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NAMING AND CATEGORIZATION IN YOUNG CHILDREN: V. MANUAL SIGN TRAINING

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Following pre-training with everyday objects, 8 children aged from 2 to 4 years learned to produce one manual sign (fists placed one above the other, in front of body) to one stimulus and an alternative manual sign (shoulders touched with ipsilateral hands) to the other stimulus, with each of three pairs of different arbitrary wooden shapes (Set 1). The six stimuli then were presented in category match-to-sample tests, which all subjects passed. Three of the children were next trained to produce the manual signs (denoted as fist/shoulder) for an additional six arbitrary stimuli, Set 2. All 3 children went on to pass category match-to-sample tests for Set 2, and for Set 1 and Set 2 combined. In the final experimental phase, 2 of the children were trained, for one of the six stimulus pairs, to produce the vocal tact ''zag'' to one stimulus and ''vek'' to the other. Both children showed category transfer of these vocalizations in test trials with each of the remaining five stimulus pairs, and all the stimuli combined in a 12-stimulus array. In line with Horne and Lowe's (1996) naming account, manual sign naming was found to be as effective as vocal naming in establishing arbitrary stimulus categorization, measured in terms of category sorting and transfer of function. The findings also have implications for the training of verbal repertoires in people with learning disabilities.

Key words: manual signing, vocal naming, tacting, transfer of function, categorization, verbal behavior, category match to sample, children

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The present article, the fifth in the series on naming, investigates whether manual sign naming has the same effects as vocal naming on bringing about categorization and the emergent phenomena that have given rise to the theories of stimulus equivalence (Sidman, 1994, 2000) and relational framing (Hayes & Hayes, 1989, 1992). According to the naming account (Horne & Lowe, 1996, 1997, 2000; Lowe & Horne, 1996), naming is a bi-directional speaker–listener relation that plays a pivotal role in establishing categorization, particularly of arbitrary stimuli, in humans. There are two key measures of the categorization effects of common naming: first, emergent name-based patterns of category sorting; and second, untrained transfer, to all members of the common name relation, of novel behaviors that are trained to only one exemplar. According to Horne and Lowe (1996), both kinds of category relations—category sorting and transfer of function—may be established simply by training the same name to several different stimuli. The prediction that training common names among arbitrary stimuli would establish name-based category sorting was confirmed in a study by Lowe, Horne, Harris, and Randle (2002) in which twelve 2- to 4-year-old children learned two 3-member common name relations among arbitrary stimuli and sorted the stimuli into common name classes without their being directly trained to do so. When 2 of the children were trained on two 6-member common name relations, they sorted the 12 stimuli into two 6-member name-based categories.

The naming account predicts that the category sorting found in the Lowe et al. (2002) study should not occur if the children only learn common listener responses to the arbitrary stimuli (Horne & Lowe, 1996; Lowe & Horne, 1996), a prediction confirmed with 1- to 4-year-old children in a study conducted by Horne, Lowe, and Randle (2004). Of the 7 children who, during listener training, learned only two 3-member listener relations, and not the corresponding common names, none sorted the stimuli into categories based on the common listener stimuli. However, when these children were subsequently trained to produce the corresponding names, 5 went on to sort the stimuli into common name categories, as had occurred in the Lowe et al.

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study in which naming was trained at the outset. Taken together, the category sorting studies of Lowe et al. and Horne et al. support the hypothesis that common naming, as opposed to common listener behavior, establishes categorization.

The prediction that naming also confers untrained transfer of novel functions (Horne & Lowe, 1996) was next investigated by Lowe, Horne, and Hughes (2005). The 1-to 4-year-old children were trained to tact three arbitrary stimuli as ''zog'' and another three as ''vek'' and next were trained, for example, to clap to one zog and to wave to one vek. All 9 children showed untrained transfer of the clap response to other stimuli of the same name and, likewise, name-based transfer of the wave response to the remaining stimuli. Emergent, name-based, transfer of the clap and wave responses also occurred for the 3 children who learned two 9-member common name relations; these children also showed emergent category sorting of the 18 arbitrary stimuli.

However, just as for category sorting, the naming account predicts that these untrained transfer effects should not occur if only common listener relations are established. This prediction was tested in the fourth study in the series (Horne, Hughes, & Lowe, 2006) conducted with 1- to 4-year-old children. Four children learned only two 3-member common listener relations, and not the corresponding common names, during the listener training procedure. When these children next learned, for example, to clap to one zog and wave to one vek, they subsequently failed the transfer tests for these novel behaviors. However, when 3 of these children were next trained to name the stimuli, they passed the transfer tests. As was the case for the category sorting measure, these differences in transfer outcomes depending on whether common speaker or common listener relations are learned, are not predicted by the stimulus equivalence or relational framing accounts (Horne et al., 2006; Horne et al., 2004; Lowe et al., 2002; Lowe et al., 2005).

The question arises, therefore, whether the same emergent effects of naming would occur if the children were trained with common manual tacts instead of vocal tacts, for the same arbitrary stimuli. According to Skinner (1957), verbal behavior may be learned as readily in the manual as in the vocal modality and Horne and Lowe (1996) have proposed that there is no reason why the name relation should function less effectively to establish categorization when names are manual signs rather than vocal responses. That is, when children produce a manual tact they should be able to respond as ''listeners'' to the visual and kinesthetic products of that response, in much the same way as they respond as listeners to the auditory stimuli they produce during vocal naming. In support of this claim, it has been shown that deaf children who learn signing, and hearing children who learn spoken languages from birth, both reach all the conventional linguistic milestones at the same rate (e.g., Brackenbury, Ryan, & Messenheimer, 2006; Genesee, 1987; Pettito, 1987, 1988, 1993; Pettito & Marentette, 1991). Pettito (1993) concludes that humans can acquire language in either spoken or manual-sign modalities but if the child is exposed only to one language environment (e.g., spoken) this becomes the main modality while the other unused modality subsequently serves a secondary signaling or augmentative function (and see Acredolo & Goodwin, 1990). The present study tested whether training manual naming is as effective as training spoken naming in establishing untrained categorization in normally developing children. Children aged from 2 to 4 years were trained on two 3-member manual tact relations among a set of arbitrary stimuli and then were required to sort the stimuli in category match-to-sample tests.

