Equivalence Class Formation in Non-Hearing Impaired Children and Hearing Impaired Children

Dermot Barnes
University College Cork, Ireland

AND

Paul D. McCullagh and Michael Keenan
University of Ulster at Coleraine Northern Ireland

The relationship between verbal behavior and stimulus equivalence was examined using three sets of children differing in chronological age and verbal ability: (1) non-hearing impaired three and four year olds who had verbal skills generally consistent with their chronological ages; (2) partially hearing (severe to profoundly deaf) children who were rated with verbal ages of above 2 years; and (3) partially hearing children (also severely to profoundly deaf) who were rated with verbal ages of below 2 years. All children were taught a series of four conditional discriminations using unfamiliar stimuli. The children were then tested to determine whether classes of equivalent stimuli had formed. Although all the children were able to learn the conditional discriminations equally well and all the verbally-able children (normal and partially hearing) formed equivalence classes, only one of the verbally-impaired children reliably demonstrated stimulus equivalence formation. These results are consistent with the suggestion that stimulus equivalence and human verbal behavior are closely related.

The bidirectionality of the relations between the component stimuli within an equivalence class suggests that the stimulus equivalence phenomenon might be of considerable relevance to the functional analysis of human verbal behavior:

> In the context of stimulus equivalence, a "symbol" and its "referents" form a class of functionally substitutable elements. The relation between a symbol and its referent is not a unidirectional conditional relation (although the members of the class are conditionally related to each other); the relation is functionally reversible. The relations among members of an class appear to approximate what psycholinguists and others mean when they say that a word represents or "stands for" its referent. (DeVany, Hayes, & Nelson, p. 244, 1986)

An association between stimulus equivalence and human verbal behavior has been supported by the finding that a wide range subjects have readily demonstrated the formation of equivalence classes (e.g., Dixon, 1976; Mackay & Sidman, 1984; Wetherby, Karlan, & Spradlin, 1983), while attempts to show equivalence in nonhumans, including higher primates, have failed (e.g., Dugdale & Lowe, 1990; Sidman, Rauzin, Lazar, Cunningham, Tailby, & Carrigan, 1982). Recent research has also shown that when young children, who have failed to show equivalence, are trained to tact in relation to the stimuli employed in the equivalence experiment equivalence responding quickly emerges (Dugdale & Lowe, 1990).

If a certain degree of verbal competence is critical for stimulus equivalence then children substantially older than 2 years but who are suffering some form of severe verbal impairment should fail to show equivalence responding. This specific suggestion was tested by Devany et al., (1986) who found that irrespective of chronological age mentally handicapped, verbally-

Requests for reprints should be addressed to Dermot Barnes at the Department of Applied Psychology, University College Cork, Cork, Ireland. The authors wish to express their gratitude to the staff and pupils at the Partial Hearing Unit at St. Conors Primary School, especially Ms. Breige McCrystal and Mrs. Maura Corey who gave so much of their time and energy. Special thanks are also extended to Sean, Niall and Anna, and to Colin Cooper for invaluable assistance in the preparation of this manuscript.

able children demonstrated equivalence class formation, whereas mentally handicapped, verbally-disabled children did not. Devany et al., (1986) urge caution, however, in using their findings to support the suggestion that there is a strong link between verbal behavior and equivalence class formation. Specifically they point out that the mentally handicapped, verbally-disabled children differed from the other subjects in ways other than a failure to speak or sign. For example, the retarded, non-verbal subjects required substantially more training and prompting to master the explicitly reinforced conditional discriminations. In effect, the factor of subject retardation prevents us from pinpointing verbal behavior as the main source of the observed differences.

It may be possible, however, to disentangle the issue of equivalence class formation and verbal behavior from that of mental handicap per se, through the employment of non-retarded children who are nevertheless suffering some form of verbal-impairment. The present study adopted such a strategy. Three sets of children were employed: normally developing preschoolers; normally developing, partially hearing children who were rated with verbal ages of above two years; and normally developing partially hearing children rated with verbal ages of below two years. All four subjects from Sets 1 and 2 and one subject from Set 3 successfully engaged in tact /object-word sequences (i.e., providing the appropriate word for an object presented by the experimenter) and tact /word-object sequences (i.e., identifying the appropriate object in the presence of a word presented by the experimenter). The remaining subject from Set 3 successfully engaged in object-word sequences, but failed to reliably engage in word-object sequences. Each subject was taught a series of four related conditional discriminations and was then subsequently tested to determine if equivalence classes had emerged.

METHOD

Subjects and subject identification

Six children (4 males and 2 females) whose ages ranged from 3 years to 8 years served as subjects. Pairs of subjects were assigned to one of three sets. Set 1 consisted of non-hearing impaired preschool children whose parents were undergraduate students from the University of Ulster. Subjects assigned to Sets 2 and 3 were severely to profoundly deaf (i.e., partially hearing children), all of whom attended the Partial Hearing Unit at St. Conors Primary School, Omagh, County Tyrone, Northern Ireland. The subjects' hearing loss had been caused by a functional disorder of the actual hearing mechanism; for example the bones of the inner ear may have been fused at birth.

