Revista Mexicana de Análisis de la Conducta • Mexican Journal of Behavior Analysis
2021 | Núm. 2 • diciembre | No. 2 • December | Vol. 47, 368 - 391
http://dx.doi.org/10.5514/rmac.v47.i2.81165

TEACHING SYMBOLIC RELATIONS IN DOWN SYNDROME THROUGH EQUIVALENCE-BASED INSTRUCTION: A CASE STUDY

ENTRENAMIENTO DE RELACIONES SIMBÓLICAS EN EL SÍNDROME DE DOWN CON INSTRUCCIÓN BASADA EN EQUIVALENCIAS: ESTUDIO DE CASO

Ángel Eugenio Tovar[1] & Alvaro Torres-Chávez
Facultad de Psicología
Universidad Nacional Autónoma de México

Abstract

A procedure for establishing equivalence classes in a participant with Down syndrome was implemented. The classes were composed of written words (A), pictorial representations (B), digit numbers (C), and auditory words (D) representing metro stations. In the training phase we implemented a successful procedure for enhancing perceptual discrimination of written words when presented as sample stimuli (A), and we established a reduced number of stimulus relations: AB, BC, DA, from which the participant was able to derive full stimulus classes that included derived relations between stimuli that had not

1. Acknowledgments: This study was supported by a grant from CONACyT México (CB 285152) to the first author. We thank the staff from Integración Down, I.A.P. for their help in conducting this study.
Corresponding author: Angel E. Tovar, Office C-218, Facultad de Psicología, UNAM, Coyoacán Z.C. 04510, Mexico City. Email: aetovar@unam.mx

been trained before: BA, CB, AC, CA, DB, and DC. The study encompassed a total of 7 sessions, and by the end these, the participant showed correct mappings between written words, pictures, auditory words, and digits. We detail adaptations to traditional training procedures that facilitated learning in the participant with Down syndrome. We argue that procedures based on equivalence instruction are beneficial for the establishment of symbolic and communicative repertoires in individuals with developmental disabilities.

Key words: Down syndrome, symbolic behavior, word object mappings, learning disabilities, equivalence class formation, reading.

Resumen

Implementamos un procedimiento para establecer clases de equivalencia en un participante con síndrome de Down. Las clases se conformaron con palabras escritas (A), representaciones en imagen (B), dígitos numéricos (C), y palabras auditivas (D) que representaron estaciones de metro. En la fase de entrenamiento implementamos un procedimiento exitoso para facilitar la discriminación perceptual de palabras escritas cuando se presentaron como estímulos de muestra (A), y establecimos un número limitado de relaciones estímulo: AB, BC, DA, a partir de las cuales el participante pudo derivar relaciones emergentes entre estímulos no entrenadas previamente: BA, CB, AC, CA, DB, Y DC. El estudio incluyó un total de 7 sesiones, para el final de éstas el participante mostró mapeos correctos entre palabras escritas, imágenes, palabras auditivas y dígitos. Aquí detallamos las adaptaciones que realizamos a procedimientos tradicionales de entrenamiento, para facilitar el aprendizaje en el participante con síndrome de Down. Discutimos que los procedimientos basados en entrenamiento de equivalencias son de beneficio para el establecimiento de repertorios de comportamiento simbólico y de comunicación en personas con desarrollo atípico.

Palabras clave: síndrome de Down, comportamiento simbólico, mapeos entre palabras y objetos, problemas de aprendizaje, formación de clases de equivalencia, lectura.

Down syndrome (DS) is the most frequent genetic cause of intellectual disability. It produces considerable impairments in physical development, behavioral and cognitive functions (Lott & Dierssen, 2010; Wiseman et al., 2009). Research on language development and communicative abilities in DS has attracted increased attention due to the numerous weaknesses in these domains observed in this population (Arias-Trejo et al., 2020; Bello et al., 2014; Chapman, 2006; Lemons et al., 2017; Mason-Apps et al., 2020; Vicari et al., 2004) and see the meta-analyses (Næss et al., 2011). Therefore, a main challenge for psychological interventions has been to find the best procedures to increase the linguistic and symbolic repertoire of people with Down syndrome. Here we contribute to these efforts by detailing a set of behavioral interventions for successfully teaching symbolic stimulus relations, useful for the everyday life on an adolescent with Down syndrome.

From a behavioral perspective, language and symbolic behavior have been closely related to studies on *equivalence class formation* (Devany et al., 1986; Dickins & Dickins, 2001; Horne & Lowe, 1996; Sidman, 1994). Equivalence classes are sets of stimuli that, regardless of physical similarity, are functionally and symbolically related (Bortoloti & de Rose, 2009).

A typical set of equivalent stimuli can be composed of a visual object (e.g., a dog, called stimulus A1), a visual symbolic representation of the object (e.g., the word *DOG*, called stimulus B1), and an auditory symbolic representation of the object (e.g., the sound of the word /dog/, called stimulus C1). A common methodology to establish a stimulus class is by training *conditional discriminations* between some members of the class via Matching to Sample (MTS) trials. For example, the relation between A1 and B1 is trained with the conditional discrimination *if A1 then B1*, by means of presenting to the individual A1 as a sample stimulus, with B1 (positive comparison) and B2 (negative comparison) presented as comparison stimuli. In this trial, the selection of B1 is praised and reinforced and the selection of B2 is extinguished. The relation between B1 and C1 is trained in the same way. Both A1rB1 and B1rC1 become the *baseline relations* of the stimulus class. Notably, training of these baseline relations can lead to deriving all possible relations inside the stimulus class A1B1C1, which is confirmed during testing phases with MTS trials.