EXPERIMENT 1A

Method

Subjects

Subjects were 4 female (GC, LI, SN, and RE) and 5 male (RP, HI, KM, OS, and PW) children who attended the Daycare Nursery and Centre for Child Development at the University of Wales Bangor. As shown in Table 1, the children were between 2 years 7 months and 3 years 7 months at the start of the study; none had any previous experimental history of conditional discrimination training, and all had normal scores on the Griffiths Mental Development Scales (Griffiths, 1954).

Table 1

Participants' gender, age at start of procedure, number of sessions conducted with everyday objects and arbitrary stimuli, age at first category test, and score on the Griffiths Mental Development Scale (GMDS). For HI and PW, who withdrew from the study for several months during their initial Set 1 training, Superscript² indicates trials when they resumed training and test sessions.

			Sessions			
Subject	Gender	Age at start (years/months)	Everyday objects	Arbitrary stimuli	Age at testing (years/months)	GMDS General quotient
RP	M	2/7	13	14	2/10	122
GC	F	2/8	3	20	2/11	137
HI	M	2/9	6	9		123
HI²				9	3/9	
LI	F	2/10	2	26	3/1	128
KM	M	2/10	4	8	3/0	133
OS	M	3/0	4	15		121
SN	F	3/2	4	7	3/3	128
RE	F	3/7	1	4	3/8	128
PW	M	3/7	7	6		137
PW²				4	4/2	

Apparatus and Stimuli

The experimental setting and apparatus, including a wooden screen, the six everyday objects, and 12 arbitrary stimuli (green wooden shapes), were as described in Lowe et al. (2002). The main scheduled reinforcer was social praise, supplemented occasionally with stickers. End-of-session and end-of-study rewards also were provided, as in Lowe et al.

Procedure

Everyday objects. The familiarization and training procedures were as in Lowe et al. (2002), except that when the six everyday toy objects (three hats and three cups) were presented, the child was told that, ''Teddy would like to know how these [indicated hats and cups] go.'' The experimenter then pointed once to each stimulus in turn as she said, ''This goes like this''; for a hat stimulus the experimenter raised her hands to her head in the motion of putting on a hat, and for a cup, she curled the fingers of her right hand as if holding a cup and raised that hand to her mouth. For each child, the experimenter randomly separated the three hats and three cups into three different training pairs, each consisting of one hat and one cup, which remained constant for the duration of the study. The children's stimulus-related, manual and vocal behaviors during sessions were recorded; sessions varied from 15 to 30 min.

Manual tact training in pairwise trials. Tact training was conducted as in Lowe et al. (2002) except that for each pair of stimuli the experimenter pointed to one stimulus and said, ''How does this go? Can you show Teddy how this goes?'' If the child produced the correct manual tact (or an accepted approximation), the experimenter responded, ''Yes, clever girl/boy! It does go like this,'' and again modeled the appropriate response. If the child produced an inaccurate tact or no response, the experimenter once again pointed to the stimulus and said, ''This goes like this,'' then modeled the correct tact, and asked the child, ''Can you do it?'' On any one trial, only one stimulus was targeted. The learning criterion was three out of four correct unprompted tact responses to each stimulus over eight consecutive trials.

Manual listener training in pairwise trials. These were similar to the manual tact trials except that when a pair of stimuli was placed in front of the child, the experimenter asked, ''Which is the one that goes like this?'' and then modeled either the hat gesture or the cup gesture—the manual behaviors previously trained as tacts. If the child pointed to the correct stimulus, the experimenter responded, ''Clever boy/girl!'' If the child pointed to the incorrect stimulus, the experimenter gave corrective feedback. The criterion for the three training pairs was the same as for manual tact training.

Manual tact training in six-stimulus trials. Manual tacting of the everyday toy objects in a six-stimulus array was established in the same manner as for vocal tacting with the six stimuli in Lowe et al. (2002), except for the different instructions required for manual tact responses (see above: *Manual tact training in pairwise trials*). To ensure that the child's responses were not cued by the experimenter, a wooden screen (see Lowe et al. for details) was placed on the table between the experimenter and the child. On each trial, the experimenter reached through the lower section of the screen and placed the stimuli on the table on the child's side of the screen. The experimenter then pointed to each stimulus in turn, asking in each case, ''How does this go?'' Trials continued until the child produced three consecutive correct responses, without feedback, for each stimulus.

Category match-to-sample training. The screen was used throughout the category match-to-sample training phase designed to establish the child's responding to each of three different sorting instructions. On each trial, the experimenter presented the six everyday objects then (using the *tact-sample match-to-sample-tact* instruction) asked, ''How does this [pointing to one object as sample] go? Can you give Teddy the other ones that go like this [modeling the hat or cup gesture]?'' If the child selected the two other stimuli from the same category as the sample stimulus, this constituted a correct category sort and the experimenter delivered verbal praise. If the child selected incorrectly, the experimenter gave corrective feedback. Trials were repeated until the child performed three consecutive, unprompted, correct sorts per category (see Lowe et al., 2002, for further details).

The *tact-sample match-to-others* instruction was then introduced. Trials were conducted in the same way and to the same criterion as for the previous instruction except that in each trial the experimenter said, ''How does this [pointing to sample] go? Can you give Teddy the others?''

In the case of the third instruction, *look-at-sample match-to-others*, the experimenter said, ''Look at this [pointing to sample]. Can you give Teddy the others?'' Trials were otherwise conducted in the same way, and to the same criterion, as for the preceding two instructions.

Arbitrary stimuli: Manual tact training in pairwise trials. For each child, six arbitrary stimuli were selected and partitioned into three training pairs (see Lowe et al., 2002, for examples). For one member of each pair, the child was trained to hold both fists about 20 cm in front of his or her body, with the right fist on top of the left (the target fist response), and for the other pair member, to place the fingertips of each hand onto the ipsilateral shoulder with elbows extended sideways (the target shoulder gesture). The pairwise manual tact training was the same as for the everyday objects except that the prospective manual tacts that were modeled by the experimenter on each trial were the shoulder and fist gestures. When the pairwise manual tact criterion was met for Pair 1 and Pair 2, the child proceeded to manual tact testing with the four stimuli from Pair 1 and Pair 2.

Manual tact testing in four-stimulus trials. These trials were conducted without reinforcement or feedback, with the screen in place, as in Lowe et al. (2002).

Pair 3 manual tact training trials. Training with Pair 3 was conducted in the same manner as for Pair 1 and Pair 2.