The non-hearing impaired children (i.e., Set 1) had verbal skills consistent with their chronological ages. Although there was no formal assessment of their verbal ages, no abnormalities of speech or verbal behavior were noted by the researchers during their interactions with these children. Furthermore no abnormalities were reported by the subjects' parents. Intelligence scores for these subjects were obtained with the Wechsler Preschool and Primary Scale of Intelligence.

Devany et al., (1986) reported that the youngest human subject to demonstrate stimulus equivalence was aged 2 years and 1 month. On the basis of this finding the partially hearing subjects in the present study were classed into Set 2 (verbal age of 2 years and above) and Set 3 (verbal age of 2 years and below). The verbal ages of the subjects had been established by a Speech Therapist using the Reynal Developmental Language Scales, and their intelligence scores obtained by the School's Educational Psychologist using the Hiskey Nebraska Test for Learning Aptitude.

Before the commencement of the first experimental session the experimenter engaged each of the six subjects individually in a series of tact /object-word and tact /word-object sequences (for convenience these will be referred to as object-word and word-object sequences respectively). The object-word sequences involved the experimenter touching an object (e.g., a table) in the experimental room and asking (speaking and signing for the partially hearing subjects) the child "what is this?" Partially hearing children could speak and/or sign their answers. The word-object sequences involved the experimenter asking (i.e., speaking and signing for the partially hearing subjects) the child to identify the location of an object in the room (e.g., "where is a chair"). Partially hearing children could speak and/or sign their answers (e.g., touching a chair and saying and/or signing "here"). Five object-word and five word-object sequences were randomly intermixed (a total of ten). Subjects were given no reinforcement or feedback during these ten sequences. The same five objects (i.e., chair, door, pencil, table, and window) were employed with each of the six subjects for both object-word and word-object sequences. Thus, each object was used in both types of sequence. During the sequences a co-researcher, who was unaware of the nature of the study, stood in a corner of the room and recorded the subject's responses on a data sheet. This sheet could not be seen by either the experimenter or the subject.

With the exception of one subject from Set 3 (i.e., Claudia) all subjects responded appropriately (i.e., gave the appropriate word or identified the appropriate object) during all of the object-word and word-object sequences. Claudia responded appropriately across all five of the object-word sequences, but failed to respond appropriately during the last three of the word-object sequences. For these sequences, she gave an inappropriate response (e.g., touching a pencil when the experimenter spoke and signed table). Claudia was immediately engaged in the ten sequences again. This time she responded appropriately across four of the five object-word sequences, and responded in appropriately across all of the five word-object sequences.

During the object-word and word-object sequences, and during experimentation the partially hearing children wore a 'phonic ear' which amplified the experimenter's voice by 40db. This device was connected to a microphone (via a radio transmitter) which hung around the experimenter's neck. The phonic ear had been used extensively, prior to the present study, as a teaching aid with all the partially hearing subjects.

The subjects' names were changed to protect their right to confidentiality. The sets, chronological and verbal ages, intelligence scores, and the fictional names for each subject are presented in Table 1.

Table 1
Subject characteristics.

	Set 1 (Normal Hearing)		Set 2 (Severe to Profoundly Deaf)		Set 3	
Subjects	Andrew	Aiden	Brian	Brendan	Clare	Claudia
Chronological Age (Years, Months)	4,7	3,4	8,1	7,11	4,10	5,10
Verbal Age (in Years)	4-5	3-4	2-2.5	2-2.5	1.5-2	1-1.5
Intelligence Quotient Score	114	120	110	121	100	115

Stimuli and Setting

During the training phase each child was taught a series of four conditional discriminations: If A1, then B1; if A2, then B2; if A1, then C1; and if A2, then C2. The tasks consisted of matching unfamiliar abstract visual stimuli using a matching-to-sample format. On any given trial A1 or A2 were used as sample stimuli and were presented with either B1 and B2, or with C1 and C2 as comparison stimuli. Each subject was trained and tested using a different six-member stimulus set, made by randomly selecting from a pool of twelve items. All the stimulus figures were drawn in thick black outline on A4 sized, laminated, colored cards. Six different colors were used: green, yellow, blue, purple, brown and red. Color assignment was random, except that all six colors had to be used in each stimulus set. Examples of the shapes which appeared on the colored cards are shown in Figure 1.