The test trials are considered probes for the properties of equivalence relations (Sidman & Tailby, 1982). Thus, after training: *if A1 then B1*, and *if B1 then C1*, those participants forming classes should respond correctly, without further instruction or reinforcement, to the symmetry tests *if B1 then A1*; *if C1 then B1*, and to the transitivity tests *if A1 then C1*, and *if C1 then A1*. Trials testing for the property of reflexivity (e.g., *if A1 then A1*) are not usually presented during testing phases.

What is particularly relevant for people with developmental disabilities, and for our study, is that they show more variability and difficulties in learning both baseline and derived stimulus relations, as expressed through the number of training trials required to master criteria and the accuracy during tests of equivalence (Grisante et al., 2014; O'Donnell & Saunders, 2003; Tovar & Westermann, 2017). Some authors have suggested that problems with deriving correct stimulus relations are correlated with poor language development (Devany et al., 1986).

A growing body of applied studies using equivalence-based instruction has explored numerous protocols for increasing efficiency in teaching complex behavioral repertoires to people with typical and atypical development (Fienup et al., 2010; Fienup & Critchfield, 2010; Grisante et al., 2014; Nedelcu et al., 2015; O'Donnell & Saunders, 2003; Pytte & Fienup, 2012; Rehfeldt, 2011).

Our main objective in this study was to establish, in an adolescent with Down syndrome, a symbolic repertoire of two categories consisting of representations of public transport stations. We also want to extend the evidence of applied research in the field of equivalence class formation and put forward a clear procedure for teaching complex behavioral repertoires in DS, with direct implications for the further development of communicative, language, and reading abilities in populations with learning difficulties.

In our study we faced different challenges for teaching the conditional discriminations. For our purposes we reviewed procedures that facilitate learning of conditional discriminations. In a recent study Grisante and colleagues (2014) evaluated emergent stimulus relations in participants with Down syndrome and typically developing children. They suggested that increasing discriminability of stimuli was helpful for most participants to learn the baseline relations and derive the emergent stimulus relations correctly. However, their procedure focused on increasing discriminability of comparison stimuli only. In a review of procedures that facilitate learning of conditional discriminations, Pérez-González (2001) stressed that successful learning of conditional relations requires not only the correct simultaneous discrimination between comparison stimuli, as in the study of Grisante et al (2014), but also the correct successive discrimination of sample stimuli (i.e., paying attention and responding under control of the actual sample stimulus) as has been demonstrated by Saunders and Spradlin in participants with learning disabilities (1990, 1993).

In our study, we enhanced discrimination of written words when they were presented as sample stimuli, by increasing perceptual differences between different samples, and by training responses to the sample before the presentation of the comparison stimuli, as has been suggested before (Constantine & Sidman, 1975). We evaluated whether this implementation facilitated equivalence class formation in the participant with Down syndrome in a single subject design.

Method

Participant

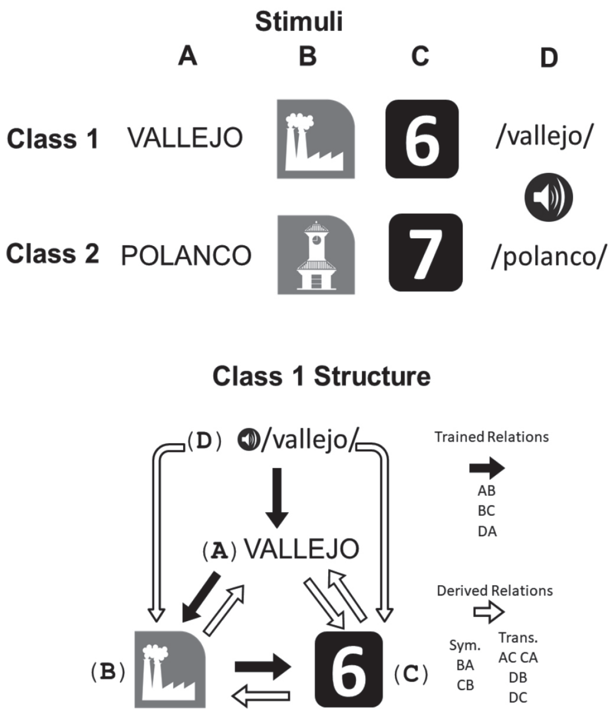
David (name changed to protect confidentiality) was an adolescent, 14 years and 2 months old by the beginning of the study, he attended a special education school and was diagnosed with DS. He showed an estimated mental age of 6 years and 4 months, and 45 points of IQ in an abbreviated form of the Wechsler Intelligence Scale for Children-IV. David showed good social abilities and attention to instructions. His communicative abilities were at a basic level; he used two or three-word sentences to communicate with others in Spanish, and he could name aloud written vowel letters and some highly trained words, like his name, but only when presented in lower case letters. His parents gave informed consent before his participation in this study. The study was approved by the Ethics Committee of the School of Psychology, in Universidad Nacional Autónoma de México.