Manual tact training in six-stimulus trials. When the child met the Pair 3 criterion the screen was reintroduced and all six arbitrary stimuli were presented in the same manner as for everyday objects six-stimulus tact training. Once the learning criterion of three consecutive correct responses to each of the six stimuli was met under continuous reinforcement, the probability of reinforcement was reduced in a stepwise manner to 50%, then 33%, and last to zero, until performance was maintained at criterion under zero reinforcement.

Category match-to-sample tests. These tests were carried out in four steps (see Lowe et al., 2002, for full details of the procedures), in the absence of reinforcement and differential feedback, with the screen in place. Step 1 consisted of an *arbitrary six-stimulus manual tact review* without feedback. The first experimenter conducted one six-stimulus manual tact test. If the child performed correctly on all review trials, a second (''blind'') experimenter conducted Steps 2–4 of the test procedure. In Step 2, the everyday objects category match-to-sample review, the experimenter conducted four category sorting trials, two for hats and two for cups, using the look-at-sample match-

Table 2

For each child, the number of trials to meet the manual tact training criterion in each training phase with the arbitrary stimuli. For HI and PW, who withdrew from the study for several months during their initial Set 1 training, Superscript[2] indicates trials when they resumed training and test sessions with the same stimuli. W indicates the child's withdrawal from the experiment after the indicated number of trials, shown in parentheses.

Subject	Pairwise		4 Stimulus	Pairwise Review		Pair-wise	6 Stimulus	Pairwise and 4 Stimulus Review Trials			
	Pair 1	Pair 2		Pair 1	Pair 2	Pair 3		Pair 1	Pair 2	4 Stimulus	Pair 3
RP	6	6	4			6	10	27	27	12	20
CG	28	18	10	22	32	6	21	16	22	4	20
HI	6	10	9		16	6	16	6	6	3	6
HI[2]	6	10	3			6	12				
LI	28	24	24	108	148	16	14	6	6	3	6
KM	6	6	4	6	7	8	15	8	6	3	6
OS	12	6	22	56	76	6	W(21)	83	85	12	12
SN	6	17	15	28	52	16	15	8	6	5	6
RE	6	6	3			6	14	6	6	3	6
PW	34	15	12	28	52						
PW[2]	6	6	3			6	12				
M	13.09	11.27	10.8			8.2	14.33				

to-others instruction. The criterion for progression to Step 3 was correct responding in all four sorting trials. If performance failed to meet criterion, it was retrained. In Step 3, the arbitrary stimuli category match-to-sample Test 1, the experimenter presented the six arbitrary stimuli and, using the look-at-sample match-to-others instruction employed in Step 2 (i.e., ''Look at this. Can you give Teddy the others?''), conducted six category match-to-sample trials; each stimulus served once as the sample. The criterion was at least three correct category sorts, including one for each common manual tact category. The probability of three or more correct sorts in six trials is .016. Children whose performance met the six-trial criterion were given a further 12 trials over which each stimulus served twice as sample, making 18 category sorting trials in all; the remaining children proceeded to Step 4. The criterion for success on category Test 1 was set at four of nine correct sorts per common manual tact category (the probability of obtaining four or more correct sorts by chance is .008). In Step 4 (category match-to-sample Test 2), Step 1 (tact review) and Step 2 (category match-to-sample review with everyday objects using the Test 2 sorting instruction) were first conducted; Step 4 was the same as for Step 3 above, except that on each trial the experimenter pointed to the sample and asked the child, ''How does this go? Can you give Teddy the others?'' (i.e., tact-sample instruction).

Procedural exceptions. One child (HI) was not willing to participate in some of the test conditions in the presence of the second experimenter; when this happened, the first experimenter conducted the trials, with the screen in place. This subject withdrew from the experiment during the category sorting tests with the arbitrary stimuli. However, after an interval of 6 months, this child participated in pairwise, four-stimulus, and six-stimulus tact review trials, using the same set of stimuli and then went on to complete the category match-to-sample tests (see Table 2). Subject PW withdrew from the study during four-stimulus trials but, after an interval of 4 months, this child participated in pairwise, four-stimulus, and six-stimulus review trials, using the initial set of arbitrary stimuli and proceeded to category testing (see Table 2).

Interobserver reliability. An independent observer scored 61% of the trials, selected on a random basis, and reported no discrepancies between the scheduled and implemented procedures; interobserver agreement was 98.5%.

Results and Discussion

Everyday Objects

Manual tact and listener behavior training. All but 2 of the 9 children's performances met the criterion within the first four trials per stimulus. The exceptions were Subject OS, who required two more trials each for two of the stimuli, and Subject SN, who required a further six trials for one stimulus. Likewise, all but 3 children produced the corresponding listener behavior to the manual tacts at criterion on the first four trials. The three exceptions were Subjects GC, SN, and PW, who required one or two additional trials for one or two of the stimuli.

Category match-to-sample training. Seven children met the criterion in the first three-trial block for each category (hats and cups) with the tact-sample match-to-sample-tact instruction. Of the remaining 2 children, Subject GC required a further block of three trials, and Subject RP, 13 more three-trial blocks, before their performances met the criterion. Five children (GC, LI, KM, OS, and RE) met the sorting criterion in the minimum of three trials per category when next given the sorting test with the tact-sample match-to-others instruction, whereas the remaining 4 (RP, HI, SN, and PW) required between 1 and 10 further trials, on either the hat or cup category. When the sorting test was repeated with the look-at-sample match-to-others instruction, 5 children (GC, LI, KM, OS, and RE) met the sorting criterion in the minimum number of trials and the remaining 4 children (RP, HI, SN, and PW) required between one and three additional trials for either the hat or cup category.

Arbitrary Stimuli

The number of trials required for each child's tact performance to reach criterion in pairwise, four-stimulus, and six-stimulus tact training is shown in Table 2.