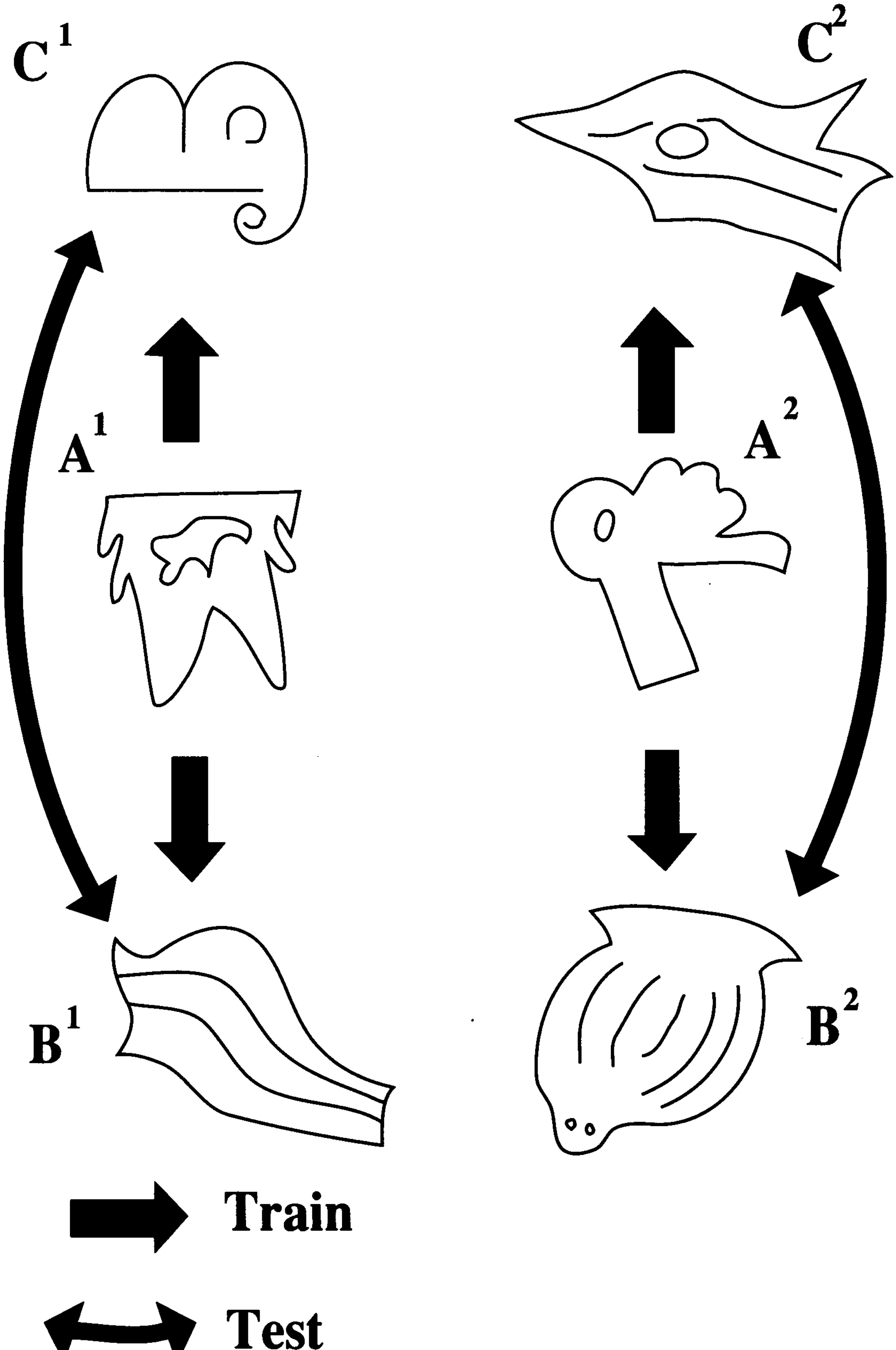

Fig. 1. Examples of the stimulus figures used during the experiment.

All the partially hearing subjects were trained and tested at a small table which was pushed up against a wall in an unused classroom. Experimental sessions for the non-hearing impaired subjects were carried out in the children's parental homes on a table similar in size to that employed with the hearing-impaired subjects.

On each trial three stimuli were presented (one sample and two comparisons). The sample stimulus was placed in the middle of the table with the comparison stimuli positioned along the table's front edge, one on either side of the sample. The left to right order of the comparisons was counterbalanced across trials to prevent subjects responding on the basis of stimulus position alone.

The materials used during the testing were the same as those employed during the training phase, except that the stimuli which had served only as comparisons during the conditional discrimination training served as both samples and comparisons during the testing. Each of the four blocks of ten test trials (forty in all) were devoted to the four types of problems: Sample B1 with Comparisons C1 and C2; Sample B2 with Comparisons C1 and C2; Sample C1 with Comparisons B1 and B2; and Sample C2 with Comparisons B1 and B2.