Setting and Stimuli

The sessions were conducted in a 4 × 4 m room, used as the library of the school that David attended. Sessions lasted between 15 and 25 minutes. During each session only two experimenters and the participant were in the library.

Two stimulus classes composed of 4 elements were used for this study. The elements in each class corresponded to different representations of two public transport stations in Mexico City: stimuli A were the written names of the stations presented in upper case letters; stimuli B were the pictorial representations of these stations; stimuli C were the numbers of the public transport lines to which the stations belonged, presented as digits; and stimuli D were the auditory names of the stations; /vallejo/ and /polanco/ (see upper part of Figure 1). The lower part of Figure 1 shows the structure of class 1, where trained baseline relations are marked with black arrows and derived relations used for tests are marked with white arrows. The same structure was used for class 2.

Figure 1. Stimulus Classes and Training Structure



Note. Upper part: The stimuli presented for classes 1 and 2. Stimuli A and C were presented in black and white as depicted in the figure, stimulus B1 was presented in a red background and stimulus B2 in an orange background. Stimuli D were presented as auditory stimuli. Lower part: shows the structure of the Equivalence Class 1 with trained and derived relations. SYM indicates relations used in symmetry probes, TRANS indicates relations used transitivity probes.

Figure 2 shows the forms of stimuli A used for the sample discrimination enhancement, and the progressive increase in complexity of stimuli A. Stimulus presentation and automatic collection of responses was controlled with Visual Basic 6 in a laptop computer. David observed stimuli and responded through a peripheral touch-screen monitor 17".

Figure 2. Progressive Increase of Stimuli A

Stimulus Nomenclature

	Aenh-1	*Aenh-2*	*Aenh-3*	A
Class 1	V	VAL	VALLE	VALLEJO
Class 2	P	POL	POLAN	POLANCO

Note. The forms used for the progressive increase in the visual complexity of stimuli A. The size of A1 on the screen was 1.5 X 7.75 cm; the size of A(enh-1) was 3 X 2.7 cm on the screen.

Procedure

All procedures were applied in short sessions to maintain high levels of attention and avoid a long participation that might interrupt the daily activities of David. For this reason, we used the lowest possible number of training and test trials. As is relevant in applied studies, and since our main objective was to teach the two stimulus classes to David, we adjusted some procedures as the training and testing sessions progressed. In the next sections we explain the different procedures used, before explaining how and when we used them.

Matching to Sample Trial Structure

For visual-visual MTS, a sample was presented at the upper center of the screen. David was instructed to touch the sample stimulus, after this response the two comparison stimuli were presented distributed at the bottom of the screen.

For auditory-visual MTS a blue square appeared at the upper center position of the screen, touching it led to reproducing an audio file with the sound of a word, and two visual stimuli appeared at the bottom of the screen as comparisons. The sound was repeated until David touched one of the visual comparisons or up to 5 repetitions (but see below).

During reinforced trials in training, the selection of the correct comparison stimulus cleared all the stimuli on the screen, then a happy face appeared for 1 s on the screen, an audio file with a female voice saying the word /bien/ ("good" in Spanish) was reproduced and verbal praise from the experimenter was given. Alternatively, the selection of an incorrect comparison stimulus cleared all stimuli from the screen, a red cross with a gray background appeared on the screen and an audio file with the female voice saying the word /mal/ ("wrong" in Spanish) was reproduced. Following incorrect responses, one experimenter asked David to pay more attention for the next trial. Trials were separated by 1 s intertrial intervals.

During un-reinforced trials used in tests and some training phases, responses led to the intertrial interval period, and the experimenter did not provide any programmed consequences to David's responses.

Pretraining and Pretest

In the first session three subtests of the WISC-IV were administered to assess mental age and IQ: Block Design, Picture Completion and Matrix Reasoning. These subtests conform a short version for assessing mental age with high reliability (0.93) and validity (0.83) values (Sattler, 2010).

Following the initial assessment, David sat down in front of the touch screen monitor and he was instructed on MTS trials. He was asked to respond to one block of 8 visual-visual identity trials (e.g., the sample was a square, the positive comparison was a square and the negative comparison was a circle, all displayed in black).

Then, a second block was presented with 8 visual-visual trials that required some degree of abstraction; during these trials pictures of animals were presented as samples and drawings of animals as comparison stimuli, and David was instructed to select the comparison that correctly matched the sample. A third block of 8 auditory-visual trials was presented. Auditory samples were the names of common objects (e.g., table, pencil) repeated up to 5 times, and visual comparisons were pictures of the objects.

After familiarizing David with MTS procedures, we presented one block of 12 trials dedicated to exploring pretest responses to the visual-visual stimulus relations further used for training (AB, BC) and for tests (BA, CB, AC, CA) of classes 1 and 2. Responses during these trials were not reinforced.

