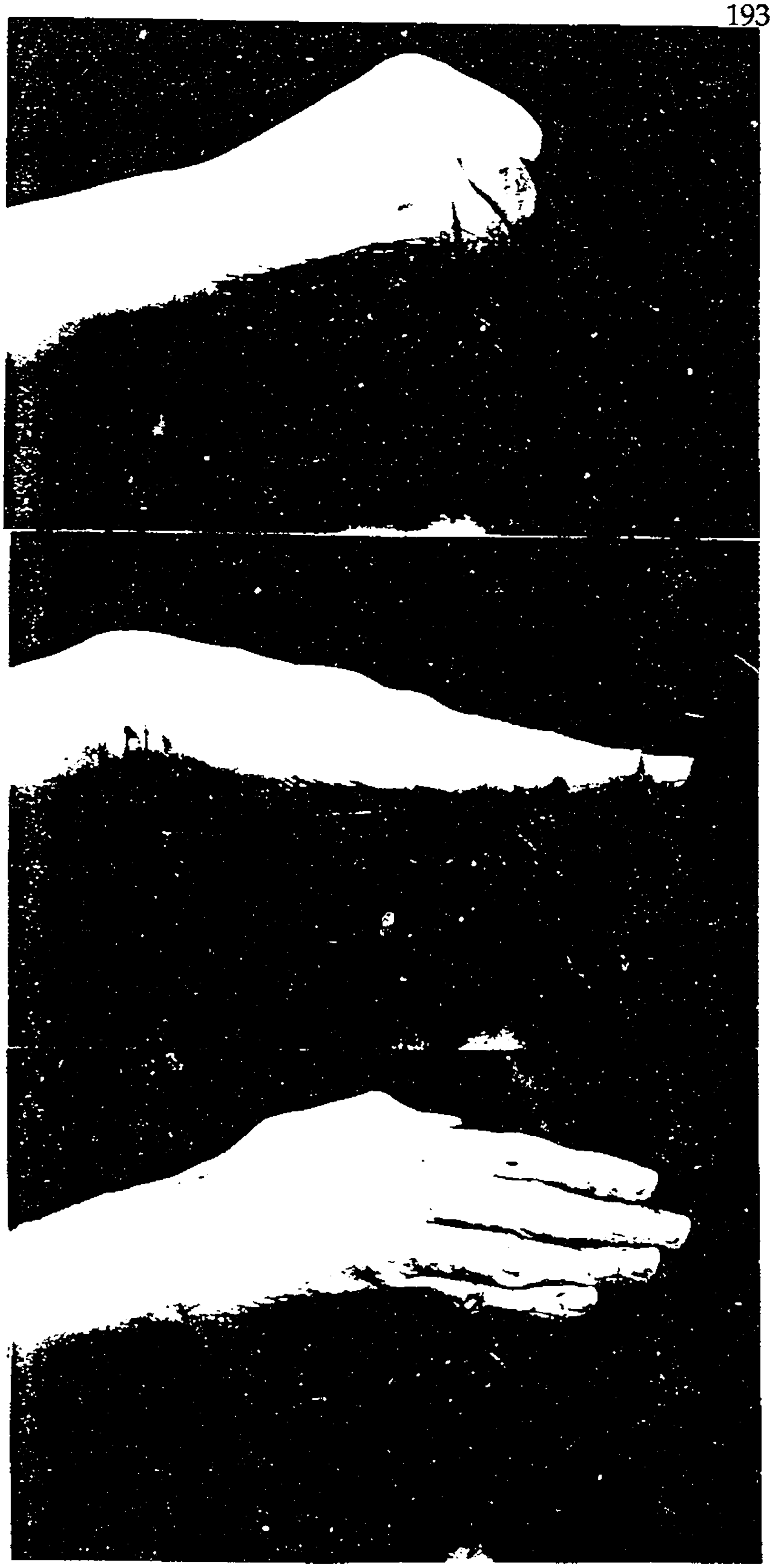
Appendix B

Nonsymbolic Actions

Photographs of postures from posture Sequences tasks, in Table, Air and Head locations: (top) "fist", (middle) "palm", and (bottom) "chop".





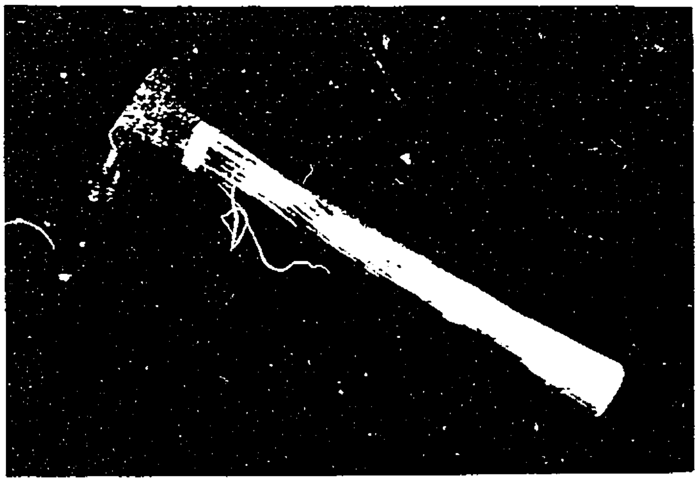


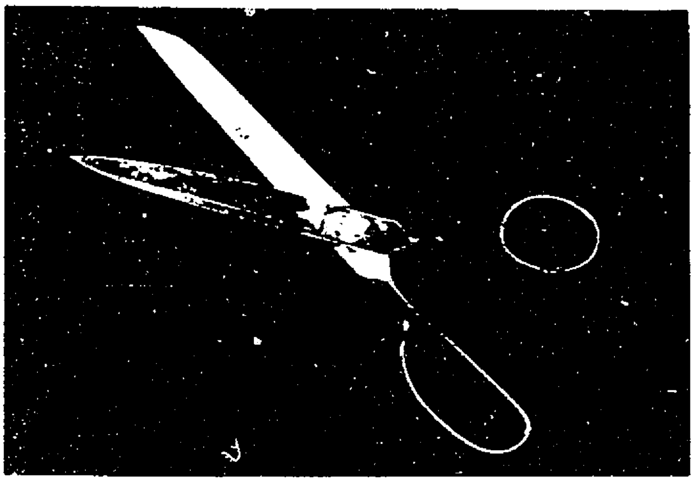
Appendix C

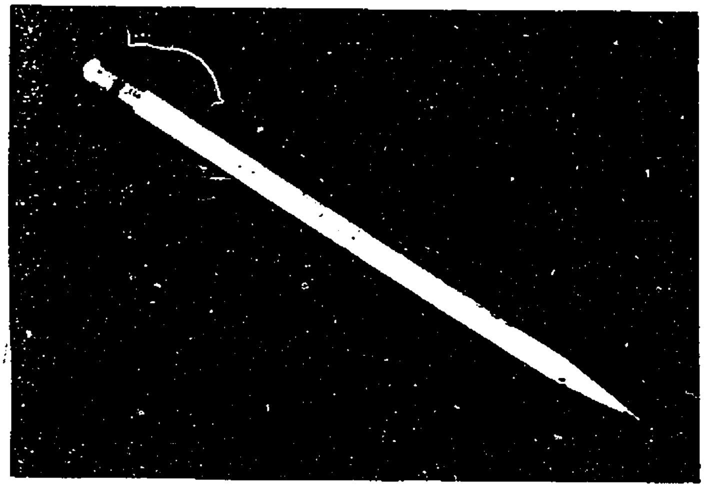
Symbolic Actions

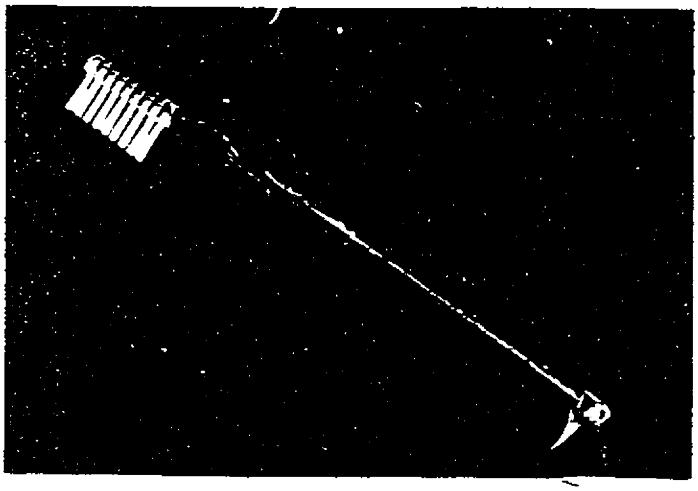
I. <u>Actions Using Objects (see photographs of objects, following pages)</u>