Procedure

All children were taught individually. The same procedures were employed for all subjects. Before the commencement of each session the experimenter interacted with all the children in the classroom and then spent several minutes specifically with the subject in the presence of the teacher. Some of the younger children took longer than the older children before they were sufficiently relaxed to go into the experimental room. Immediately before the commencement of the first session each child was engaged in the object-word and word-object sequences (these have already been described). During matching-to-sample training and testing the experimenter sat down beside the child on a low chair. The co-researcher sat directly behind the subject so as not to cause any distraction. The main function of the co-researcher was to record the subject's responses as either correct or incorrect. The experimenter started off the experimental procedure by saying; "Do you want to help me play some games? If you do well then you will get some sweets and juice."

The child was initially taught to select B1 in the presence of A1. That is, the subject was shown Sample stimulus A1 placed on the table with the two Comparisons, B1 and B2 on either side of the Sample. The subject was then asked to indicate which of the two Comparison stimuli 'goes' with this one (the Sample). If the subject chose correctly then he/she was reinforced with a small, easily digested sweet (chewing lasting no more than five seconds). Fruit drinks and praise (smiling, patting on the head) were also employed as reinforcers occasionally. Each subject was required to make 10 out of 10 consecutive, unprompted, correct responses (this defined the mastery criterion) before moving on to the next conditional conditioning exercise. Once mastery criterion was achieved on A1-B1 the child moved on to training on A2-B2, that is selecting B2 in the presence of A2. These two tasks were then mixed; the Sample stimuli A1 and A2 were presented in a random order with B1 and B2. Training now began with A1-C1, and once this was mastered A2-C2 was taught. A1-C1 and A2-C2 were then trained in a randomly mixed order. After the subject had mastered this task all four conditional discriminations were randomly presented. This was known as the final mix. Once the final mastery criterion was reached on this task the subject moved on to the test phase.

During the early stages of the conditional discrimination training feedback was used, where the experimenter said "No." and shook his head when the child made an incorrect response. One subject, however, required a single physical prompt at the outset of training on A1-B1 which involved guiding the subject's hand to the correct stimuli.

Initially all correct responses lead to the delivery of one of the consequences. At the end of the training phase, during the final mix, continuous reinforcement was gradually reduced until a programmed consequence was delivered only after every four correct responses (i.e., Fixed-Ratio 4). This was done in order to equate the rate of reinforcement in training to that used in the testing phase.

During testing rewards contingent upon responses consistent with the formation of an equivalence class were not delivered. The four types of trial (these have already been described) were randomly presented. For the first thirteen test trials there were no programmed consequences. On the fourteenth test trial (and every fourth trial thereafter) the child was praised or was given a sweet or drink for cooperation, good attention or good behavior. This noncontingent reinforcement was incorporated into the test procedures in order to prevent extinction of subjects' responding. Any subject who requested direct feedback about a response was told by the experimenter, "I must be very quiet, but you are doing a good job helping me here."

The data were collected over several sessions with each child. Sessions lasted approximately 20 minutes, but no longer than 30 minutes. Equivalence testing was always conducted immediately after the subject reached final mastery criterion.

Some of the partially hearing children, due to the nature of their disability, depended upon the experimenter's facial expression, and particularly his eyes, as a guide to making the correct response. This was a useful teaching aid during the conditional discrimination training. However, during testing this factor had to be eliminated. Consequently, when the experimenter had placed the comparison stimuli on the table he looked away from them, just keeping the stimuli in the periphery of his vision and only looking back when the subject had made a response.

Recording and Reliability

Responses were scored as correct or incorrect. A correct response was defined as touching the correct Comparison stimulus. An incorrect response was defined as touching the incorrect Comparison, touching the sample, or touching an inappropriate part of the table on which the stimuli were placed.

Reliability data were collected in over 80% of the sessions for each subject. The data were collected by final-year undergraduates with experience of recording techniques and by the experimenter who had previous experience of working with children with special educational needs. The co-researcher sat behind the experimenter and the subject where the experimenter's data sheet could not be seen. Neither the experimenter nor the coresearcher had knowledge of each other's scoring during the session. Reliability was calculated on a trial by trial basis using the formula (agreements/agreements + disagreements x 100). An agreement was scored if both the experimenter and the coresearcher recorded a response as correct or as incorrect. Inter-observer agreement per subject ranged between 90 and 100 per cent (see Table 2).

Table 2
Interobserver agreement.

Subject	Percentage Agreement
Andrew	90
Aiden	96
Brian	100
Brendan	92
Clare	98
Claudia	97

RESULTS

The individual data for each pair of subjects in Sets 1, 2 and 3 are presented in Figures 2, 3 and 4 respectively. The data are presented as percentages of correct responses in blocks of ten consecutive trials.