Manual tact training in six-stimulus trials. Except for OS, who withdrew from the study before he completed this training phase, the performances of all children met the criterion. Only 2 (HI^2 and PW^2) of the 9 children showed no deterioration in performance when all six stimuli were combined for the first time in the six-stimulus tact test (see Table 2). During tact testing with four or six stimuli, although most children moved their hands and arms to a resting position in their laps at the end of each trial, Subject HI held them in a particular configuration (fist or shoulder) across trials until he saw which stimulus was the new target. For example, if the appropriate response to the first stimulus targeted on Trial 1 was the fist gesture, he produced that

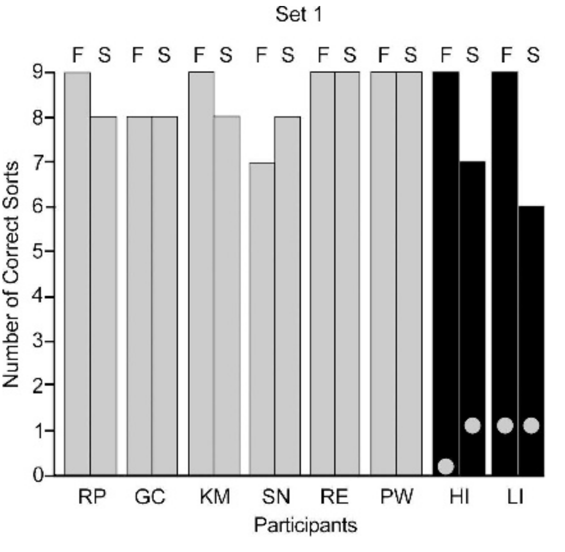

Fig. 1. For each subject, number of correct category sorts to each Fist (F) and Shoulder (S) sample. Sorting under the look-at-sample instruction is shown by gray bars for subjects who completed all 18 test trials and by gray filled circles for subjects who failed to meet criterion in the first six trials. The performances of these latter subjects on the 18 trials under the tact-sample instruction are shown by the black bars.

response and held it in position over the target stimulus. If the next stimulus targeted also was one that required a fist response he moved his fists away from the previous target and placed them above the new one; otherwise he produced a shoulder response. Likewise, if he had produced a shoulder tact response to the first stimulus targeted, he held it until he saw the target stimulus in the next trial; if it also required a shoulder response he simply leaned his shoulders over the new target and said, ''Did it!''

Category match-to-sample tests. Figure 1 (gray bars) shows that under the look-at-sample match-to-others instruction, 6 of the children (RP, GC, KM, SN, RE, and PW) met the sorting criterion in the first six trials and so were given a further 12 trials in order to complete the full 18-trial category sorting test, which they all passed. The performances of 2 children (HI and LI) failed to meet the six-trial sorting criterion (gray circles); they proceeded to the tact sample version of the categorization test, which they both passed (black bars).

Verbal behavior. Table 3 shows the unprompted manual tact responses and vocalizations produced by 5 of the children during the

Table 3

Children's spontaneous manual tacting and vocalizations during the category match-to-sample (cat. mts) tests and the posttest interview.

Experiment and Test	Subject	Experimenter's verbal behavior	Child's manual testing + vocalizations
Experiment 1A Cat. mts (Set 1)	RP	''Look at this (pointing to sample). Can you give Teddy The others?''	On four trials, child produced manual tact and selected correct comparisons saying, ''Here's one and here's one.'' On Trial 9 (correct sorting), child said, ''You want this one, and this one.''
	HI		On one trial, child selected comparisons (incorrect) then said, ''He doesn't want the lot.''
	KM		On one trial, following comparison selection (correct), ''Just two'', and on two other such trials, ''Just the ones that go''.
	SN		On one trial, child produced manual tact when the Experimenter pointed to sample and, after comparison selection (correct), pointed to one comparison and produced manual tact (correct).
	PW		On all trials, child selected two correct comparisons then said, ''That's all'' or ''That's it''.
Experiment IB Cat. mts (Set 1 + Set 2)	GC		On one trial, child selected correct comparisons, then said, ''That was all of them''. On three trials, after sorting correctly, child said, ''Um, no more''. On one trial, selected four comparisons, visually scanned remaining stimuli saying, ''One more – one more left'' then selected fifth comparison to produce a correct category sort.
	PW		On all 12 trials, child selected correct comparisons, put his arm around the incorrect comparisons and said, ''The gate is closed'' and then, on 10 of the trials, ''That's all''.
Experiment 1B Posttest Interview (Set 1 + Set 2)	PW	''Why did you give Teddy these (indicating child's comparison selections)?''	''Because he wants those ones''.
		''Why does Teddy want these ones?''	''Because of that (pointing to the sample stimulus)''.
		''Why does this one (sample) mean that Teddy wants these (comparisons)?''	''Because that (pointing to sample) goes like that (producing manual tact)''.
		''So why did you give Teddy these (selected comparisons)?''	''That one (pointing to first selection) goes like that (produces manual tact) and that one (pointing to second selection) goes like that (producing manual tact again).

category sorting tasks. Of these, though not required to do so, 2 (RP and SN) produced the manual tact when asked, ''Look at this. Can you give Teddy the others?'' before they selected the (correct) comparisons. The other 3 children vocalized as they sorted saying, for example, ''Just two'' or ''Just the ones that go''.

In the present study, all 8 subjects who learned the common manual tacts went on to sort the stimuli into two 3-member classes in the category match-to-sample tests (either in Test 1 or in Test 2). We next investigated whether a subset of the subjects in the present study would learn common manual tact relations for an additional set of arbitrary stimuli, and then proceed to sort the stimuli into two six-member classes.

EXPERIMENT 1B

METHOD

Subjects

After they completed the Set 1 procedures, 3 of the children, 2 female (GC and LI) and 1 male (PW), participated in manual tact training and category testing with a second set of stimuli. These children were aged 2 years 9 months, 3 years 2 months, and 4 years 2 months, respectively, at the start of Set 2 training.

Apparatus and Stimuli

Each child was assigned a new set (Set 2) of six arbitrary stimuli from a pool of 12 (see Lowe et al., 2002, Figure 1). For the purpose of reporting, and scheduling stimulus presentations, members of the first training pair were designated Fist 4 and Shoulder 4, the second training pair as Fist 5 and Shoulder 5, and the third pair as Fist 6 and Shoulder 6.

Procedure

The tact-training procedure was the same as for the Set 2 stimuli, and Set 1 and Set 2 stimuli combined, in Lowe et al. (2002, Experiment 1B), except that the instructions were adapted to the manual modality, as for the Set 1 stimuli in the present study. Following manual tact training with the Set 2 stimuli, categorization tests were conducted with Set 2. Next, after a tact review for the 12 stimuli in Set 1 and Set 2, categorization tests were first conducted on six stimuli selected at random (with the constraint that there were three stimuli from each set); and second with all 12 stimuli, from Set 1 and Set 2. The criterion for success in the 12-stimulus test was set at one correct sort per category (i.e., to a Fist and a Shoulder sample stimulus, respectively). The probability of a correct sort (i.e., of all five correct comparisons being selected) to either a Fist or a Shoulder sample by chance is .002. The second experimenter conducted all the test trials, with the screen in place.