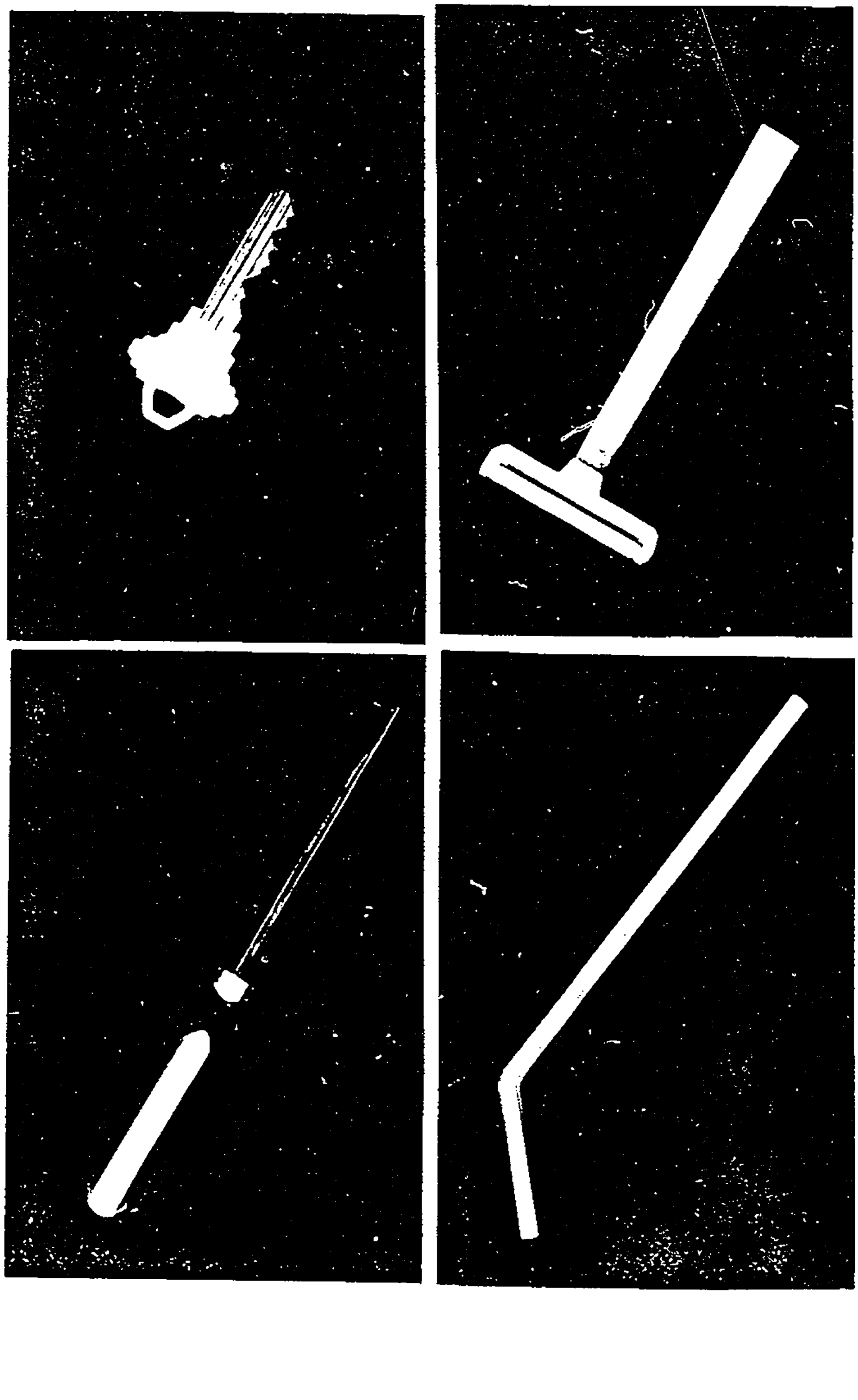
1. hammer (hammer)
2. cut (scissors)
3. write (pencil)
4. comb (comb)
5. brush teeth (toothbrush)
6. eat (spoon)
7. twist (screwdriver)
8. turn (key)
9. suck (straw)
10. shave (razor)











Appendix D

Symbolic Actions

II. <u>Unconventional Actions Using Objects</u>

1. eat (comb)
2. cut (pencil)
3. hammer (toothbrush)
4. comb (scissors)
5. write (hammer)
6. brush teeth (spoon)
7. twist (razor)
8. turn (straw)
9. such (screwdriver)
10. shave (key)

Appendix E

Symbolic Actions

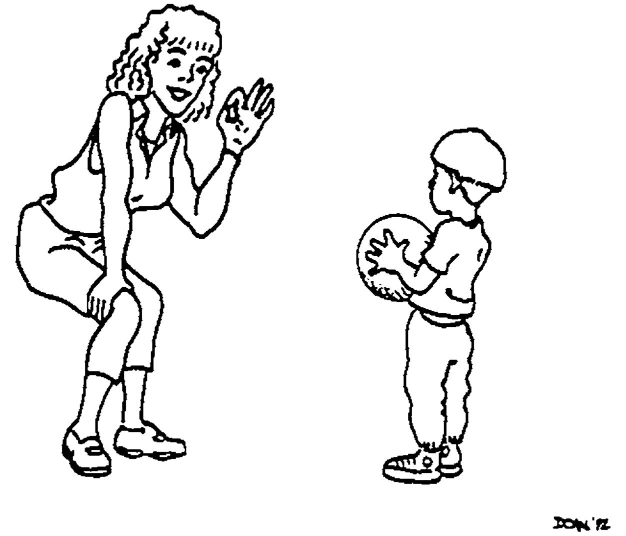
C- .municative Gestures

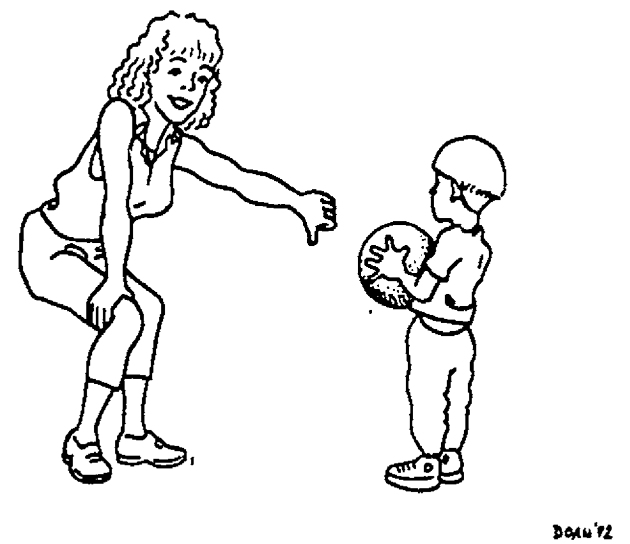
1. "OK" (circle thumb and index finger)
2. come here (beckon with index finger)
3. quiet (silent "ssh" with index finger)
4. scold (wag index finger)
5. goodbye (wave)
6. applause (clap)