AB and BC Training

This training phase consisted of teaching 4 stimulus relations with MTS: A1B1, B1C1, A2B2, B2C2 (see Table 1). These were progressively introduced in training blocks with the following sequence: block 1 presented 8 A1B1 trials; block 2 presented 8 B1C1 trials; block 3 presented 8 A2B2 trials interleaved with 2 A1B1 maintenance trials; finally, block 4 presented 8 B2C2 trials interleaved with 2 B1C1 maintenance trials.

From block 5 we programmed trials of the 4 stimulus relations semi-randomly interleaved. To balance the number of presentations of each relation, during block 5, 2 A1B1, 2 B1C1, 3 A2B2, and 3 B2C2 trials were programmed. In blocks 6, 7 and 8, each trained relation was presented 4 times; and during the training blocks 7 and 8 we decreased the reinforcement probability to 50% and 0%, respectively for each trained relation to prepare David for responding during tests without reinforcement.

The criterion for moving on to the next training block was having at least 87% of correct responses in each block. Failures in fulfilling the criterion resulted in the repetition of the training block.

Table 1. The Training Schedule for AB and BC Relations

Block	Trained Relations	Number of Trials	Reinforced Trials (%)	Criterion (Correct/Trials)
1	A1B1	8	100	7/8
2	B1C1	8	100	7/8
3	A2B2, A1B1	8 2	100	9/10
4	B2C2, B1C1	8 2	100	9/10
5	Interl-1 (A1B1, B1C1, A2B2, B2C2)	2 2 3 3	100	9/10
6	Interl-2	4 X each relation	100	14/16
7	Interl-2	4 X each relation	50	14/16
8	Interl-2	4 X each relation	0	14/16

Note. The training structure for AB and BC relations presented in the first sessions with the number of trials, percentage of reinforced trials and mastering criteria. Interl-1 indicates the first block of interleaved relations. During Interl-2 each AB and BC trained relation was presented 4 times, as indicated by 4x.

Sample Discrimination Enhancement

We initially presented the AB and BC training using stimuli A in its original forms (Figure 1). As we will detail in the Results section, during the first two days of training David showed difficulties in mastering training block 3; when A1B1 and A2B2 trials were interleaved. Therefore, from day 3 we started the training trials with the same structure and sequence as depicted in Table 1, but instead of using the words *VALLEJO* and *POLANCO*, we used enhanced forms of stimuli A. Our manipulation to increase perceptual differences of stimuli A consisted of presenting only the initial letter of each word; *V* or *P*, as depicted by stimuli A1*enh-1* and A2*enh-1* in Figure 2. These were also displayed in a larger size compared with the size of the initial letters used as A1 and A2. Notably, this method was based on facilitating the perceptual discrimination of stimuli A, which may be complementary to procedures more focused on training discriminative responses (e.g., naming) to different sample stimuli (Constantine & Sidman, 1975; Saunders & Spradlin, 1990, 1993). David did not show difficulties discriminating stimuli B during BC trials.

Symmetry and Transitivity Probes

After training with the enhanced forms-1 of A, we presented one block composed of 12 symmetry probes; three trials for each of the following symmetry relations: B1A1*enh-1*, C1B1, B2A1*enh-1*, C2B2.

Then, we presented one block of transitivity probes combined with trials testing for the maintenance of the trained relations. Each trained relation; A1*enh-1*B1, B1C1, A2*enh-1*B2, B2C2, was presented once, and each transitive relation; A1*enh-1*C1, A2*enh-1*C2, C1A1*enh-1*, and C2A2*enh-1*, was presented twice in a semi-random sequence. Transitivity blocks were programmed to be repeated up to 3 times in case more than one mistake was made in each block.

Transfer of Stimulus Control from Highly Discriminable- to Less Discriminable-Stimuli

After training and testing with the enhanced forms of stimuli A, we implemented a procedure to maintain the functional properties of AB relations while gradually increasing the visual complexity of stimuli A until they were presented as the full written words *VALLEJO* and *POLANCO*.

The training blocks and stimuli used for this procedure are shown in Figure 2 and Table 2. Our objective in the first transfer block was to provide a review of the training on AB and BC relations. In this block we presented 2 trials of each trained relation (A1*enh-1*B1, B1C1, A2*enh-1*B2, B2C2). The AB trials were presented once with the enhanced form and once with the initial letter of the word in its original size (size of A*enh-1* was 3 × 2.7 cm; size of the initial letter of A1 was 1.5 × 1.25 cm on the screen).

During transfer blocks 2 to 4 we gradually increased the number of letters in each word of stimuli A. During these blocks we only presented AB trials; five A1B1 and five A2B2 trials per block (Table 2). After completing the transfer block 4, we presented one block of 8 trials with each trained relation presented 2 times, with A1 and A2 presented in its original complex form. All responses were reinforced.

We then presented the AB and BC relations interleaved in training blocks 5 and 6. During Blocks 7 and 8, the four stimulus relations were presented again but the reinforcement probability was decreased to 50% and 0%, respectively (Table 2).

After this procedure we presented blocks of symmetry and transitivity probes, as previously described, to evaluate whether David was able to respond to both stimulus classes when A1 and A2 were the full written words.