Posttest interview. The first experimenter conducted two additional 12-stimulus categorization test trials (one with a fist sample and one with a shoulder sample) without the screen in place. After each sorting trial, the experimenter asked the child a number of open-ended questions such as, ''How did you do that?'' or ''Why did you give Teddy these?'' or ''What should Teddy look for now?'' The child's verbal responses were recorded.

Interobserver reliability. An independent observer scored 25.7% of the training trials, selected at random, and 100% of test trials. Inter-observer agreement was 98.6%.

Results and Discussion

Arbitrary stimuli Set 2: Manual tact training in pairwise trials. For the Pair 4 stimuli, Subject LI met the criterion in the minimum six trials;

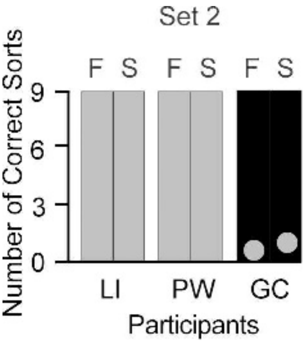

Fig. 2. For 3 subjects, category sorting performances with a second set of arbitrary stimuli. (See Figure 1 for details.)

Subjects GC and PW each required two more. Subjects LI and PW met the criterion for the Pair 5 stimuli in the minimum of six trials; Subject GC required nine more.

Manual tacting in four-stimulus test trials. Subject PW met the criterion within four trials, but Subjects GC and LI required retraining with Pair 4 and Pair 5. The number of four-stimulus test trials to criterion ranged from 4 to 11 over the 3 subjects.

Pair 6 manual tact training trials. Two subjects (LI and PW) met the criterion in the minimum of six trials whereas the third (GC) required one more trial.

Manual tacting in six-stimulus trials. Subject PW met the criterion of three consecutive correct tact responses to each of the six stimuli, at different levels (100%, 50%, 33%, and 0%) of reinforcement, in the minimum of 12 blocks of six-stimulus trials. Subjects GC and LI required pairwise retraining and four-stimulus review trials before they met the six-stimulus criterion in 33 and 22 blocks of six-stimulus trials, respectively.

Category match-to-sample tests: Set 2. Figure 2 shows that 2 children (LI and PW) sorted the six stimuli correctly to the look-at-sample (category Test 1) instruction on all nine trials for each category (fist and shoulder). Subject GC failed Test 1, but when presented with category Test 2 in which the tact-sample match-to-others instruction was employed, she sorted the six stimuli correctly on all nine trials for each common tact category.

Arbitrary stimuli Set 1 and Set 2: Pairwise manual tact review trials. Subjects LI and PW met the criterion in the minimum number of

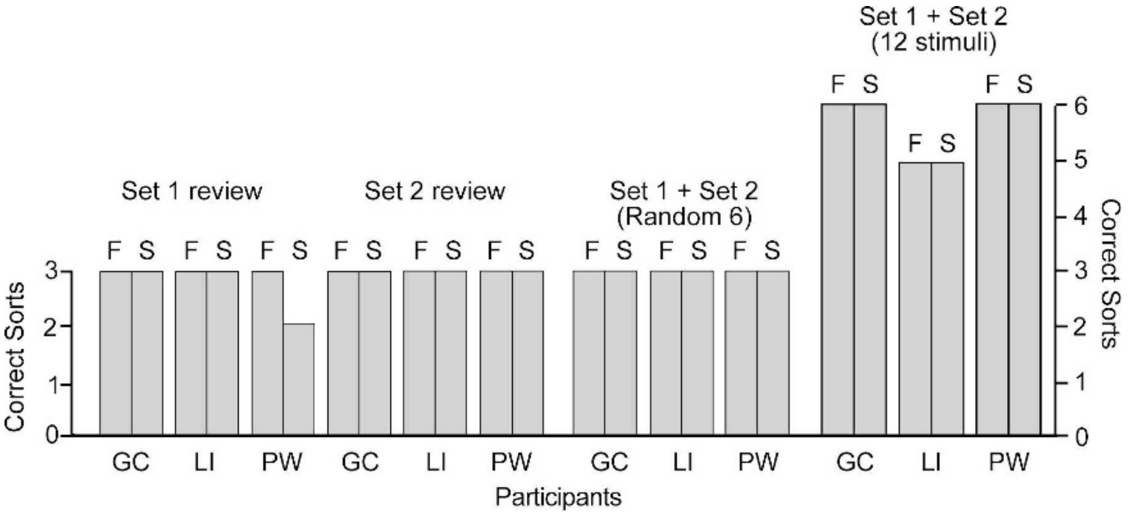

Fig. 3. For each of the 3 subjects, GC, LI, and PW, number of correct category sorts under the look-at-sample instruction on the Set 1 and Set 2 category match-to-sample review trials; on a random selection of six from the Set 1 and Set 2 stimuli (Random 6); and on the full 12-stimulus test combining all Set 1 and Set 2 stimuli.

review trials; Subject GC required one additional review trial.

Six-stimulus manual tact review trials. Subjects LI and PW met the criterion in the minimum number of trials for both Set 1 and Set 2. Subject GC required pairwise retraining, four-stimulus review trials, and additional six-stimulus test trials (13 on Set 1 and 18 on Set 2) to meet the criterion.

Twelve-stimulus tact test trials: Set 1 and Set 2 combined. All 3 children tacted without error the 12 stimuli from Set 1 and Set 2 combined.

Category match-to-sample review with Set 1 and Set 2 arbitrary stimuli. Figure 3 shows that all 3 children passed the category sorting Test 1 review on both Set 1 and Set 2; performance was 100% correct for the 3 children on both categories, except for Subject PW who made one error on one Shoulder trial for Set 1.

Six-stimulus category match-to-sample tests: Random selections from Set 1 and Set 2 combined. The 3 children sorted correctly the six randomly selected stimuli from Sets 1 and 2 (see Figure 3).

Twelve stimulus category match-to-sample test: Set 1 and Set 2 combined. Two children (GC and PW) sorted the 12 stimuli correctly on all six trials of each category; Subject LI sorted correctly on 5 out of 6 trials in each category (see Figure 3).