Inspection of the individual data for conditional discrimination training shows there were some variations between the subjects in the number of trials required to

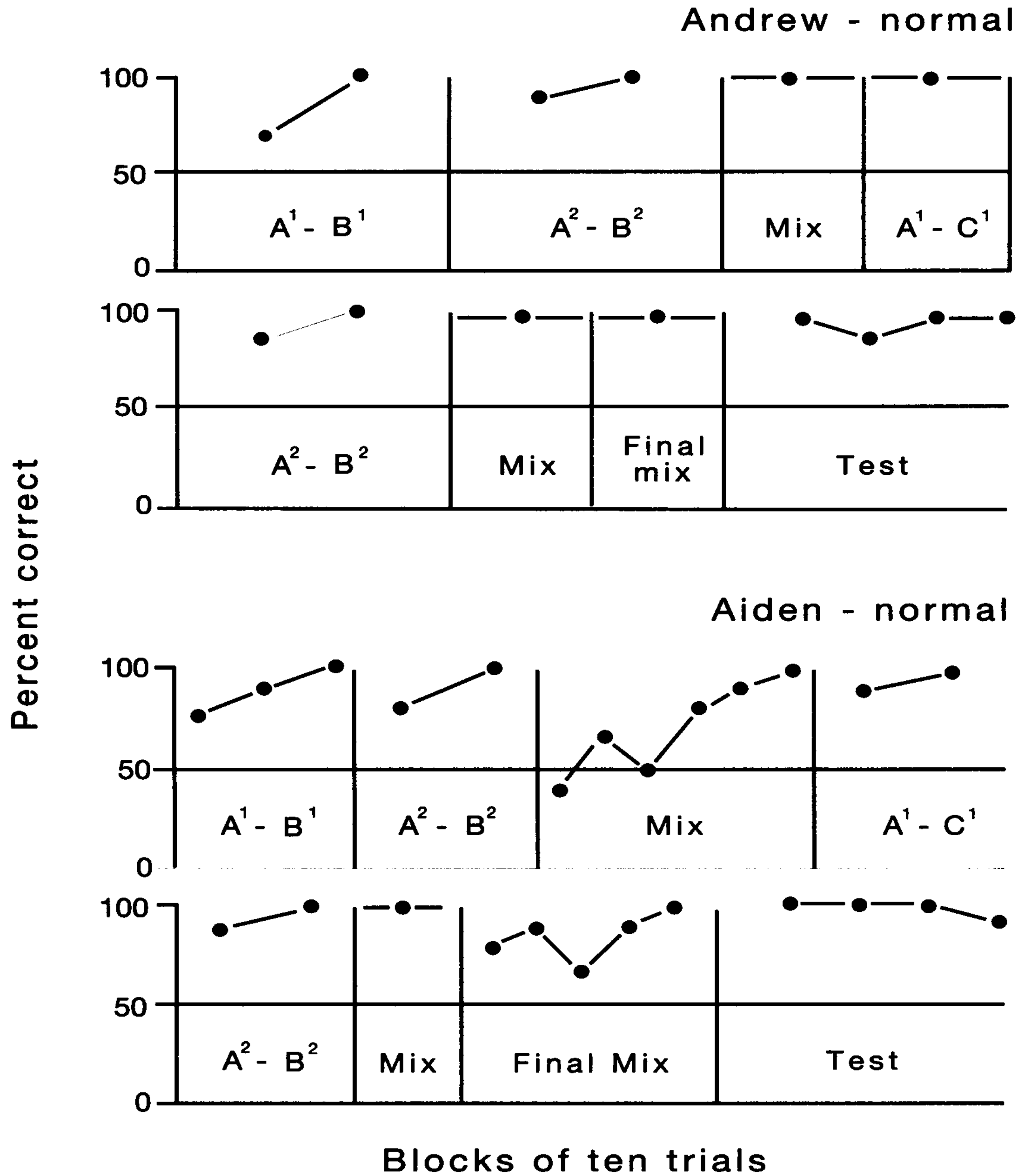

Fig. 2. Individual training and testing data for Andrew and Aiden (normal hearing). The data are graphed as the percentage of correct trials (vertical axis) across blocks of ten trials (horizontal axis).

reach final mastery criterion. In Set 1 (non-hearing impaired) Andrew required 100 trials, and Aidan required 210 trials to obtain final mastery criterion. In Set 2 (partially hearing, verbal age of above 2 years) Brian required 110, and Brendan required 100 trials. In Set 3 (partially hearing, verbal age of below 2 years) Clare required 160 trials and Claudia 160 trials to complete training.