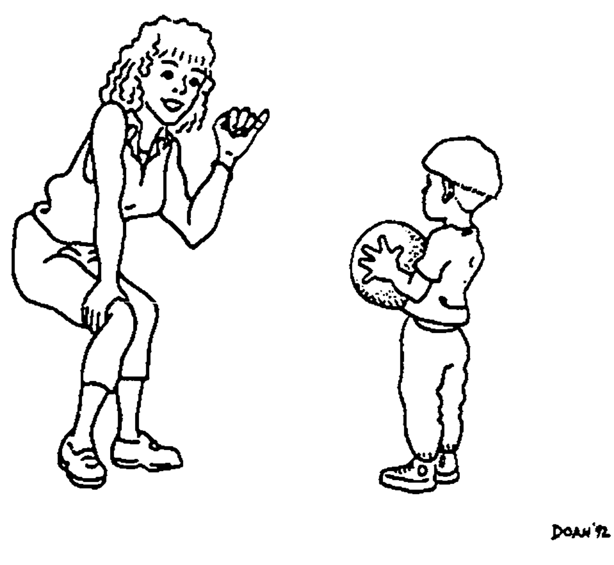
Appendix F

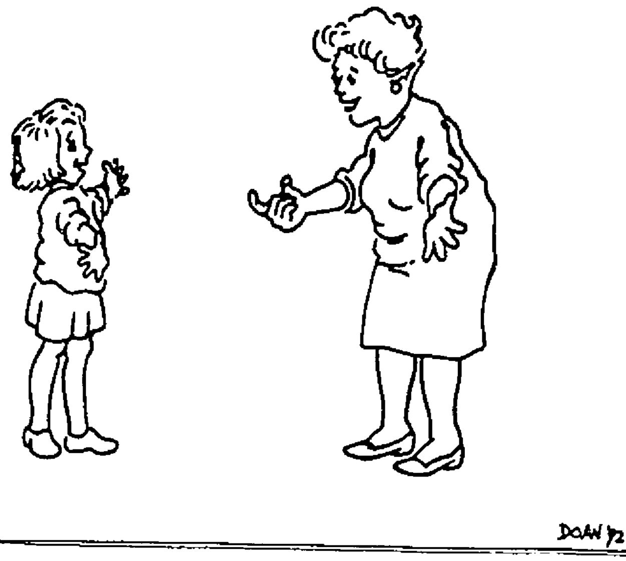
Symbolic Actions

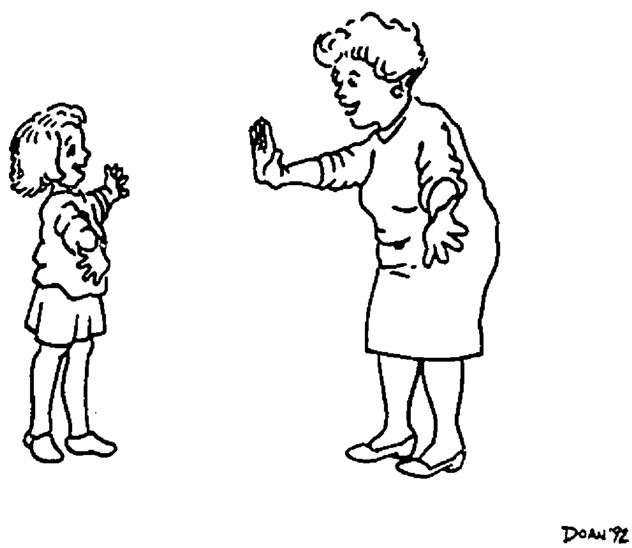
Line drawings used in the Communicative Gestures comprehension in context task: (top or left) correct gesture in context, (middle) inappropriate gesture, (bottom or right) nonsense gesture.