Verbal behavior. The children's vocal and manual verbal responses during the sorting tests are shown in Table 3; these mostly consisted of vocal utterances such as ''One more'' (GC) and ''That's all'' (PW). During the posttest interview in which the children were asked why they made particular selections in an immediately preceding category match-to-sample trial, only PW produced relevant verbal responses, which are presented in Table 3. For example, when asked, ''So why did you give Teddy these?'' Subject PW replied, ''That one (pointing to the stimulus he had first selected in the category sorting trial) goes like that (he then produced the fist gesture) and that one (pointing to his second stimulus selected) goes like that (he again made the fist gesture).

The 3 subjects in the present study learned manual tacts for an additional set of six stimuli and, having done so, sorted the 12 stimuli into two 6-member common name classes. Transfer of function is a second measure of the categorization effects of common naming (Horne & Lowe, 1996). Lowe et al. (2005) have shown that when young children were trained common vocal tacts (''zog''/''vek'') to establish two 6-member tact relations and then to clap to one of the zogs and wave to one of the veks, the clap and wave responses transferred without training to the five other members of the zog and vek classes, respectively. The next experiment investigated whether vocal responses would transfer in the same manner among six-member manual tact classes.

EXPERIMENT 1C

Method

Subjects

Following their completion of Experiment 1B procedures, 2 children, GC and LI, participated in Experiment 1C. They were 3 years 2 months and 3 years 3 months, respectively, at the start.

Vocal tact training—Fist 1 and Shoulder 1 stimuli. The children were presented with the Fist 1 and Shoulder 1 stimuli (Pair 1) for which the experimenter first conducted a block of eight vocal response exposure trials in which she pointed to one of the stimuli and said, ''This is a zag [vek]. Can you tell Teddy what this is?'' If the child produced the correct vocal response, the experimenter said, ''Yes, clever girl! It is a zag [vek].'' If the child produced an incorrect response, or remained silent, the experimenter (pointing to the stimulus) said, ''That is a zag [vek]. Can you say it?'' In subsequent training trials, the experimenter pointed to one of the stimuli and asked, ''What is this? Can you tell Teddy what this is?'' with praise for correct responses and correction for incorrect or no responses. The criterion was three consecutive correct vocal responses to each stimulus (minimum six trials).

Transfer of vocal tacting: Arbitrary stimuli Pairs 2–6. Eight unreinforced trials of vocal tact transfer were first conducted with Pair 2 (Fist 2 and Shoulder 2). In each trial, the experimenter presented the two stimuli, pointed to one and asked, ''What is this? Can you tell Teddy what this is?'' Stimulus location and order of targeting were randomized and counterbalanced over trials as in manual tact training. The same procedure was then repeated for each of the four remaining stimulus pairs.

Twelve-stimulus vocal tact test. In each unreinforced trial, the experimenter presented all the Set 1 and Set 2 stimuli in one random array. The experimenter asked the child, ''What is this? Can you tell Teddy what this is?'' as she pointed to each of the 12 stimuli in turn. This 12-stimulus vocal tact test was conducted three times.

Interobserver reliability. The independent observer scored 53.2% of the trials, selected at random, and agreement was 92.7%.

Results and Discussion

Arbitrary stimuli Set 1 and Set 2—Transfer of vocal behavior

Vocal tact training—Pair 1 stimuli. Subjects GC and LI learned to echo the two vocal responses ''zag'' and ''vek'' in one block of eight exposure trials and met the vocal response criterion for the Pair 1 stimuli in 16 and 14 training trials, respectively.

Transfer of vocal behavior tests: Arbitrary stimuli Pairs 2–6. Figure 4 shows that both children transferred the vocal responses ''zag'' and ''vek'' correctly in all trials.

Twelve stimulus vocal tact test. Both children produced the correct vocal tacts to the 12 stimuli in all 36 trials (see Figure 4).

GENERAL DISCUSSION

Manual Naming and Category Match-To-Sample: Three-Member Classes

All of the 8 children who completed manual tact training passed the arbitrary stimulus category sorting tests (either category Test 1 or, if they failed the latter, category Test 2), which were conducted entirely in the absence of reinforcement. This outcome is similar to the findings of the vocal tact training study of Lowe et al. (2002) in which 12 children of a similar age to those in the present study learned two 3-member common vocal tact relations among the six arbitrary stimuli which they then sorted into two common name classes.

In category sorting, 6 children passed Test 1 (which employed the look-at-sample instruction) whereas 2 failed but passed Test 2 (tact-sample instruction). As in Lowe et al. (2002), success on Test 1 in the present study did not appear to be age-related. Over the two studies, 12 of 20 children succeeded on Test 1 and the remaining 8 on Test 2. Across both tact training studies, therefore, the children's compliance with the Test 2 instructions that required them to tact the sample stimulus (either as a vocal tact in Lowe et al. or a manual tact in the present study) was sufficient for the emergence of common name classes whereas training a common response per se was not.