During the test phase of the experiment both children in Set 1 obtained 97.5% correct responses. In Set 2 Brian scored 95% correct and Brendan 97.5% correct responses. The children in both these sets had formed stimulus equivalence classes. In the third set of children Clare scored 97.5% correct responses during testing, thus demonstrating equivalence responding. Claudia, however, scored 0% correct

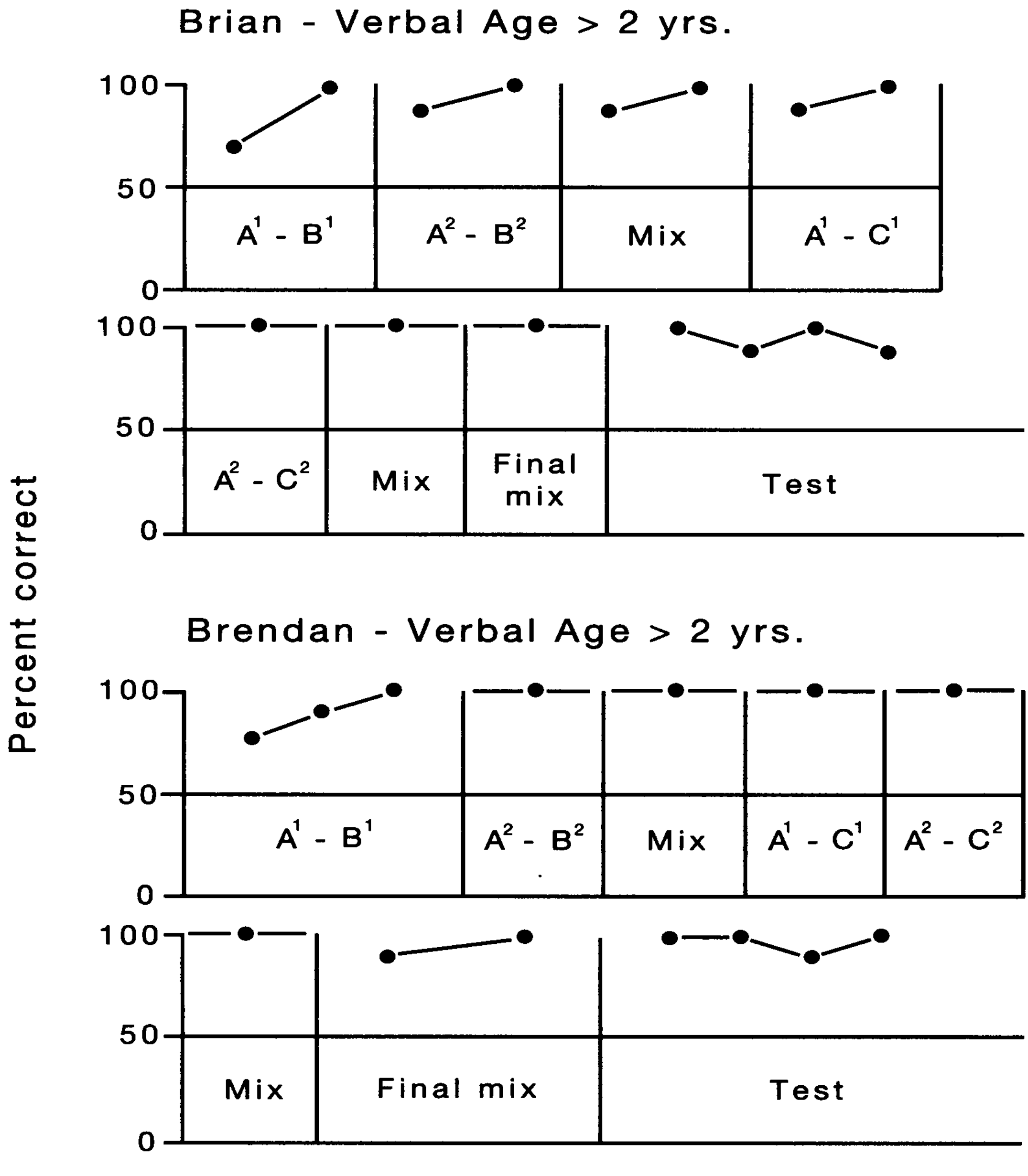

Fig. 3. Individual training and testing data for Brian and Brendan (verbal age above 2 years). The data are graphed as the percentage of correct trials (vertical axis) across blocks of ten trials (horizontal axis).

responses during the test. Due to the unusual nature of this result she was trained with the same stimulus set and tested again. During the second exposure to the training procedures Claudia required 80 trials (20 trials during the final mix) to obtain final mastery criterion; because nothing unusual emerged during this training only test data are presented. On the second test Claudia scored 50% correct responses. This was exactly at chance level, thereby indicating that this subject did not form equivalence classes.