Table 2. Training Schedule for the Transfer of Stimulus Control

Block	Relation	Number of Trials	Reinforced Trials (%)	Criterion (Correct/Trials)
1	A1*enh-1* B1 A2*enh-1* B2 B1C1 B2C2	2 2 2 2	100	7/8
2	A1*enh-2* B1 A2*enh-2* B2	5 5	100	9/10
3	A1*enh-3* B1 A2*enh-3* B2	5 5	100	9/10
4	A1B1 A2B2	5 5	100	9/10
5	Interl-3 (A1B1, B1C1, A2B2, B2C2)	2 X each relation	100	7/8
6	Interl-4	4 X each relation	100	14/16
7	Interl-4	4 X each relation	50	14/16
8	Interl-4	2 X each relation	0	7/8

Note. Blocks of training trials presented during transfer of stimulus control in Session 5, from highly discriminable- to less discriminable-stimuli. "Interl" indicates blocks with at least two interleaved stimulus relations. 2x or 4x indicate the number of repetitions for each trained relation in the Interl blocks.

Addition of an Auditory Stimulus and Final Tests

We designed a procedure to further analyze class expansion from 3 to 4 elements, trough the inclusion of an auditory stimulus in each class. Our first implementation failed because auditory stimuli were annoying to David and seemed to have a disruptive effect on his performance. In the following paragraphs we describe the two implementations used, and we will show the behavioral performance on both procedures in the Results section. Since both implementations were similar, we will describe in detail the first implementation and then we will indicate the main differences for the second implementation.

We trained D1A1 and D2A2 relations through auditory visual MTS. Stimuli D corresponded to the words /vallejo/ and /polanco/ in auditory modality. Both stimuli were generated in a computer with a neutral Latin American accent. After touching a blue square on the upper center position of the screen, the corresponding sound was reproduced. Each word was repeated 3 times with 500 ms separating each repetition. In a first training block we presented 8 trials of D1A1 and 8 trials of D2A2. In the second training block we presented all the trained relations in a block of 12 trials in a way that each stimulus relation (A1B1, B1C1, D1A1, A2B2, B2C2, D2A2) was presented twice.

During tests, to present as less trials as possible, and due to the fact that David previously showed equivalence class formation with MTS, we didn't decrease the reinforcement probability previously to test trials, and we didn't include trials to evaluate maintenance of baseline relations in this first implementation. We presented one block of 16 test trials, where each of the next transitive relations was presented two times: A1C1, C1A1, A2C2, C2A2, D1B1, D1C1, D2B2, D2C2. A total of 14 of the 16 trials were required correct in order to finish the test phase, otherwise the test block was repeated up to 3 times.

In the second implementation we started D1A1 and D2A2 training with only one repetition of the auditory stimulus after touching the blue square. For this implementation we included a third training block where the reinforcement probability was reduced to 50% of the trials before presentation of tests trials.

After completing training, we presented a test block of 28 trials, with two trials of each transitive relation as in the first implementation, and to determine whether failures in equivalence formation could be attributed to baseline disruption, we evaluated the maintenance of baseline relations by semi-randomly interleaving two trials of each of the trained relations in the test block. At least 25 of the 28 trials were required to be correct in order to finish the test phase, otherwise the test block was repeated up to 3 times. Table 3 shows a summary of the trained relations in the second implementation.

Table 3. Training Schedule for the Inclusion of Auditory Stimuli D

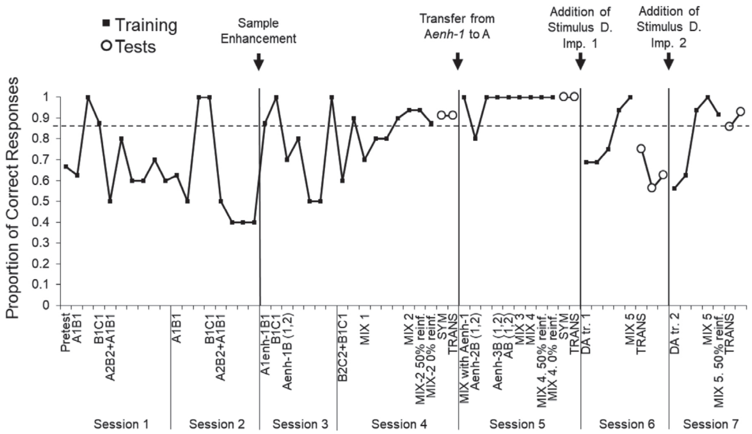
Block	Relation	Number of Trials	Reinforced Trials (%)	Criterion (Correct/Trials)
1	D1A1 D2A2	8 8	100	14/16
2	Interl-5 (A1B1, B1C1, D1A1, A2B2, B2C2, D2A2)	2 X each relation	100	11/12
3	Interl-5	2 X each relation	50	11/12

Note. Blocks of training trails presented for the inclusion of auditory stimuli D in the stimulus classes. "Interl" indicates blocks with at least two interleaved stimulus relations. 2x indicates the number of repetitions of each trained relation in the Interl blocks.

Results

The performance of David across the different phases of training and tests is summarized in Figure 3. Our single-subject pre-post design was composed of several training and test blocks. Each of these had a different number of trials; however, a value of (at least) 87% of correct trials captures the criteria to move on across all the blocks of the study. This criterion value is also shown in Figure 3.