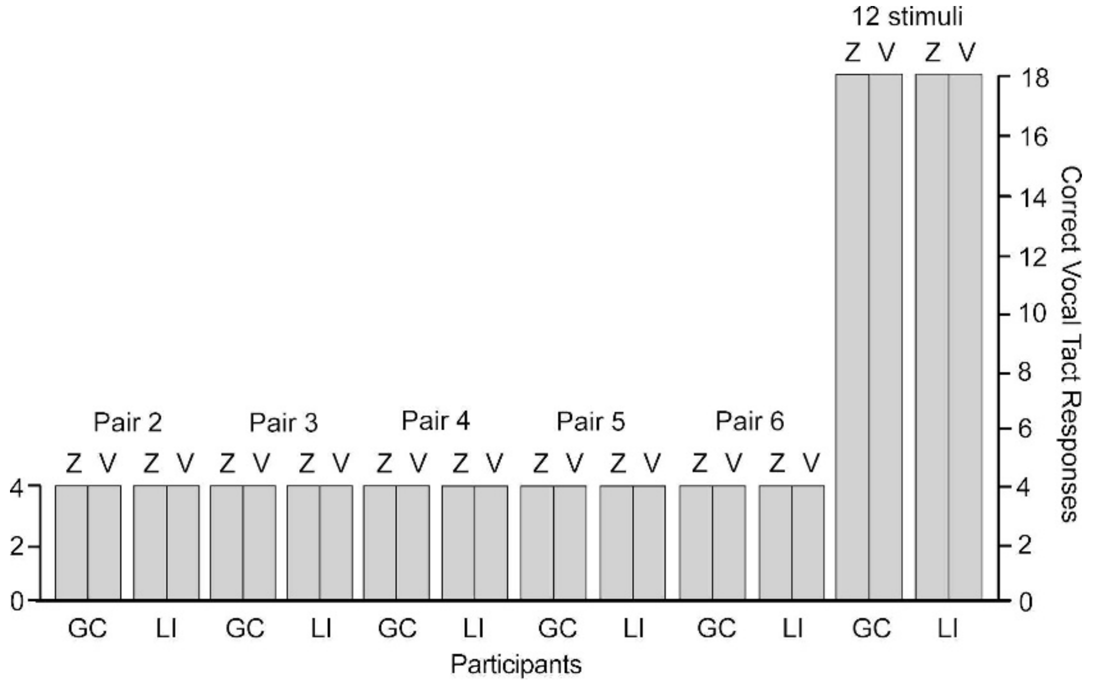

Fig. 4. For the 2 subjects, GC and LI, number of correct vocal tact responses in the 8-trial transfer of function test conducted with Pair 2 and Pair 3 (Set 1), Pair 4, Pair 5, and Pair 6 (Set 2), and on the 36-trial vocal behavior transfer test with all 12 arbitrary stimuli from Set 1 and Set 2.

Four of the 12 children who passed Test 1, either in the present manual tact study or the vocal tact study of Lowe et al. (2002), also were heard (Subjects GH and WA in Lowe et al.) or seen (Subjects RP and SN in the present study) to tact the sample stimulus even though the Test 1 sorting instruction only required the children to *look* at the sample before selecting comparisons. Though the remaining 8 children also succeeded on Test 1 but produced no overt sample names, it is possible that they produced covert sample names, which in turn governed their comparison selections. However, this interpretation must remain speculative; a functional analysis of the transition from overt to covert forms of naming and other verbal behavior has yet to be fully developed (Catania, 1996; Palmer et al., 2004), and a detailed specification of the properties of covert verbal behavior in both the sign and vocal modalities remains a key issue for behavior analysis.

Manual Naming and Category Match-To-Sample: Six-Member Classes

In the present study, 3 children learned common manual tacts for six additional arbitrary stimuli, Set 2. They categorized the new stimuli into three-member classes and, when Set 1 and Set 2 stimuli were combined, they sorted the 12 stimuli into six-member classes. This outcome is similar to that for the vocal naming studies of Lowe et al. (2002) and Lowe et al. (2005) and suggests that manual naming is as effective as vocal naming in establishing large arbitrary stimulus classes in very young children. The facility with which three young children learned the baseline relations and passed tests for arbitrary stimulus-class formation contrasts with the difficulties encountered when more conventional match-to-sample training and testing procedures have been employed. For example, Pilgrim, Jackson, and Galizio (2000) note that when these latter procedures are employed, even normally developing children may fail to learn the baseline conditional discriminations and so cannot go forward to the tests for stimulus-class formation. Even when the prerequisite baselines are learned, children frequently fail tests of stimulus-class formation (Saunders, Drake, & Spradlin, 1999).

Manual Naming and Category Transfer of Function: Six-Member Classes

The second main measure of the categorization effects of common naming is transfer of function. In the present study, following the common manual tact training described above, 2 children were trained in addition to vocally name one of the Pair 1 stimuli as ''zag'' and the other as ''vek.'' For Pairs 2 through 6, the 2 children showed perfect transfer of these vocalizations to stimuli in the same manual name category. Both Lowe et al. (2005) and Horne et al. (2006) report comparable outcomes in children who first learned common vocal names among the 12 stimuli and were then trained to produce a manual behavior (clap/wave) to the Pair 1 stimuli, which they transferred without training to the remaining stimuli.

Category Sorting and Transfer of Function

When the data from the present study are combined with those of our previous four studies on naming and categorization (summarized in Horne et al., 2006), all forty 1- to 4-year-old children who initially learned common names among six arbitrary stimuli went on to categorize them correctly in either a category sorting or a transfer of function test, whichever was initially presented. Of these 40 children, 11 of 11 also named and categorized 12 arbitrary stimuli into six-member classes in one or other (or both) of these categorization tests. On both measures—category sorting and transfer of function—common sign naming appears to be every bit as potent as common vocal naming in establishing emergent categorization behavior. This contrasts with the findings of a common response-training study with somewhat older children (aged between 4 and 5 years) conducted by Smeets, Barnes, and Roche (1997). Rather than the manual tact training conducted in the present study, Smeets et al. trained common location responses in their attempts to establish stimulus classes among arbitrary stimuli. However, 3 of 18 children failed to show within-class transfer of a novel location response and 4 of the remaining 15 children failed the match-to-sample test for equivalence among members of each functional class. These failures led the authors to conclude that functional equivalence can imply but does not require stimulus equivalence. In our study, with considerably younger children and employing common manual naming rather than the location responses employed by Smeets et al., the transfer of function and category sorting measures correlated perfectly. Unfortunately, studies that have employed a many-to-one training paradigm with pigeons and reported evidence of functional equivalence in reinforced test trials have not directly tested for stimulus equivalence (e.g., Urcuioli, 1996), and so the comparison between functional equivalence and stimulus equivalence cannot be made in the case of these nonverbal subjects (and see Horne et al., 2006, for a critique of the acquired equivalence studies conducted in pigeons).

Common Naming: Modality Effects on Rate of Learning?

In the vocal tact training study of Lowe et al. (2002), the mean number of tact training trials to criterion for 5 subjects (FK, JC, BJ, JA, WA) was 220 whereas in the present study, for the 5 subjects (RP, GC, LI, KM, and RE) who are matched in age (to within one month) to those in Lowe et al., a mean of 165 manual tact-training trials were required. Though the numbers are small, these data provide evidence that manual names are learned at least as readily as vocal names. This finding is consistent with a recent report that human infants as young as 6 months can learn to sign in as little as 4 hours of training (Thompson, McKerchar, & Dancho, 2004).

Given that only common manual tacts were trained in the present study, one conclusion is that common naming in the manual sign modality was solely responsible for the children's categorization performances. However, because these children had a history of naming in the vocal-auditory modality, it also is possible that these outcomes were primarily driven by the children's covert vocal naming of the stimuli (e.g., ''fists'' and ''shoulders''), rather than the corresponding manual signs. Indeed, it is likely that at least some of the children would have been able to name the fist gesture as ''fists'' (or ''hands'') and the shoulder gesture as ''shoulders'' and such covert names might have been produced concurrently with their manual counterparts in each manual tact trial.

