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**ORIGINAL ARTICLE**

# Learning Rudiments of Music Reading with Cumulative and Noncumulative Teaching of Conditional Relations[1]

Elenice S. Hanna[2]
Erick Rôso Huber
Paula Carvalho Natalino
*Universidade de Brasília*
*National Institute of Science and Technology*
*on Behavior, Cognition and Teaching*

**ABSTRACT** - This study investigated the effects of cumulative training of conditional relations on learning rudiments of musical reading. The stimuli were sequences of notes in three modalities: sound (A); treble clef pentagram (B); and picture of keyboard (C). Five undergraduates were exposed to the Noncumulative Condition, which consisted of training AB and BC and testing, using different stimuli in each experimental phase. For the other five participants of Cumulative Condition, stimuli trained in Phase 1 were revised in the training of Phase 2. The Cumulative Condition showed maintenance of a larger number of AB relations, higher performances in tests of equivalence stimulus classes and higher scores of recombinative reading than Noncumulative Condition.

**Keywords**: conditional relation, musical stimulus, stimulus equivalence, recombinative reading, cumulative teaching, undergraduate students

# Aprendizagem de Rudimentos de Leitura Musical com Ensino Cumulativo e Não Cumulativo de Relações Condicionais

**RESUMO** - O estudo avaliou o efeito de treino cumulativo de relações condicionais sobre a aprendizagem de rudimentos de leitura musical. Os estímulos foram sequências de notas nas modalidades: sonora (A), pentagrama em clave de sol (B) e figura de teclado (C). Cinco estudantes universitários realizaram a Condição Não Cumulativa, composta por treinos AB e BC e testes, com dois exemplares diferentes em cada fase experimental. Na Condição Cumulativa, outros cinco participantes aprenderam as relações condicionais com os exemplares da Fase 2 acumulados aos da Fase 1. A Condição Cumulativa mostrou a manutenção de um número significativamente maior de relações AB, desempenhos superiores nos testes de formação de classes de estímulos equivalentes e escores mais elevados de leitura recombinativa do que a Condição Não Cumulativa.

**Palavras-chave**: relações condicionais, estímulos musicais, equivalência de estímulos, leitura recombinativa, ensino cumulativo, universitários

Music is a concept of complex definition and even more complex in all its theory. Med (1996) defines music as the art of matching sounds simultaneously and successively with order, balance and proportion in time. Merriam (1964) defines music as a human phenomenon existing only in terms of social interaction. In this sense, musical behavior is a sort of verbal behavior. The behavior of the listener is shaped by the effects it produces on the speaker (musician) and the speaker's (musician's) behavior is shaped by the effect it has on the listener's behavior (Skinner, 1957).

The need for transmitting knowledge about music led to the creation of registry systems. Musical notation is understood as the signs that represent musical writing. The registry system used today organizes different symbols that signalize length, pauses, loudness and pitches on five lines with four spaces in-between, known as pentagram. On these five lines and four spaces the notes are placed on positions that are defined in relation to the clef, which is a symbol located on the beginning of the pentagram. The clef establishes the position of the note of reference to the remainder notes (for example, on the Treble Clef the note sol is on the third line). This information allows identifying the position of the other notes (Leinig, 2008).

Tena and Velázquez (1997) state that beginner musicians have great difficulty in learning to read musical score following the traditional teaching method. In addition, they refer to the shortage of experimental research on music education and music reading training (see also

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2 Contact: hanna@unb.br

Sloboda, 2005). The stimuli involved in music reading are compounds that include several properties that are simultaneously presented (e.g., length, interval, loudness) so that the musician must respond differently to each of them. A way of handling this difficulty is to develop alternative teaching methods that follow the pace of each student while developing control through different properties.

An economic and alternative teaching methodology that has been used to establish text and music reading basic skills is based on the stimulus equivalence paradigm proposed by Sidman and Tailby (1982) and on the matching-to-sample procedure (Cumming & Berryman, 1961). This procedure facilitates teaching conditional relations between, for example, dictated and printed words (e.g., de Rose, de Souza & Hanna, 1996) or between sounds and their representations on pentagram (e.g., Hanna, Batitucci & Natalino-Rangel, 2016; Tena & Velázquez, 1997) conditioning the right choice of a stimulus (e.g., printed words or pentagram) to the presence of a stimulus presented as sample (e.g., a dictated word or a sound). Learning conditional relations can convert isolated events into equivalent stimuli, i.e., different stimuli may become replaceable in the control of behaviors (Sidman & Tailby, 1982; Vaughan, 1988). Teaching symbolic repertoires that demand learning different conditional relations between sounds, objects and characters, supported by these instructional technologies, may facilitate learning and reduce teaching time. Matching-to-sample (MTS) procedures systematically planned and with differential consequences for right and wrong choices, quickly establish conditional relations in human beings, and may produce relations that are not directly taught (Sidman & Tailby, 1982).