Figure 3. Performance during Training and Tests



Note. Proportion of correct responses in all training and test blocks during the seven sessions of the study. Black square markers show training blocks and white circles show test blocks. SYM indicates blocks with symmetry probes, TRANS indicates blocks with transitivity probes. The criterion of 87% of correct responses is shown with a dashed line.

Training of A1B1, B1C1, and A1*enh*-1B1 and A1*enh*-1B2

During the first two sessions, training of AB and BC relations was programmed using the original forms of stimuli A. Interleaving A1B1 with A2B2 had a disruptive effect on David's performance and he showed no motivation to keep on with the task. From our observations, we noted that he was not differentiating between written words presented as A1 = *VALLEJO* and A2 = *POLANCO*, which caused later wrong selections of the comparison stimuli (B1 and B2). Instead of learning that the selection of either B1 or B2 depended on the corresponding sample A1 or A2, the participant was apparently trying to remember the last reinforced stimulus B, from the previous trial, to choose that one again. David was failing in the prerequisite of successive discriminating between samples which was a prerequisite for successfully responding in the block of interleaved trials. Failures in differentiating between A1 and A2 may have also been a consequence of limited reading experience.

At the beginning of the third session, we programmed training with the enhanced forms of stimuli A. David initially showed again a disruption in accuracy when A2*enh-1*B2 trials were interleaved with A1*enh-1*B1 trials. However, he demonstrated higher motivation to respond; he started to be more sensitive to the programmed reinforcement and we decided to maintain the presentation of these training trials in this way. By the fifth block of A2*enh-1*B2 interleaved with A1*enh-1*B1 trials, he achieved an errorless performance, showing indication of correct sequential discrimination of sample stimuli (Figure 3).

Symmetry and Transitivity Probes 1

During session four, David completed the programmed training and he performed in symmetry and transitivity probes with scores exceeding the learning criteria values, demonstrating successful formation of two stimulus classes composed of 3 visual stimuli.

Transfer of Stimulus Control from Highly Discriminable- to Less Discriminable-Stimuli, and Symmetry and Transitivity Probes 2

During session 5 we introduced the procedure to transfer the stimulus control from highly discriminable- to less discriminable-stimuli. The procedure showed to be successful. In the second block of this procedure, when the number of letters in the sample stimuli increased, David required 2 training blocks to reach the learning criterion. After this block, he responded to the remaining trials of training and to symmetry and transitivity tests with an errorless performance.

Addition of an Auditory Stimulus and Final Tests

In session 6 we presented the first implementation for the training of D1A1 and D2A2. David required 4 blocks of DA training trials. He expressed that he didn't want to hear the voice after touching the sample stimulus, during some trials he put his hands on his ears after touching the sample stimulus and then he selected the comparison stimuli. During the training block of interleaved trials with all the baseline relations he responded with 100% of accuracy. Then, during tests he repeated 3 blocks of transitivity trials. In the first of these blocks he responded correctly to 75% of the trials; however, during transitivity blocks 2 and 3 he responded at chance levels with 56% and 62% of correct trials, respectively.

During session 7, we presented the second implementation for the training of D1A1 and D2A2. David gradually recovered a high accuracy level in this session. He completed DA training trials in three blocks, then he moved on to the interleaved blocks of training trials with 100% and 50% of reinforcement probability, respectively, and finally he responded correctly to the block of transitivity trials interleaved with baseline trials. In this session, during the first presentation of the final test block he responded to 24 of the 28 trials correctly, just one correct response away of the criterion level (25/28 to achieve at least 87% correct). In a second presentation of the test block of trials David responded correctly to 26 of the 28 trials demonstrating the formation of two equivalence classes composed of 4 members.

Discussion

The literature on the psychological profile of Down syndrome has described numerous weaknesses in language and communicative abilities in this population (Dierssen, 2012; Næss et al., 2011; Pennington et al., 2003; Stojanovik, 2014). In the present study we designed a procedure to teach a symbolic repertoire to a participant with Down syndrome through equivalence-based instruction.

Our procedure consisted of teaching three conditional discriminations: AB, BC, DA, for two different sets of stimuli that represented public transport stations. From this training, we documented the emergence of 6 additional stimulus relations: BA, CB, AC, CA, DB, DC, in each of the two stimulus classes. As in previous studies, this demonstrates the efficiency of equivalence-based instruction, where an adequate selection of the trained stimulus relations leads to an expansion in the number of equivalence relations acquired by the participant (Fienup et al., 2010; Sidman, 1994).

We observed difficulties in mastering blocks of trials that contained more than one stimulus relation (e.g., A1B1 interleaved with A2B2). These observations are in line with previous reports of learning disruptions in participants with Down syndrome when at least two types of training trials are interleaved in one training block (Tovar et al., 2018). This suggests that future interventions in Down syndrome should take this into consideration, exploring ways of facilitating learning under these conditions, or avoiding interleaving different types of tasks at the time (Saunders & Spradlin, 1990, 1993). Additionally, further studies should evaluate the effect of presenting a different set of trained relations for the same stimulus classes, as it has been shown that participants under one-to-many training structures (e.g., AB, AC training) usually outperform those in linear series training, which was the one used here (e.g., AB, BC training; (Arntzen & Holth, 1997).