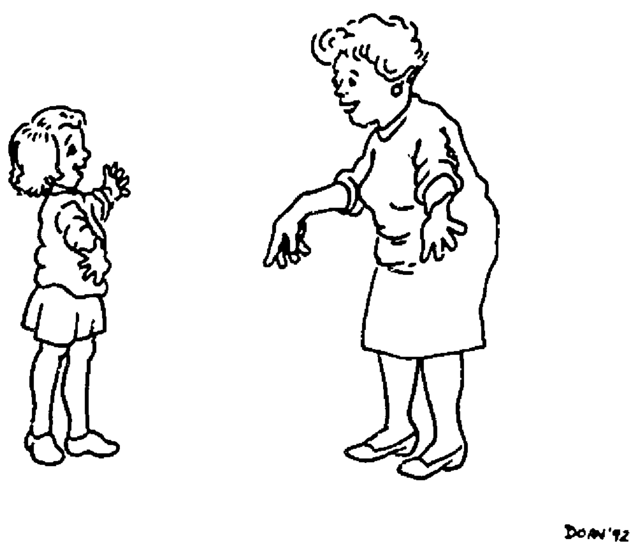

DOAN '92

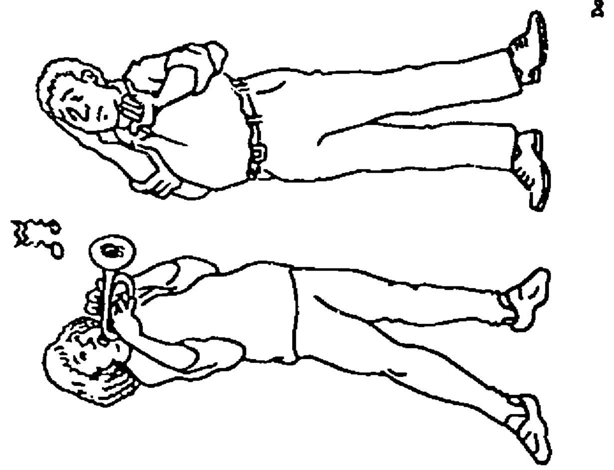

DOAN '92

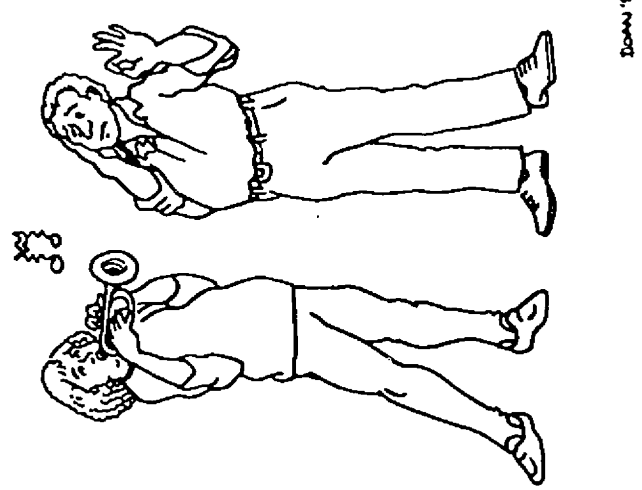

DOAN '92

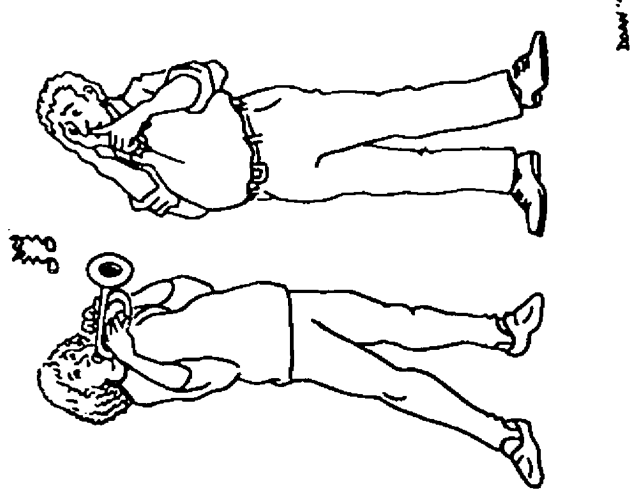

DOAN '92

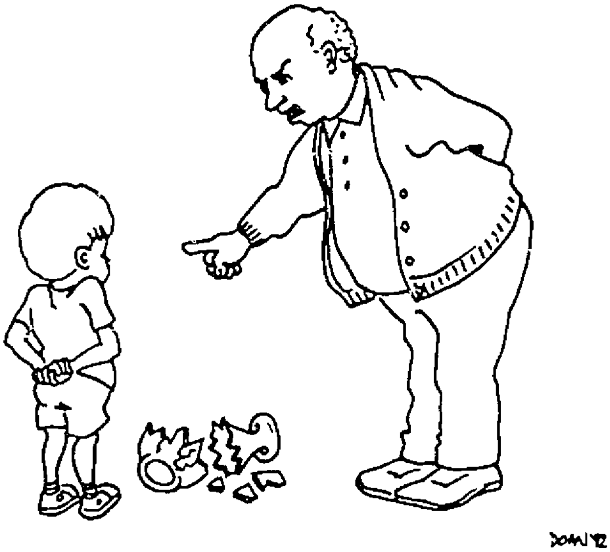

DOAN '92


DOAN '92

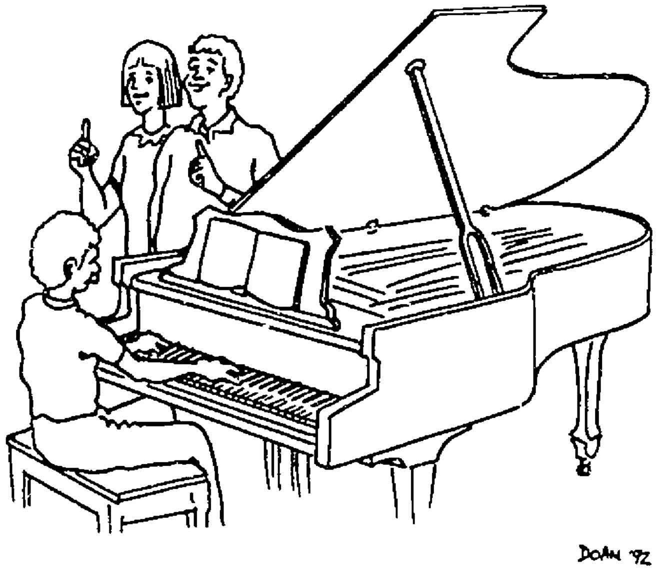

DOAN '92

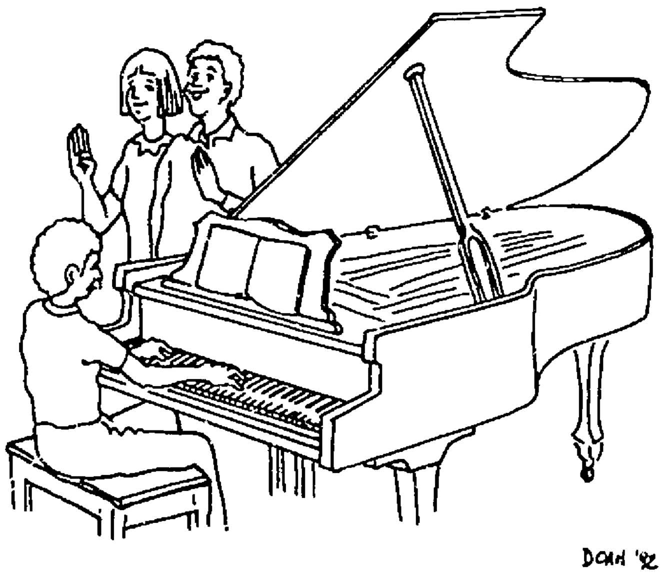

DOAN '92

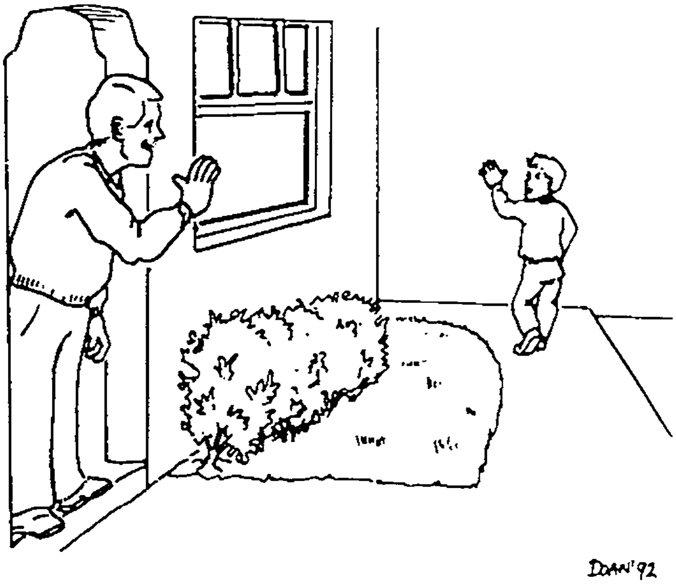

DOAN '92

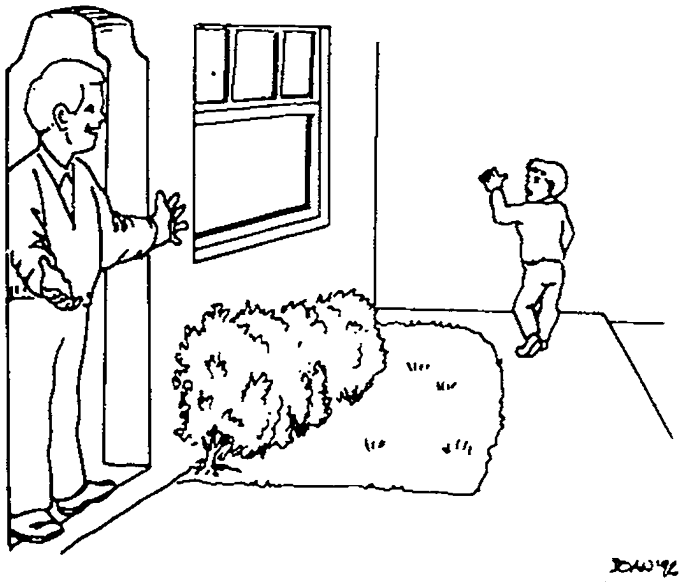


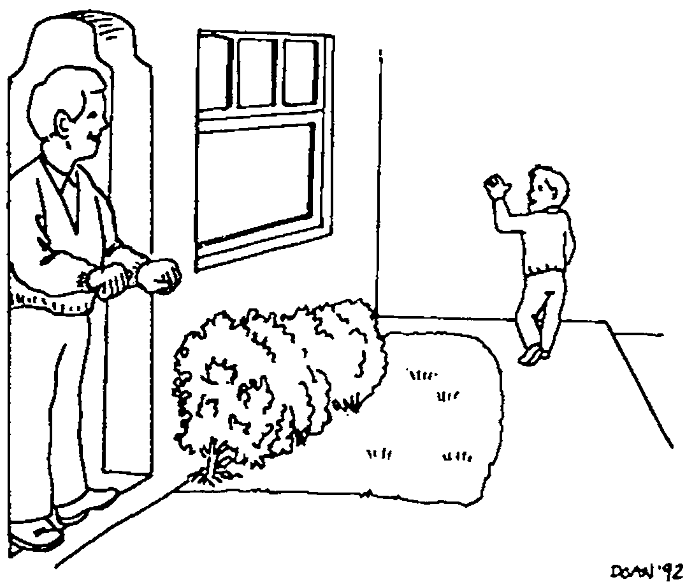

DOAN '92


DOAN '92


DOAN '92


DOAN '92


DOAN '92


DOAN '92

REFERENCES

Abrahamsen, E.P. & Mitchell, J.R. (1990). Communication and sensorimotor functioning in children with autism. *Journal of Autism and Developmental Disorders, 20,* 75-86.

Allport, A. (1987). Selection for action: Some behavioral and neurophysiological considerations of attention and action. In H. Heuer and A.F. Sanders (Eds), *Perspectives on perception and action* (pp. 395-419). Hillsdale, NJ: L. Erlbaum.

American Psychiatric Association (1987). *Diagnostic and statistical manual of mental disorders,* 3rd ed. revised. Washington, DC: Author.

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

Annett, M. (1970). The growth of manual preference and speed. *British Journal of Psychology, 61* 545-558.

Archer, L.A. & Witelson, S.F. (1988, January). *Manual motor functions in developmental dysphasia.* Poster presented at the International Neuropsychological Society, New Orleans, LA.

Asperger, H. (1991). 'Autistic psychopathy' in childhood (U. Frith, Trans). In U. Frith (Ed), *Autism and Asperger syndrome* (pp. 37-92). Cambridge, U.K.: Cambridge University Press (pp. 37-92). (Original work published in 1944)

Attwood, A., Frith, U., & Hermelin, B. (1988). The understanding and use of interpersonal gestures by autistic and Down's syndrome children. *Journal of Autism and Developmental Disorders, 18,* 241-257.

Bailey, A., Phillips, W., & Rutter, M. (1996). Autism: Towards an integration of clinical, genetic, neuropsychological, and neurobiological perspectives. *Journal of Child Psychology and Psychiatry, 37,* 89-126.

Bakeman, R. & Gottman, J.M. (1986). *Observing interaction: An introduction to sequential analysis.* Cambridge, U.K.: Cambridge University Press.

Baron-Cohen, S. (1988). Social and pragmatic deficits in autism. *Journal of Autism and Developmental Disorders, 18,* 379-402.

Baron-Cohen, S. (1989a). The autistic child's theory of mind: A case of specific developmental delay. *Journal of Child Psychology and Psychiatry, 30,* 285-297.

Baron-Cohen, S. (1989b). Perceptual role taking and protodeclarative pointing in autism. *British Journal of Developmental Psychology, 7,* 113-127.

Baron-Cohen, S. (1996). Can children with autism integrate first and third person representations? (Commentary). *Behavioural and Brain Sciences, 19,* 123-124.

Baron-Cohen, S., Tager-Flusberg, H., & Cohen, D.J. (Eds) (1993). *Understanding other minds: Perspectives from autism.* Oxford: Oxford University Press.

Barresi, J., & Moore, C. (1996a). Intentional relations and social understanding. *Brain and Behavioral Sciences, 19,* 107-122.

Barresi, J., & Moore, C. (1996b). (Authors' response) Understanding self and other. *Brain and Behavioral Sciences, 19,* 142-154.

Bartak, L., Rutter, M., & Cox, A. (1975). A comparative study of infantile autism and specific developmental language disorder: I. The children. *British Journal of Psychiatry, 126,* 127-145.

Bates, E., Benigni, L., Bretherton, I., Camaioni, L., & Volterra, V. (1979). *The emergence of symbols: Cognition and communication in infancy.* New York: Academic Press.

Bergès, J. & Lézine, I. (1965). The imitation of gestures. *Clinics in Developmental Medicine,* No. 18. London: Spastics Society/William Heinemann.

Bishop, D.V.M. (1989). Autism, Asperger's syndrome and semantic-pragmatic disorder: Where are the boundaries? *British Journal of Disorders of Communication, 24,* 107-121.

Bishop, D.V.M. (1993). Autism, executive functions and theory of mind: A neuropsychological perspective. *Journal of Child Psychology and Psychiatry, 34*, 279-293.

Bowman, E.P. (1988). Asperger's syndrome and autism: The case for a connection. *British Journal of Psychiatry, 151*, 377-382.