Reading is a repertoire under the control of symbols that could be defined as a network of relations between stimuli and between stimuli and responses (de Rose, 2005; de Souza, de Rose & Domeniconi, 2009; Serejo, Hanna, de.Souza & de Rose, 2007). The same analysis is valid to the music reading that integrates relations between, for example, note signs, time, chord, etc. that together control the playing or singing. To show understanding about musical symbols the musical stimuli must form classes of equivalence, involving printed, auditory or other stimuli. In addition, it needs some specific response to these stimuli.

The development of equivalence relations involving musical stimuli is documented in studies with undergraduate students and children, using different stimuli (Acín, Garcia, Zayas & Domínguez, 2006; Hanna et al., 2016; Hayes, Thompson & Hayes, 1989; Perez & de Rose, 2010; Tena & Velázquez, 1997). Generally speaking, the studies showed that the teaching of some conditional relationships (e.g., AB and BC) between two or more sets of stimuli (e.g. A, B and C) involving musical stimuli, produced relations of symmetry (BA and CB) and transitivity (AC) with no need for direct teaching.

Tena and Velázquez (1997) trained children of 4 to 5 years old in the AB, AC and BD conditional relations involving the dictated name of each musical note (A), the corresponding chord notation or capital letter (B), the printed name (C) and the representation in Treble Clef (D). The authors reported that four children learned all the relations taught, showed the emergence of relations between the non-taught visual stimuli sets (BC, CB, DB, CD and DC) and the reading of the B, C and D sets.

Another study about the building of equivalent musical stimulus classes with undergraduate students, Hanna et al. (2016) used sequences of three notes reproduced in the sound of piano (A), Treble Clef notations (B), Bass Clef notations (C) and drawings of pentagrams indicating the three musical notes (D). After being taught the AB, AC and AD relations, the undergraduate students showed that sounds, pentagram in both clefs and images of keyboards became part of the equivalent stimulus classes.

Reading with understanding is evaluated based on the building of conditional and equivalent relationships network, while generalized reading (here referred to as recombinative) is evidenced in tests with stimuli formed by new combinations of elements of stimuli taught (de Souza, Hanna, Albuquerque & Hübner, 2014). Reading new texts and pentagram demand learning the relationship between the units of stimuli taught, identification of these units in different positions and contexts, and the issuance of new responses under the control of new stimuli made up by elements of the stimuli that were taught (De Rose, 2005; de Souza et al., 2014; Goldstein, 1983; Hanna et al., 2011; Serejo et al., 2007).

The results of studies that assessed the recombinative text reading report wide variability between participants. However, they clearly show that the number of words taught with overlapping units is an important variable to develop the recombinative repertoire (e.g., de Souza et al., 2014; Hanna et al., 2011; Mueller, Olmi & Saunders, 2000). Some studies (e.g., Albuquerque, 2001; de Souza et al., 2009) presented results suggesting that cumulative training with words may have contributed to learn reading, although this variable has not been directly manipulated. In this training, some relations trained in a given stage are reviewed in another stage jointly with new relations. Training comprising only new relations has less successive discriminations between sample stimuli than training that, in addition to new relations, review the relations already taught. In Hanna et al. (2016) study, despite the assemblage of equivalent stimuli classes, the recombinative reading testing produced low and variable scores after the noncumulative teaching of conditional relations.

This study evaluated whether cumulative training of relations between musical stimuli influences the assemblage of equivalent stimuli classes and the development of recombinative reading differently from the noncumulative training. Different stimuli were constructed for both stages of the study. Only in cumulative training the relations learned in Phase 1 were presented again during the teaching of new relations. Evaluations of the development of equivalence between stimuli and recombinative reading were performed after the teaching stages for the purposes of comparing the effects of different teaching conditions. The study has also evaluated the musical stimulus control of playing the keyboard that was not directly taught.

## Method

### Participants

Ten undergraduate students from 18 to 24 years old, voluntaries from the *Universidade de Brasilia* were recruited. Of these, two were men and eight women. The students of human sciences courses (except for one student of Mathematics) showed interest in musical initiation, and did not take Psychology courses approaching the topic of stimulus equivalence. We selected students who had not attended any musical theory courses, and who informed not having skills to read pentagram and play musical instruments. The selection criteria also included less than 30% of success in the pre-test of playing the keyboard, and lower than or equal to 50% of success in tests on competence of relating musical stimuli of different sets as described in the procedure.