There is, however, no direct evidence to support a vocal naming explanation of the categorization outcomes in the present study. For example, neither during the manual tact tests nor the category tests did any child actually say ''fists'' or ''shoulders'' (or similar) out loud when the experimenter pointed to a particular stimulus and asked, ''How does this go?'' In addition, although several children commented vocally as they made their stimulus selections, these vocalizations never included the names for the manual gestures trained in the study. For example, even under prolonged questioning in the posttest interview at the end of Experiment 1B, when PW was asked, ''Why did you give Teddy these [indicating comparison selections]?'' he responded ''Because of *that* [pointing to sorting stimulus]'' and when next asked, ''Why because of *that* [pointing to same stimulus]?'' he responded, ''Because *that* [pointing to first selection] goes like *that* [making shoulder gesture] and *that* [pointing to second selection] goes like *that* [shoulder gesture again].'' In other words, PW's verbalizations consisted of signing interspersed with vocal behavior, but the manual names were never replaced with the corresponding vocal names (see Table 3) even though it can be argued that less effort would have been involved in producing a verbal response consisting only of vocal behavior (particularly if the relevant vocal labels for the manual names had already been produced covertly during training and test trials). However, despite the fact that these children never produced overt vocal names for the trained manual tact gestures during either the training trials or categorization trials, or the posttest interview, it remains possible that these occurred, but exclusively at the covert level.

The Applied Significance of Manual Naming

Children normally learn first to categorize stimuli that share certain features, for example, ''trees'', ''birds'', and ''flowers'', and later to categorize more arbitrary stimuli, for example, ''letters'' (of the alphabet) or ''numbers'', a variety of creatures as ''animals'', and various objects as ''furniture, ''clothes'', ''vehicles'' or ''toys'' (Markman, 1989). The common naming procedure employed in all five of our studies suggests that naming is an extremely efficient way of learning such categories, particularly among stimuli that have no common features. Typically, this category name training is conducted by parents, teachers, and other members of the child's verbal community and occurs predominantly in the auditory-visual modalities. It has been estimated, however, that around 15% of people with learning difficulties have hearing impairments, and that 70% have a speech problem (Luftig, 1982). Not surprisingly, therefore, their learning of vocal verbal behavior is often poor, particularly in the case of severely mentally retarded individuals. Manual sign training, however, often has proved to be a more effective means of establishing verbal behavior in such populations (Kahn, 1981; Potter & Brown, 1997; Sundberg, 1993). In addition to an increase in social interaction as the sign repertoire develops (Lloyd, 1976), there is evidence of a concomitant reduction in challenging behaviors (e.g., Casey, 1978). Moreover, when in some cases manual signs were presented along with their vocal counterparts, manual sign training has even resulted in the development of oral competency for the first time (Lloyd, 1976; Luftig, Gauthier, Freeman, & Lloyd, 1980; Remington & Clarke, 1993a, b). Given that some people in special populations who have failed to learn a spoken repertoire can learn to communicate using manual signs, the present study suggests that they also may be able to reap the substantial benefits of common naming that are now well documented for auditory–vocal modalities, that is, not only to sort stimuli with no common features into categories but also to acquire novel behaviors for all category members when a novel behavior is trained to only one of them. If people in special populations can learn to common name using manual signs then this may result in enormous savings in learning, with huge benefits not only to their communication with others but also to the way they conceptualize and respond to their environment.

To achieve these special effects on learning, this alternative means of acquiring a verbal repertoire needs to be underpinned in much the same way as for vocal naming, that is, by the establishment of the corresponding listener and echoic repertoires. Both listener and manual echoic repertoires (manual imitation) must therefore be trained to manual signs, so that appropriate listener behavior and manual echoing in the presence of the referents can be established, and with it, manual sign naming. A crucial determinant of the name relation is that the child learns to become a conventional listener to his or her own speech as well as that of others (Horne & Lowe, 1996). For example, the child needs to orient to a cat irrespective of who is saying the word ''cat''. The same kinds of generalization must occur for any manual sign ''listener'' stimulus. However, this parity may be more difficult to establish than for a vocal echoic repertoire: From the perspective of a child producing a particular manual sign, the latter may look different in several respects from the same manual sign made by someone else (Baer & Deguchi, 1985). Depending on who is signer and who is observer, a sign may be seen respectively as movement away from rather than towards the body, with palms of hands facing versus away, and so on. As Horne and Erjavec (2007) have shown in human infants, imitation of manual gestures is a behavioral repertoire that cannot be assumed, but may require training of a considerable number of matching relations before approximate, untrained matching responses can occur to models of novel behaviors.

Conclusion

The present study on naming in the manual sign modality in normally developing 2- to 4-year old children demonstrates that common sign training is a very economic and potent means of establishing a large number of untrained novel behaviors. The results suggest that signing is no less effective in this regard than vocal naming. The experiments reported here were not designed to provide a differential test of the main behavior-analytic theories of categorization, that is, stimulus equivalence theory (Sidman, 1994), relational frame theory (Hayes & Hayes, 1992), and the naming account (Horne & Lowe, 1996). However, the findings do have theoretical implications. For example, the naming account predicts that whether or not a child will pass a categorization test will depend on whether they name the stimuli. Thus, in the present study, 8 of the 20 children passed the category sorting test only when given a version that required them to name the sample stimulus, a finding also reported in Lowe et al. (2002). This outcome is not predicted by either the Sidman or Hayes theories.

A more serious difficulty for these latter accounts is the finding that emerges from all five studies taken together: When 40 children were trained with a common name (either vocal or manual) for a number of stimuli, they proceeded to categorize them whereas another 11 children who learned only common listener relations, but not common names, all failed to categorize. This profound difference in outcomes, which clearly supports the view that naming may be necessary for categorization of arbitrary stimuli, is not predicted by either of the competing theories, nor can it be explained by them (and see Horne et al., 2006).

The present study certainly opens up new directions for further critical tests of theories in this domain. It might be possible, for example, to study the emergence of stimulus classes in very young normally developing children, or those who are hearing impaired, who have not yet learned to name either vocally or manually. According to the naming account, such children will not categorize arbitrary stimuli unless they are trained to name. Indeed, the present results indicate that common sign training may be a very effective naming intervention not just for children who are deaf but also those who are not. Such studies are very difficult and time consuming to conduct but could be valuable in revealing the key determinants of categorization in humans.

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