Boyatzis, C.J., & Watson, M.W. (1993). Preschool children's symbolic representation of objects through gestures. *Child Development, 64*, 729-735.

Brian, J.A., & Bryson, S.E. (in press). Disembedding performance and recognition memory in autism. *Journal of Child Psychology and Psychiatry.*

Bryson, S.E. (1983). Interference effects in autistic children: Evidence for the comprehension of single stimuli. *Journal of Abnormal Psychology, 92*, 250-254.

Bryson, S.E. (1990). Autism and anomalous handedness. In S. Coren (Ed.), *Left-handedness: Behavioral implications and anomalies* (pp. 441-456). Amsterdam: Elsevier North-Holland.

Bryson, S.E. (1995, March). *Impaired components of attention in autism.* Paper presented at the meeting of the Society for Research in Child Development. Indianapolis, IN.

Bryson, S.E., Clark, B.S., & Smith, I.M. (1988). First report of a Canadian epidemiological study of autistic syndromes. *Journal of Child Psychology and Psychiatry, 29*, 443-445.

Bryson, S.E., Landry, R., & Wainwright, J.A. (in press). A componential view of executive dysfunction in autism: Review of recent evidence. In J.A. Burack & J.T. Enns (Eds), *Attention: Development and psychopathology*. N.Y.: Guilford Press.

Bryson, S.E., Porac, C., & Smith, I.M. (1990). Lateral preferences in autistic children. *Canadian Journal of Psychology, 31*, 369.

Bryson, S.E., Wainwright-Sharp, J.A., & Smith, I.M. (1990). Autism: A developmental "spatial" neglect syndrome? In J. Enns (Ed.), *The* *development of attention: Research and theory* (pp. 405-427). Amsterdam: Elsevier North-Holland.

Carroll, W.R., & Bandura, A. (1990). Representational guidance of action production in observational learning: A causal analysis. *Journal of Motor Behavior, 22,* 85-97.

Casati, I., & Lézine, I. (1968). *Les etapes de l'intelligence sensorimotrice.* Paris: Les Editions de Centre de Psychologie Applique.

Castelloe, P. & Dawson, G. (1993). Subclassification of children with autism and pervasive developmental disorder: A questionnaire based on Wing's subgrouping scheme. *Journal of Autism and Developmental Disorders, 23,* 229-241.

Cermak, S. (1985). Developmental dyspraxia. In E.A. Roy (Ed.), *Neuropsychological studies of apraxia and related disorders* (Advances in Psychology, Vol. 23) (pp. 225-248). Amsterdam: North-Holland.

Cermak, S.A., Coster, W., & Drake, C. (1980). Representational and nonrepresentational gestures in boys with learning disabilities. *American Journal of Occupational Therapy, 34,* 19-26.

Charman, T., & Baron-Cohen, S. (1994). Another look at imitation in autism. *Development and Psychopathology, 6,* 403-413.

Ciesielski, K.T., Courchesne, E., & Elmasian, R. (1990). Effects of focused selective attention tasks on event-related potentials in autistic and normal individuals. *Electroencephalography and Clinical Neurophysiology, 75,* 207-220.

Conrad, K.E., Cermak, S.A., & Drake, C. (1983). Differentiation of praxis among children. *American Journal of Occupational Therapy, 37,* 466-473.

Courchesne, E., Townsend, J.P., Akshoomoff, N.A., Yeung-Courchesne, R., Lincoln, A., James, H.E., Haas, R.H., Schreibman, L., & Lau, L. (1994). A new finding: Impairment in shifting attention in autistic and cerebellar patients. In S.H. Broman & J. Grafman, J. (Eds.), *Atypical cognitive deficits in developmental disorders: Implications for brain function* (pp. 101-137). Hillsdale, NJ: Erlbaum.

Curcio, F. (1978). Sensorimotor functioning and communication in mute autistic children. *Journal of Autism and Childhood Schizophrenia, 8,* 281-292.

Curcio, F., & Piserchia, E.A. (1978). Pantomimic representation in psychotic children. *Journal of Autism and Childhood Schizophrenia, 8,* 181-189.

Dawson, G. (1988). Cerebral lateralization in autism: Clues to its role in language and affective development. In D.L. Molfese & S.J. Segalowitz (Eds.), *Brain lateralization in children: Developmental implications.* New York: Guilford Press.

Dawson, G. (1991). A psychobiological perspective on the early socio-emotional development of children with autism.. In D. Cicchetti & S. Toth (Eds.), *Rochester Symposium on Developmental Psychopathology,* Vol. 3. (pp. 207-234). Rochester, N.Y.: University of Rochester Press.

Dawson, G., & Adams, A. (1984). Imitation and social responsiveness in autistic children. *Journal of Abnormal Child Psychology, 12,* 209-226.

Dawson, G., & Galpert, L. (1990). Mothers' use of imitative play for facilitating social responsiveness in young autistic children. *Development and Psychopathology, 2,* 151-162.

Dawson, G., & Lewy, A. (1989a). Arousal, attention, and the socioemotional impairments of individuals with autism. In G. Dawson (Ed.), *Autism: Nature, diagnosis, and treatment* (pp. 49-74). New York: Guilford Press.

Dawson, G. & Lewy, A. (1989b). Reciprocal subcortical-cortical influences in autism: The role of attentional mechanisms. In G. Dawson (Ed.), *Autism: Nature, diagnosis, and treatment* (pp. 144-173). New York: Guilford Press.

Dawson, G., Warrenburg, S., & Fuller, P. (1983). Hemisphere functioning and motor imitation in autistic persons. *Brain and Cognition, 2,* 346-354.

DeMyer, M.K. (1975). The nature of the neuropsychological disability in autistic children. *Journal of Autism and Childhood Schizophrenia, 5,* 109-128.

DeMyer, M.K., Alpern, G.D., Barton, S., DeMyer, W.E., Churchill, D.W., Hingtgen, J.N., Bryson, C.Q., Pontius, W., & Kimberlin, C. (1972). Imitation in autistic, early schizophrenic, and non-psychotic children. *Journal of Autism and Childhood Schizophrenia, 2*, 264-287.

DeMyer, M.K., Hingtgen, J.N., & Jackson, R.K. (1981). Infantile autism reviewed: A decade of research. *Schizophrenia Bulletin, 7*, 388-451.

De Renzi, E. (1985). Methods of limb apraxia examination and their bearing on the interpretation of the disorder. In E.A. Roy (Ed.), *Neuro-psychological studies of apraxia and related disorders* (Advances in Psychology, Vol. 23) (pp. 45-64). Amsterdam: North-Holland.

Dewey, D. (1993). Error analysis of limb and orofacial praxis in children with developmental motor deficits. *Brain and Cognition, 23*, 203-221.

Dewey, D. (1995). What is developmental dyspraxia?*Brain and Cognition,, 29*, 254-274.

Diamond, A. (1995a, March). *Dissociations between knowledge and action: Inhibitory problems in children 3 to 7 years of age.* Paper presented to the meeting of the Society for Research in Child Development, Indianapolis, IN.

Diamond, A. (1995b, March). *Exciting new findings in developmental cognitive neuroscience.* Master lecture presented to the meeting of the Society for Research in Child Development, Indianapolis, IN.

Dunn, L.M., & Dunn, L.M. (1981). *Peabody Picture Vocabulary Test - Revised.* Circle Pines, MN: American Guidance Service.

Eskes, G.A., Bryson, S.E., & McCormick, T.A. (1990). Comprehension of concrete and abstract words in children with autism. *Journal of Autism and Developmental Disorders, 20*, 61-73.

Fein, D., Humes, M., Kaplan, E., Lucci, D., & Waterhouse, L. (1984). The question of left hemisphere dysfunction in infantile autism. *Psychological Bulletin, 95*, 258-281.

Fleiss, J.L. (1981). Statistics for rates and proportions. New York: Wiley.

Fox, N.S., & Tallis, F. (1994). Utilization behaviour in adults with autism: A preliminary investigation. *Clinical Psychology and Psychotherapy, 1,* 210-218.

Freund, H.-J. (1987). Abnormalities of motor behavior after cortical lesions in humans. *Handbook of physiology: The nervous system,* Vol. 5 (pp. 763-810). Bethesda, MD: American Physiological Society.

Frith, U. (1989). *Autism: Explaining the enigma.* Oxford: Basil Blackwell.

Frith, U., & Baron-Cohen, S. (1987). Perception in autistic children. In D.J. Cohen, A. Donnellan, & R. Paul (Eds.), *Handbook of autism and pervasive developmental disorders* (pp. 85-102). N.Y.: Wiley.

Frith, U., & Happé, F. (1994). Autism: Beyond "theory of mind". *Cognition, 50,* 115-132.