DISCUSSION

During testing the non-hearing impaired subjects (Set 1) formed equivalence classes, as did the partially hearing subjects with a verbal age of above 2 years (Set 2). The par-

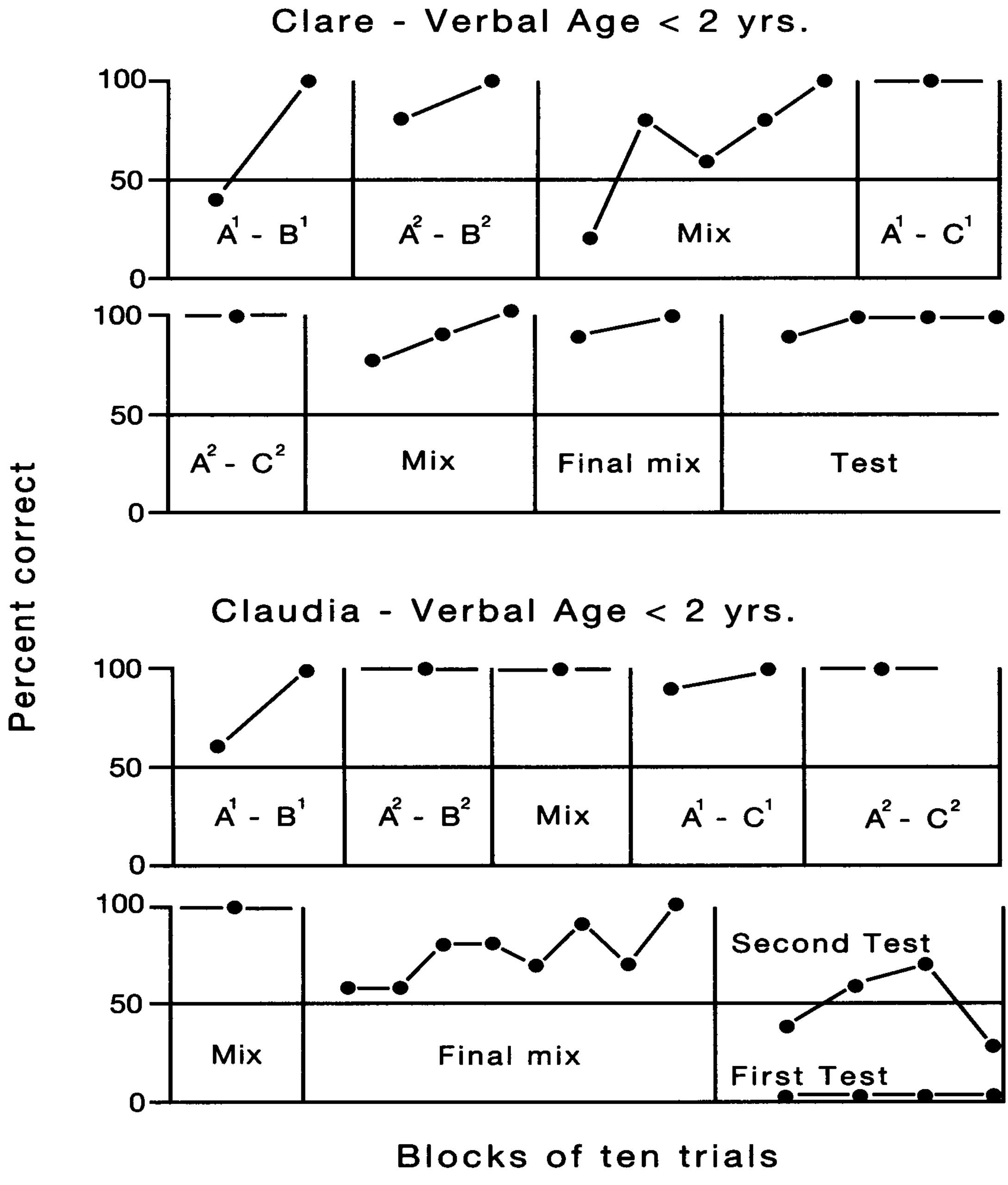

Fig. 4. Individual training and testing data for Clare and Claudia (verbal age below 2 years). The data are graphed as the percentage of correct trials (vertical axis) across blocks of ten trials (horizontal axis).

tially hearing subject from Set 3 who also demonstrated stimulus equivalence possessed a verbal age of between 1.5 and 2.0 years. Claudia, who did not reliably demonstrate equivalence class formation, was rated with the lowest verbal age (i.e., 1.0 to 1.5 years) of all six subjects. In addition, Claudia was the only subject who did not engage in tact /word-object sequences with the experimenter, thereby indicating that perhaps the behavioral relations observed in such verbal sequences are linked to equivalence responding (this is an important result and will be discussed later). These findings are correlational, and the critical data are restricted to one subject. With continued training and testing Claudia might have demonstrated equivalence responding (cf. Fields, 1990). Nevertheless, the present results are consistent with the view that equivalence and certain aspects of verbal behavior are in some way interrelated. This conclusion is bolstered by the fact that all subjects were non-retarded and thus any differences cannot be attributed to mental handicap.

Devany et al., (1986) reported that those subjects who failed to show stimulus equivalence required significantly more training trials than did those subjects who formed equivalence classes. They suggested that this discrepancy in training performance between subjects might have arisen from unspecified differences caused by their mental retardation. If such an effect does exist then one would expect that a non-retarded subject, who failed to show stimulus equivalence, would not require a greater number of training trials than those subjects who eventually formed equivalence classes. This was indeed a finding of the present study. For example, Claudia who did not reliably form equivalence classes required less trials to meet the mastery criterion in the training phase of the experiment than did Aiden who readily demonstrated stimulus equivalence.