In our study, we explored whether difficulties with interleaved relations in blocks were caused by problems with the successive discrimination of written words, presented as sample stimuli A. It turned out that visual discrimination of these words was a demanding task for David, probably due to poor reading experience, as may be the case in most people with Down syndrome. To facilitate the discrimination of stimuli A we introduced a procedure that enhanced perceptual differences of sample stimuli (i.e., using only one bigger letter instead of full words). After mastering the conditional discriminations and forming two equivalence classes with the simplified forms of A, we progressively increased the visual complexity of these stimuli until they were presented as full words. Notably, full words kept the functional and symbolic properties of the enhanced forms of A. Remarkably, this procedure may be implemented as an intervention for increasing reading abilities in people with developmental disabilities that have difficulties in discriminating written words, and may be used as a complementary method when teaching naming repertoires.

An auditory stimulus D was added to each stimulus class. Our procedure required adjustments to fit the needs of David. Particularly, by presenting only one repetition of the auditory words instead of many repetitions. Finally, we documented class expansion and high accuracy levels during the equivalence tests.

The procedures used here led to high levels of accuracy in MTS trials. By the end of the study David was able to match written words with their corresponding sounds, pictorial forms and digits. This stresses the relevance of equivalence-based instruction in teaching complex symbolic repertoires in people with learning disabilities.

These results extend the evidence of successful teaching of complex behavioral repertories through equivalence-based instruction. Training of symbolic repertoires in people with developmental disabilities could benefit from using these methodologies, as they lead to reliable results in a limited number of sessions. In the current study only 7 sessions, including training and tests, were required to demonstrate the establishment of two 4-member equivalence classes. Finally, future studies implementing this kind of equivalence-based instruction in participants with learning disabilities, should seek to evaluate the extended benefits of the training program on other behavioral repertories; for example, behavior circumscribed to the discrimination of metro stations.

References

Arias-Trejo, N., Angulo-Chavira, A. Q., Demara, B., Figueroa, C., & Edgin, J. (2020). The influence of sleep on language production modalities in preschool children with Down syndrome. *Journal of Sleep Research*, e13120. https://doi.org/10.1111/jsr.13120

Arntzen, E., & Holth, P. (1997). Probability of stimulus equivalence as a function of training design. *The Psychological Record*, *47*(2), 309–320. https://doi.org/10.1007/BF03395227

Bello, A., Onofrio, D., & Caselli, M. C. (2014). Nouns and predicates comprehension and production in children with Down syndrome. *Research in Developmental Disabilities, 35*(4), 761–775. https://doi.org/10.1016/j.ridd.2014.01.023

Bortoloti, R., & de Rose, J. C. (2009). Assessment of the relatedness of equivalent stimuli through a semantic differential. *The Psychological Record, 59*(4), 563–590.

Chapman, R. S. (2006). Language learning in Down syndrome: The speech and language profile compared to adolescents with cognitive impairment of unknown origin. *Down's Syndrome, Research and Practice, 10*(2), 61–66.

Constantine, B., & Sidman, M. (1975). Role of naming in delayed matching-to-sample. *American Journal of Mental Deficiency, 79*(6), 680–689.

Devany, J. M., Hayes, S. C., & Nelson, R. O. (1986). Equivalence class formation in language-able and language-disabled children. *Journal of the Experimental Analysis of Behavior, 46*(3), 243–257. https://doi.org/10.1901/jeab.1986.46-243

Dickins, T. E., & Dickins, D. W. (2001). Symbols, stimulus equivalence and the origins of language. *Behavior and Philosophy, 29,* 221–244.

Dierssen, M. (2012). Down syndrome: The brain in trisomic mode. *Nature Reviews. Neuroscience, 13*(12), 844–858. https://doi.org/10.1038/nrn3314

Fienup, D. M., Covey, D. P., & Critchfield, T. S. (2010). Teaching brain-behavior relations economically with stimulus equivalence technology. *Journal of Applied Behavior Analysis, 43*(1), 19–33. https://doi.org/10.1901/jaba.2010.43-19

Fienup, D. M., & Critchfield, T. S. (2010). Efficiently Establishing Concepts Of Inferential Statistics And Hypothesis Decision Making Through Contextually Controlled Equivalence Classes. *Journal of Applied Behavior Analysis, 43*(3), 437–462. https://doi.org/10.1901/jaba.2010.43-437

Grisante, P. C., de Rose, J. C., & McIlvane, W. J. (2014). Controlling Relations in Stimulus Equivalence Classes of Preschool Children and Individuals with Down Syndrome. *The Psychological record, 64*(2), 195–208. https://doi.org/10.1007/s40732-014-0021-3

Horne, P. J., & Lowe, C. F. (1996). On the origins of naming and other symbolic behavior. *Journal of the Experimental Analysis of Behavior, 65*(1), 185–241.