Frith, U. & Hermelin, B. (1969). The role of visual and motor cues for normal, subnormal and autistic children. *Journal of Child Psychology and Psychiatry, 10,* 153-163.

Geschwind, N. (1975). The apraxias: Neural mechanisms of disorders of learned movements. *American Scientist, 63,* 188-195.

Ghaziuddin, M., Tsai, L.Y., & Ghaziuddin, N. (1992). A reappraisal of clumsiness as a diagnostic feature of Asperger syndrome. *Journal of Autism and Developmental Disorders, 22,* 651-656.

Goldman-Rakic, P.S. (1994). Specification of higher cortical functions. In S.H. Broman & J. Grafman, J. (Eds.), *Atypical cognitive deficits in developmental disorders: Implications for brain function* (pp. 3-17). Hillsdale, NJ: Erlbaum.

Golumb, C. (1979). Pretense play: A cognitive perspective. In N.R. Smith & M.B. Franklin (Eds)., *Symbolic functioning in childhood* (pp. 101-116). Hillsdale, NJ: Erlbaum.

Goodman, R. (1989). Infantile autism: A syndrome of multiple primary deficits? *Journal of Autism and Developmental Disorders, 19,* 409-424.

Grandin, T. (1996). Brief report: Response to National Institutes of Health report. *Journal of Autism and Developmental Disorders, 26,* 185-187.

Green, J. (1990). Is Asperger's a syndrome? *Developmental Medicine and Child Neurology, 32,* 743-747.

Gubbay, S.S. (1975). *The clumsy child.* New York: W.B. Saunders.

Hammes, J.G.W., & Langdell, T. (1981). Precursors of symbol formation and childhood autism. *Journal of Autism and Developmental Disorders, 11,* 331-346.

Happé, F. (1994). Annotation: Current psychological theories of autism: The "theory of mind" account and rival theories. *Journal of Child Psychology and Psychiatry, 35,* 215-229.

Harris, P. (1993). Pretending and planning. In S. Baron-Cohen, H. Tager-Flusberg, and D.J. Cohen (Eds), *Understanding other minds: Perspectives from autism* (pp. 228-246). Oxford: Oxford University Press.

Harris, S.L. (1975). Teaching language to autistic children - with emphasis on problems of generalization. *Psychological Bulletin, 82,* 565-580.

Harris, S.L., & Handleman, J.S. (Eds) (1994). *Preschool education programs for children with autism.* Austin, TX: PRO-ED.

Haviland, J.M., Walker-Andrews, A.S., Huffman, L.R., Toci, L., & Alton, K. (1996). Intermodal perception of emotional expressions by children with autism. *Journal of Developmental and Physical Disabilities, 8,* 77-88.

Hay, D.F., Stimson, C.A., & Castle, J. (1990). A meeting of minds in infancy: Imitation and desire. In D. Frye & C. Moore (Eds.), *Children's theories of mind* (pp. 115-137). Hillsdale, N.J.: Erlbaum.

Hermelin, B. (1976). Coding and the sense modalities. In L. Wing (Ed.), *Early childhood autism,* 2nd edition (pp. 135-168). Oxford: Pergamon Press.

Hermelin, B., & O'Connor, N. (1970). *Psychological experiments with autistic children.* Oxford: Pergamon Press.

Hobson, R.P. (1991). Methodological issues for experiments on autistic individuals' perception and understanding of emotion. *Journal of Child Psychology and Psychiatry, 32,* 1135-1158.

Hobson, P. (1993). *Autism and the development of mind.* Hillsdale, NJ: Erlbaum.

Hofsten, C. von (1989). Motor development as the development of systems: Comments on the special section. *Developmental Psychology, 25,* 950-953.

Hughes, C. (1996a). Control of action and thought: Normal development and dysfunction in autism: A research note. *Journal of Child Psychology and Psychiatry, 37,* 229-236.

Hughes, C. (1996b). Planning problems in autism at the level of motor control. *Journal of Autism and Developmental Disorders, 26,* 90-107.

Hughes, C., & Russell, J. (1993). Autistic children's difficulty with mental disengagement from an object: Its implications for theories of autism. *Developmental Psychology, 29,* 498-510.

Hughes, C., Russell, J., & Robbins, T.W. (1994). Specific planning deficit in autism: Evidence for a central executive dysfunction. *Neuropsychologia, 32,* 477-492.

Jarrold, C., Boucher, J., & Smith, P.K. (1993). Symbolic play in autism: A review. *Journal of Autism and Developmental Disorders, 23,* 281-308.

Jarrold, C., Boucher, J., & Smith, P.K. (1994). Executive function deficits and the pretend play of children with autism: A research note. *Journal of Child Psychology and Psychiatry, 35,* 1473-1482.

Jarrold, C., Smith, P., Boucher, J., & Harris, P. (1994). Comprehension of pretence in children with autism. *Journal of Autism and Developmental Disorders, 24,* 433-455.

Jones, V., & Prior, M.P. (1985). Motor imitation abilities and neurological signs in autistic children. *Journal of Autism and Developmental Disorders, 15,* 37-46.

Kanner, L. (1973). Autistic disturbances of affective contact. In *Childhood psychosis: Initial studies and new insights*. Washington, D.C.: V.H. Winston. (Original work published in 1943)

Kaplan, E.F. (1968). Gestural representation of implement usage: An organismic developmental study. *Dissertation Abstracts International,* 2193-B.

Kertesz, A. (1985). Apraxia and aphasia. Anatomical and clinical relationship. In E.A. Roy (Ed.), *Neuropsychological studies of apraxia and related disorders* (Advances in Psychology, Vol. 23) (pp. 163-178). Amsterdam: North-Holland.

Kimura, D. (1977). Acquisition of a motor skill after left hemisphere damage. *Brain, 100,* 527-542.

Kimura, D. (1982). Left-hemisphere control of oral and brachial movements and their relation to communication. *Philosophical Transactions of the Royal Society of London, B298,* 135-149.

Kimura, D., & Archibald, Y. (1974). Motor functions of the left hemisphere. *Brain, 97,* 337-350.

Kinsbourne, M. (1987). Cerebral-brainstem relations in infantile autism. In E. Schopler & G. Mesibov (Eds.), *Neurobiological issues in autism* (pp. 107-126). New York: Plenum Press.

Klein, R.M. (1977). Attention and visual dominance: A chronometric analysis. *Journal of Experimental Psychology: Human Perception and Performance, 3,* 365-378.

Klein, R.M., & Posner, M.I. (1974). Attention to visual and kinaesthetic components of skills. *Brain Research, 71,* 401-411.

Klinger, L.G., & Dawson, G. (1995). A fresh look at categorization abilities in autism. In E. Schopler & G. Mesibov (Eds.), *Cognition and learning in autism* (pp. 119-136). New York: Plenum Press.

Krug, D.A., Arick, J.R., & Almond, P.J. (1980a). *Autism screening instrument for educational planning*. Portland, OR: ASIEP Education Company.

Krug, D.A., Arick, J.R., & Almond, P.J. (1980b). Behavior checklist for identifying severely handicapped individuals with high levels of autistic behavior. *Journal of Child Psychology and Psychiatry, 21*, 221-229.

Landis, R.J. & Koch, G.G. (1977). The measurement of interobserver agreement for categorical data. *Biometrics, 33*, 159-174.

Lewis, V., & Boucher, J. (1988). Spontaneous, instructed, and elicited play in relatively able autistic children. *British Journal of Developmental Psychology, 6*, 325-339.

Lezak, M.D. (1983). *Neuropsychological assessment* (2nd ed). New York: Oxford University Press.

Lhermitte, F. (1983). 'Utilization behaviour' and its relation to lesions of the frontal lobe. *Brain, 106*, 237-255.

Liepmann, H. (1980). The left hemisphere and action. In D. Kimura (Ed and Trans), *Translations from Liepmann's essays on apraxia* (Research Bulletin #506). London, Ontario: Department of Psychology, University of Western Ontario. (Original work published 1905)

Lockyer, L., & Rutter, M. (1970). A five to fifteen year follow-up study of infantile psychosis: IV. Patterns of cognitive ability. *British Journal of Clinical Psychology, 9*, 156-163.

Lotter, V. (1966). Epidemiology of autistic conditions in young children. I. Prevalence. *Social Psychiatry, 1*, 124-137.

Loveland, K.A., Tunali-Kotoski, B., Chen, R., Brelsford, K.A., Ortegon, J., & Pearson, D.A. (1995). Intermodal perception of affect in persons with autism or Down syndrome. *Development and Psychopathology, 3*, 409-418.

MacKay, D.G. (1985). A theory of the representation, organization and timing of action with implications for sequencing disorders. In E. A. Roy (Ed), *Neuropsychological studies of apraxia and related disorders* (pp.267-308). (Advances in Psychology, Vol. 23). Amsterdam: North-Holland.