It is interesting that Claudia on initial testing scored 0% correct responses. If this subject was performing at purely chance level we would have expected at least some of her responses to be correct. During her first exposure to the test phase, however, Claudia consistently selected the comparison stimulus that was not related, through symmetry and transitivity, to the sample. This initial test result indicates that the controlling relations involved the samples and negative stimuli (i.e., S-minus control, rather than S-plus control) and thus Claudia's first test performance might represent a type of equivalence relation (Barnes & Keenan, 1989; Sidman, personal communication).

Alternatively, perhaps the absence of an explicit history of reinforcement during the equivalence test allowed Claudia's responding to be consistently controlled by some unspecified non-equivalence relation, such as stimulus artifacts (e.g., always choosing the more attractive stimulus). Indeed, Claudia's failure to demonstrate either positive or negative equivalence during her second exposure to the test phase would seem to indicate that she had not been responding equivalently during the first test. In any event, Claudia's two very different performances across the equivalence tests are interesting, and such effects warrant further investigation.

Clare from Set 3 in the present study showed that her performance on an equivalence test was excellent. However, Claudia whose verbal age was rated at only approximately six months less than Clare failed to show the consistent formation of equivalence classes. A more thorough analysis of the verbal behavior demonstrated by these two subjects may shed some light on the source of this discrepancy in responding, and it is to this issue we now turn.

The tact /object-word and tact /word-object sequences showed that Clare could participate successfully in both types of sequence, but Claudia could only participate successfully in the former. Consultation with the children's speech therapist and their teacher, and casual observation of these subjects, indicated no other major differences in verbal skills. This is an interesting finding because it is consistent with the view that equivalence responding on the matching-to-sample task, and object-word and word-object sequences can both reflect the common, underlying behavioral property of responding in accordance with the relational frame of "sameness" or "coordination" (cf. Hayes & Hayes, 1989). This interpretation will be examined more closely here, because it directs attention towards the verbal contingencies that may give rise to stimulus equivalence (the reader is referred to Hayes, 1990, for a detailed discussion of the relational frame interpretation of stimulus equivalence).

In brief, the relational frame account of the present data is this. For the young child both object-word and word-object sequences are explicitly reinforced across a vast number of verbal interactions. An object-word sequence, for example, would be reinforced in the following type of verbal exchange; Father holding toy bear: "Who is this?" / Child: "Teddy" / Father: "Good girl!", and gives toy to child. An example of a reinforced word-object sequence would be as follows; Father holding toy bear "Where is teddy?" / Child: "There," and reaches out to grasp toy bear / Father: "Good girl!", and gives toy to child. As a result of innumerable verbal interactions such as these, where many object-word and word-object relations are learned, derived performances may be possible. For example, suppose the child is now explicitly reinforced for emitting the appropriate novel word when asked "what is this?" in the presence of a novel object (i.e., object-word sequence). Contextual cues, such as the relational autoclitic "is," reliably predict that if the word is the object, the object is also the word. Thus, the child may select this object in the presence of the word (i.e., word-object sequence) without explicit reinforcement. This derived relation between word and object is an example of arbitrarily applicable relational responding in accordance with the relational frame of sameness or coordination (Hayes & Hayes, 1989).

The relational frame theory suggests that a subject who successfully engages in object-word and word-object sequences indicates a history of reinforcement appropriate for the development of coordination. Thus, when such a subject is exposed to the matching-to-sample procedure aspects of this context[1] may bring the relational frame of sameness or coordination to bear on the stimuli involved, and responding in accordance with this relational frame will be seen (e.g., symmetry and equivalence). The relational frame account therefore predicts the present findings; subjects who successfully participate in both object-word and word-object sequences are more likely to show coordination on the matching-to-sample task than a subject who fails to participate in both of these verbal sequences.

Stimulus equivalence has created considerable excitement within the behavior analytic community in recent years. This has been due, in part, to the suggested functional similarity between equivalence phenomena and certain aspects of verbal behavior. Although the present findings are tentative in this respect they are instructive, because they suggest that future studies using either normally developing children or verbally-disabled members of the population (e.g., aphasics) might help to further clarify the extent to which specific verbal skills are reflected in the equivalence procedure. Indeed, such studies may lead to the development of powerful training techniques for the remediation of verbal and generalization deficits in verbally-disabled populations (see, Sidman, 1971, 1977).

[1]One of the contextual cues that are often present when a child learns to respond in accordance with the relational frame of coordination is the matching-to-sample format itself. Consider, for example, the number of pre-school education exercises that involve asking a child which picture "is the same as" or "goes with" another picture. Thus, the matching-to-sample format alone may be able to invoke relational responding in accordance with coordination (cf. Hayes & Hayes, p. 176, 1989; Steele, 1987).

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