Lemons, C. J., King, S. A., Davidson, K. A., Puranik, C. S., Al Otaiba, S., Fulmer, D., Mrachko, A. A., Partanen, J., & Fidler, D. J. (2017). Developing an Early Reading Intervention Aligned With the Down Syndrome Behavioral Phenotype. *Focus on Autism and Other Developmental Disabilities, 32*(3), 176–187. https://doi.org/10.1177/1088357615618941

Lott, I. T., & Dierssen, M. (2010). Cognitive deficits and associated neurological complications in individuals with Down's syndrome. *The Lancet. Neurology, 9*(6), 623–633. https://doi.org/10.1016/S1474-4422(10)70112-5

Mason-Apps, E., Stojanovik, V., Houston-Price, C., Seager, E., & Buckley, S. (2020). Do Infants With Down Syndrome Show an Early Receptive Language Advantage? *Journal of Speech, Language, and Hearing Research: JSLHR, 63*(2), 585–598. https://doi.org/10.1044/2019_JSLHR-19-00157

Næss, K.-A. B., Lyster, S.-A. H., Hulme, C., & Melby-Lervåg, M. (2011). Language and verbal short-term memory skills in children with Down syndrome: A meta-analytic review. *Research in Developmental Disabilities, 32*(6), 2225–2234. https://doi.org/10.1016/j.ridd.2011.05.014

Nedelcu, R. I., Fields, L., & Arntzen, E. (2015). Arbitrary conditional discriminative functions of meaningful stimuli and enhanced equivalence class formation. *Journal of the Experimental Analysis of Behavior, 103*(2), 349–360. https://doi.org/10.1002/jeab.141

O'Donnell, J., & Saunders, K. J. (2003). Equivalence relations in individuals with language limitations and mental retardation. *Journal of the Experimental Analysis of Behavior, 80*(1), 131–157. https://doi.org/10.1901/jeab.2003.80-131

Pennington, B. F., Moon, J., Edgin, J., Stedron, J., & Nadel, L. (2003). The neuropsychology of Down syndrome: Evidence for hippocampal dysfunction. *Child Development, 74*(1), 75–93.

Pérez-González, L. A. (2001). Procesos de aprendizaje de discriminaciones condicionales. *Psicothema, 13,* 650–658.

Pytte, C. L., & Fienup, D. M. (2012). Using Equivalence-Based Instruction to Increase Efficiency in Teaching Neuroanatomy. *Journal of Undergraduate Neuroscience Education, 10*(2), A125–A131.

Rehfeldt, R. A. (2011). Toward A Technology Of Derived Stimulus Relations: An Analysis Of Articles Published In The Journal Of Applied Behavior Analysis, 1992–2009. *Journal of Applied Behavior Analysis, 44*(1), 109–119. https://doi.org/10.1901/jaba.2011.44-109

Sattler, J. M. (2010). *Evaluación infantil: Fundamentos cognitivos.* (Quinta edición). Editorial El Manual Moderno.

Saunders, K. J., & Spradlin, J. E. (1990). Conditional Discrimination in Mentally Retarded Adults: The Development of Generalized Skills. *Journal of the Experimental Analysis of Behavior, 54*(3), 239–250. https://doi.org/10.1901/jeab.1990.54-239

Saunders, K. J., & Spradlin, J. E. (1993). Conditional discrimination in mentally retarded subjects: Programming acquisition and learning set. *Journal of the Experimental Analysis of Behavior, 60*(3), 571–585. https://doi.org/10.1901/jeab.1993.60-571

Sidman, M. (1994). *Equivalence Relations and Behavior: A Research Story*. Boston: Authors Cooperative.

Sidman, M., & Tailby, W. (1982). Conditional discrimination vs. matching to sample: An expansion of the testing paradigm. *Journal of the Experimental Analysis of Behavior, 37*(1), 5–22. https://doi.org/10.1901/jeab.1982.37-5

Stojanovik, V. (2014). Language in genetic syndromes and cognitive modularity. En L. Cummings (Ed.), *The Cambridge handbook of communication disorders* (pp. 541–558). Cambridge University Press.

Tovar, Á. E., & Westermann, G. (2017). A Neurocomputational Approach to Trained and Transitive Relations in Equivalence

Classes. *Frontiers in Psychology, 8*. https://doi.org/10.3389/fpsyg.2017.01848

Tovar, Á. E., Westermann, G., & Torres, A. (2018). From altered synaptic plasticity to atypical learning: A computational model of Down syndrome. *Cognition, 171*, 15–24. https://doi.org/10.1016/j.cognition.2017.10.021

Vicari, S., Bates, E., Caselli, M. C., Pasqualetti, P., Gagliardi, C., Tonucci, F., & Volterra, V. (2004). Neuropsychological profile of Italians with Williams syndrome: An example of a dissociation between language and cognition? *Journal of the International Neuropsychological Society: JINS, 10*(6), 862–876.

Wiseman, F. K., Alford, K. A., Tybulewicz, V. L. J., & Fisher, E. M. C. (2009). Down syndrome—Recent progress and future prospects. *Human Molecular Genetics, 18*(R1), R75–R83. https://doi.org/10.1093/hmg/ddp010

Received: March 9, 2021
Final Acceptance: August, 12, 2021