Manjiviona, J., & Prior, M. (1995). Comparison of Asperger syndrome and high-functioning autistic children on a test of motor impairment. *Journal of Autism and Developmental Disorders, 25,* 23-39.

Masterton, B.A., & Biederman, G.B. (1983). Proprioceptive versus visual control in autistic children. *Journal of Autism and Developmental Disorders, 13,* 141-152.

McEvoy, R.E., Rogers, S.J., & Pennington, B.F. (1993). Executive function and social communication deficits in young autistic children. *Journal of Child Psychology and Psychiatry, 34,* 563-578.

McManus, I.C., Murray, B., Doyle, K., & Baron-Cohen, S. (1992). Handedness in childhood autism shows a dissociation of skill and preference. *Cortex, 28,* 373-381.

McManus, I.C., Sik, G., Cole, D.R., Mellon, A.F., Wong, J., & Kloss, J. (1988). The development of handedness in children. *British Journal of Developmental Psychology, 6,* 257-273.

Meijer, O.G., & Roth, K. (Eds.) (1988). *Complex movement behaviour: 'The' motor-action controversy* (Advances in Psychology, Vol. 50). Amsterdam: North-Holland.

Meltzoff, A.N. (1988). Infant imitation after a one-week delay: Long-term memory for novel acts and multiple stimuli. *Developmental Psychology, 24,* 470-476.

Meltzoff, A.N. (1990). Foundations for developing a concept of self: The role of imitation in relating self to other and the value of social modelling and self practice in infancy. In D. Cicchetti & M. Beeghly (Eds.), *The self in transition* (pp. 139-164). Chicago: University of Chicago Press.

Meltzoff, A.N., & Gopnik, A. (1993). The role of imitation in understanding persons and developing a theory of mind. In S. Baron-Cohen, H. Tager-Flusberg, & D.J. Cohen (Eds), *Understanding other minds: Perspectives from autism* (pp. 335-366). Oxford: Oxford University Press.

Menyuk, P., & Quill, K. (1985). Semantic problems in autistic children. In E. Schopler & G. Mesibov (Eds), *Communication problems in autism* (pp. 127-145). New York: Plenum Press.

Minshew, N.J., Goldstein, G., Muenz, L.R., & Peyton, L.R. (1992). Neuropsychological functioning in nonmentally retarded autistic individuals. *Journal of Clinical and Experimental Neuropsychology, 14,* 749-761.

Morgan, S.B., Cutrer, P.S., Coplin, J.W., & Rodrigue, J.R. (1989). Do autistic children differ from retarded and normal children in Piagetian sensorimotor functioning? *Journal of Child Psychology and Psychiatry, 30,* 857-864.

Ohta, M. (1987). Cognitive disorders of infantile autism: A study employing the WISC, spatial relationship conceptualization and gesture imitations. *Journal of Autism and Developmental Disorders, 17,* 45-62.

Overton, W.F., & Jackson, J.P. (1973). The representation of imagined objects in action sequences: A developmental study. *Child Development, 44,* 309-314.

Ozonoff, S., Pennington, B.F., & Rogers, S.J. (1991). Executive function deficits in high-functioning autistic individuals: Relationship to theory of mind. *Journal of Child Psychology and Psychiatry, 32,* 1081-1105.

Ozonoff, S., Rogers, S.J., & Pennington, B.F. (1991). Asperger's syndrome: Evidence of an empirical distinction from high-functioning autism. *Journal of Child Psychology and Psychiatry, 32,* 1107-1122.

Pennington, B.F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry, 37,* 51-87.

Piaget, J. (1952). *The origins of intelligence in children.* New York: Norton.

Piaget, J. (1962). *Play, dreams and imitation in childhood.* New York: Norton.

Pick, H.L., Jr. (1989). Motor development: The control of action. *Developmental Psychology, 25,* 867-870.

Posner, M.I., Nissen, M.J., & Klein, R.M. (1976). Visual dominance: An information-processing account of its origins and significance. *Psychological Review, 83,* 157-171.

Prior, M.R. (1977). Psycholinguistic disabilities of autistic and retarded children. *Journal of Mental Deficiency Research, 21*, 37-45.

Prior, M.R. (1979). Cognitive abilities and disabilities in infantile autism: A review. *Journal of Abnormal Child Psychology, 7*, 357-380.

Raade, A.S., Rothi, L.J.G., & Heilman, K. (1991). The relationship between buccofacial and limb apraxia. *Brain and Cognition, 16*, 130-146.

Ratner, V.L. (1985). Spatial relationship deficits in deaf children: The effect on communication and classroom performance. *American Annals of the Deaf, 130*, 250-254.

Ricks, D.M., & Wing, L. (1975). Language, communication, and the use of symbols in normal and autistic children. *Journal of Autism and Childhood Schizophrenia, 5*, 191-221.

Riddoch, M.J., Humphreys, G.W., & Price, C.J. (1989). Routes to action: Evidence from apraxia. *Cognitive Neuropsychology, 6*, 437-454.

Rincover, A., Feldman, M., & Eason, L. (1986). "Tunnel vision": A possible keystone stimulus control deficit in autistic children. *Analysis and Intervention in Developmental Disabilities, 6*, 283-304.

Rodger, R.S. (1969). Linear hypotheses in 2 X a frequency tables. *British Journal of Mathematical and Statistical Psychology, 22*, 29-48.

Rodger, R.S. (1975). The number of non-zero, post hoc contrasts from anova and error-rate I. *British Journal of Mathematical and Statistical Psychology, 28*, 71-78.

Rogers, S.J., and McEvoy, R.E. (1993). *Praxis in high-functioning persons with autism.* Poster presented at the meeting of the Society for Research in Child Development, New Orleans, LA.

Rogers, S., & Pennington, B.F. (1991). A theoretical approach to the deficits in infantile autism. *Development and Psychopathology, 3*, 137-162.

Rosenbaum, D.A., Marchak, F., Barnes, H.J., Vaughan, J., Slotta, J.D., & Jorgensen, M.J. (1990). Constraints for action selection: Overhand versus underhand grips. In J. Long and A. Baddeley (Eds), *Attention and Performance* (Vol. 13, pp. 321-342). Hillsdale, NJ: Erlbaum.

Rothi, L.J.G., Ochipa, C., & Heilman, K.M. (1991). A cognitive neuropsychological model of limb praxis. *Cognitive Neuropsychology, 8,* 443-458.

Roy, E.A. (1981). Action sequencing and lateralized cerebral damage: Evidence for asymmetries in control. In J. Long and A. Baddeley (Eds), *Attention and Performance* (Vol. 9, pp. 487-500). Hillsdale, NJ: Erlbaum.

Roy, E.A. (1983). Neuropsychological perspectives on apraxia and related action disorders. In R.A. Magill (Ed), *Memory and control of action* (pp. 293-320). (Advances in Psychology, Vol. 12) Amsterdam: North-Holland.

Roy, E.A. (Ed). (1985). *Neuropsychological studies of apraxia and related disorders* (Advances in Psychology, Vol. 23). Amsterdam: North-Holland.

Roy, E.A., Elliott, D., Dewey, D., & Square-Storer, P. (1990). Impairments to praxis and sequencing in adult and developmental disorders. In C. Bard, M. Fleury, & L. Hay (Eds.), *Development of eye-hand coordination across the life span* (pp. 358-384). Columbia, SC: University of South Carolina Press.

Roy, E.A., Square, P.A., Adams, S., & Friesen, H. (1985). Error/movement notation systems in apraxia. *Semiotic Inquiry, 5,* 402-412.

Rumsey, J.M. (1985). Conceptual problem-solving in highly verbal, nonretarded autistic men. *Journal of Autism and Developmental Disorders, 15,* 23-36.

Rumsey, J.M., & Hamburger, S.D. (1988). Neuropsychological findings in high functioning men with infantile autism, residual state. *Journal of Clinical and Experimental Neuropsychology, 10,* 201-221.

Russell, J., & Jarrold, C.R. (1995). *Executive functions, working memory, and autism.* Paper presented to the Society for Research in Child Development, Indianapolis, IN, March.

Rutter, M. (1996). Autism research: Prospects and priorities. *Journal of Autism and Developmental Disorders, 26,* 257-275.

Sattler, J.M. (1992). *Assessment of children* (rev 3rd ed). San Diego, CA: Jerome M. Sattler, Publisher, Inc.

Schopler, E., Reichler, R.J., & Renner, B.R. (1988). *The Childhood Autism Rating Scale (CARS).* Los Angeles: Western Psychological Services.

Shafer, S.Q., Shaffer, D., O'Connor, P.A., & Stokman, S.J. (1983). Hard thoughts on neurological "soft signs". In M. Rutter (Ed.), *Developmental neuropsychiatry* (pp. 133-143). N.Y.: Guilford Press.

Shaffer, D., O'Connor, P.A., Shafer, S.Q., & Prupis, S. (1983). Neurological "soft signs": Their origins and significance for behaviour. In M. Rutter (Ed.), *Developmental neuropsychiatry* (pp. 144-163). N.Y.: Guilford Press.

Shah, A., & Frith, U. (1983). An islet of ability in autistic children: A research note. *Journal of Child Psychology and Psychiatry, 24,* 613-620.

Shallice, T. (1988). *From neuropsychology to mental structure.* Cambridge: Cambridge University Press.

Shallice, T., Burgess, P., Schon, F., & Baxter, D.M. (1989). The origins of utilization behaviour. *Brain, 112,* 1587-1598.

Sigman, M., & Ungerer, J. (1981). Sensorimotor skills and language comprehension in autistic children. *Journal of Abnormal Child Psychology, 9,* 149-165.

Sigman, M. & Ungerer, J. (1984). Cognitive and language skills in autistic, mentally retarded, and normal children. *Developmental Psychology, 20,* 293-302.

Smith, I.M., & Bryson, S.E. (1994). Imitation and action in autism: A critical review. *Psychological Bulletin, 116,* 259-273.

Smith, I.M., & Moore, C. (in preparation). *Intersensory functioning in autism: A reconsideration.*

Snowling, M.J. (1983). The comparison of acquired and developmental disorders of reading - A discussion. *Cognition, 14,* 105-118.

Sonksen, P.M., Levitt, S., & Kitsinger, M. (1984). Identification of constraints acting on motor development in young visually disabled children and principles of remediation. *Child Care, Health and Development, 10,* 273-286.

Soper, H.V., Satz, P., Orsini, D.L., Henry, R.R., Zvi, J.C., & Schulman, M. (1986). Handedness patterns in autism suggest subtypes. *Journal of Autism and Developmental Disorders, 16,* 155-167.

SPSS, Inc. (1988). *SPSS-X User's Guide* (3rd edition). Chicago, IL: Author.

Stone, W.L., Lemanek, K.L., Fishel, P.T., Fernandez, M.C., & Altemeier, W.A. (1990). Play and imitation skills in the diagnosis of autism in young children. *Pediatrics, 86,* 267-272.

Stott, D.H., Moyes, F.A., & Henderson, S.E. (1984). *Manual: Test of Motor Impairment (Henderson Revision).* Guelph, ON: Brook International.

Stuss, D.J. & Benson, F.D. (1986). *The frontal lobes.* New York: Raven Press.

Szatmari, P., Bartolucci, G., Finlayson, A., & Krames, L. (1986). A vote for Asperger's syndrome [Letter]. *Journal of Autism and Developmental Disorders, 16,* 515-517.

Szatmari, P., Tuff, L., Finlayson, A.J., & Bartolucci, G. (1990). Asperger's syndrome and autism: Neurocognitive aspects. *Journal of the American Academy of Child and Adolescent Psychiatry, 29,* 130-136.

Tabachnick, B.G., & Fidell, L.S. (1989). *Using multivariate statistics* (2nd edition). New York: HarperCollins.

Tager-Flusberg, H. (1985a). Basic level and superordinate level categorization by autistic, mentally retarded and normal children. *Journal of Experimental Child Psychology, 40,* 450-469.

Tager-Flusberg, H. (1985b). The conceptual basis for referential word meaning in children with autism. *Child Development, 56,* 1167-1178.

Tallal, P., Miller, S., & Fitch, R.H. (1993). Neurobiological basis of speech: A case for the preeminence of temporal processing. *Annals of the New York Academy of Sciences, 682,* 27-47.

Tantum, D. (1988). Asperger's syndrome (Annotation). *Journal of Child Psychology and Psychiatry, 29,* 245-255.

Tate, R.L., & McDonald, S. (1995). What is apraxia? The clinician's dilemma. *Neuropsychological Rehabilitation, 5,* 273-297.

Tiegerman, E. & Primavera, L. (1984). Imitating the autistic child: Facilitating communicative gaze behavior. *Journal of Autism and Developmental Disorders, 11,* 427-438.

Tipper, S.P., Lortie, C., & Baylis, G.C. (1992). Selective reaching: Evidence for action-centred attention. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 891-905.

Townsend, J., & Courchesne, E. (1994). Parietal damage and narrow "spotlight" spatial attention. *Journal of Cognitive Neuroscience, 6,* 220-232.

Trites, R.L. (1977). *Neuropsychological test manual.* Ottawa, ON: Royal Ontario Hospital.

Ungerer, J.A. (1989). The early development of autistic children: Implications for defining primary deficits. In G. Dawson (Ed.), *Autism: Nature, diagnosis, and treatment* (pp. 75-91). New York: Guilford Press.

Uzgiris, I.C. (1981). Two functions of imitation during infancy. *International Journal of Behavioral Development, 4,* 1-12.

Uzgiris, I.C., & Hunt, J.M. (1975). *Assessment in infancy.* Urbana, IL: University of Illinois Press.

Vaina, L. (1983). From shapes and movements to objects and actions. *Synthese, 54,* 3-36.

Wadden, N.P.K., Bryson, S.E., & Rodger, R.S. (1991). A closer look at the Autism Behavior Checklist: Discriminant validity and factor structure. *Journal of Autism and Developmental Disorders, 21,* 529-541.

Wainwright-Sharp, J.A., & Bryson, S.E. (1993). Visual orienting deficits in high-functioning people with autism. *Journal of Autism and Developmental Disorders, 23,* 1-14.

Wechsler, D. (1974). *Manual for the Wechsler Intelligence Scale for Children - Revised*. San Antonio: The Psychological Corporation.

Wechsler, D. (1981). *Manual for the Wechsler Adult Intelligence Scale - Revised*. San Antonio: The Psychological Corporation.

Wechsler, D. (1991). *Manual for the Wechsler Intelligence Scale for Children - Third Edition*. San Antonio: The Psychological Corporation.

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

Wing, L., & Attwood, A. (1987). Syndromes of autism and atypical development. In D.J. Cohen & A.M. Donnellan (Eds.), *Handbook of autism and pervasive developmental disorders* (pp. 3-19). New York: John Wiley and Sons.

World Health Organization (1992). *International classification of diseases* (10th edition). Geneva: Author.

Young, J.M., Krantz, P.J., McClannahan, L.E., & Poulson, C.L. (1994). Generalized imitation and response-class formation in children with autism. *Journal of Applied Behavior Analysis, 27*, 685-697.

Yule, W. (1978). Research methodology: What are the "correct controls"? In M. Rutter & E. Schopler (Eds.), *Autism: A reappraisal of concepts and treatment* (pp. 155-162). N.Y.: Plenum Press.

Yurmiya, N., Sigman, M., & Zacks, D. (1994). Perceptual perspective-taking and seriation abilities in high-functioning children with autism. *Development and Psychopathology, 6*, 263-272.

Zelazo, P.D., Reznick, J.S., & Piñon, D.E. (1995). Response control and the execution of verbal rules. *Developmental Psychology, 31*, 508-517.

Dalhousie University

Department of Psychology
Halifax, Nova Scotia
Canada B3H 4J1

(902) 494-3417
FAX: (902) 494-6585

12 July, 1996

Ms. Karen Thomas
American Psychological Association
Journals Office

FAX # (202) 336-5549

Dear Ms. Thomas:

/259-273

I wrote an article entitled "Imitation and action in autism: A critical review, which was published in 1994 in Psychological Bulletin, 116 (2) with co-author, Susan E. Bryson. Approximately fifty percent of the material in this article also appears in the Introduction to my dissertation (written under Dr. Bryson's supervision), which I am about to submit. The university requires that I grant it rights to reproduce the thesis for non-commercial purposes one copy at a time, upon individual request. I am also required to sign a form attesting that permission has been obtained for use of any copyrighted material in the thesis.

I am writing to request that APA, as holder of the copyright on the Psychological Bulletin article, provide a letter confirming permission to use my previously published material in this manner. My intention is to submit the thesis on Friday, July 19th, so receipt of such a letter by Thursday, July 18 would be greatly appreciated, if at all posssible. I can receive the letter by either of two fax numbers:

(902) [redacted]
or
(902) 494[redacted]

If I can provide any additional information to expedite this request, I can be reached by telephone at (902) [redacted] or through e-mail at isasmith@is.dal.ca. Your prompt attention to this matter is appreciated.

Sincerely,

Isabel Smith

Isabel M. Smith

Permission granted without fee for non-exclusive, one time use of APA-copyrighted material for the purposes stated in your request. Permission does not apply to future editions of your work or to its appearance in a format different from that for which you have requested permission. Reprinted material must include full bibliographic citation and the following notice: Copyright 1994 by the American Psychological Association. Reprinted (or Adapted) by permission.

Karen A. Thomas 7-15-96
Permissions Office
American Psychological Association