Before starting the survey, participants read and signed the Free and Informed Consent Term that described the activities to be developed in the study, clearly stating its voluntary nature and the possibility of leaving it at any time, if the participant so wanted.

### Experimental arrangement

Activities were programmed on a HP Pavilion TX2075BR computer with Touchscreen. During the sessions, participants used a *Goldship* headphone. Test sessions were also recorded on a digital video camera Sony DCR DVD 0810 on a tripod. Only the monitor screen was recorded.

The contingencies of training and testing conditional relations were programmed using the *Contingência Programada 2.0* software, developed by L. A. V. Batitucci, J. S. L. Batitucci e E. S. Hanna (Hanna, Batitucci & Batitucci, 2014) to the Windows system. This software allows presenting musical stimuli, programming contingencies of conditional discrimination with differential consequences, and recording the responses given by touching the screen. The keyboard playing tests were programmed in the P*iano Eletrônico* 1.0 (PE 1.0) software developed by M. B. Moreira and E. S. Hanna in 2009, which simulates a musical keyboard with seven musical notes on the computer monitor, using the Windows operating system, and allows presenting auditory and visual stimuli and recording responses on the screen.

Sessions were held in an experimental cubicle of the Human Learning Laboratory of the Universidade de Brasilia, of 2m in length, 2 m in width, and 2.41 m in height. The room had ventilation system with exhaustion, acoustic insulation and lighting with fluorescent lamps. Participants sat down in front of the computer, while the experimenter and the camera were behind, on the left side of the participant.

### Stimuli

Three sets of stimuli were used: one auditory and two visual sets. All sets were composed by sequences of three and four musical notes (Figure 1). Stimuli in Set A were sequences of three and four musical notes played on the piano sound, lasting 1.5 s (sequence of three notes) and 2 s (sequence of four notes), recorded in the wave format, with 44kHz/stereo quality and edited on the WavePad (version 3.05) program. The two sets of visual stimuli (B and C) were edited in Photoshop 7.0. The stimuli in Set B were drawings of pentagrams representing three or four quarter notes in the Treble Clef notation. Stimuli in Set C were drawings of a full octave of three overlapping keyboards. The drawing of a hand was placed on each keyboard, on the corresponding note.

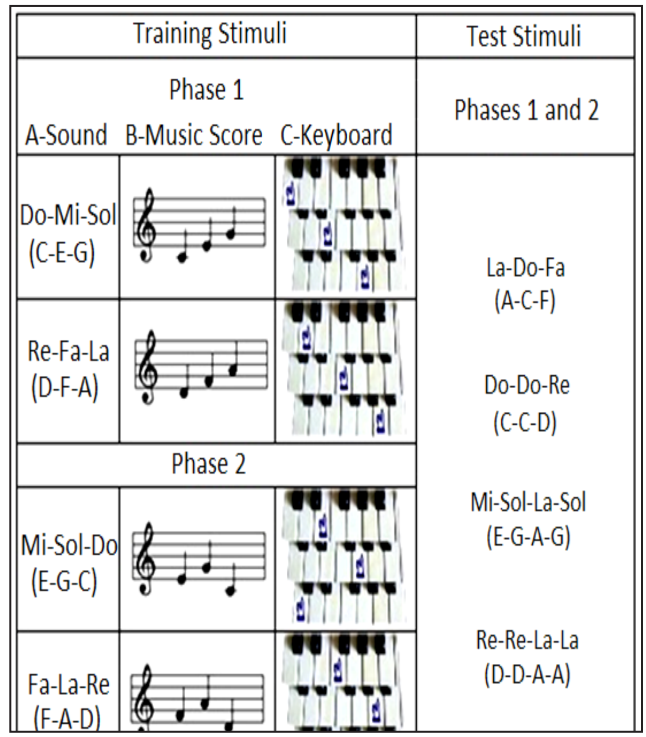



*Figure 1.* Stimuli trained and tested during the experiment.
beginning of Phase 2 of that condition.

Four stimuli of three notes were set aside to be used in training sessions. These were built by changing the position of the notes in different samples (e.g., Do-Mi-Sol and Mi-Sol-Do notes). Stimuli with three and four notes were built for the tests evaluating recombinative reading. All the test stimuli were composed by the six notes of the training stimuli.

### Procedure

All participants started the study performing tests to evaluate if: (1) they played the keys of a virtual keyboard corresponding to the stimuli of A, B and C sets; (2) they presented arbitrary conditional relations between the stimuli of different sets in a matching-to-sample task (AB, BA, AC, CA, BC and CB relations); and, (3) presented identity relations with the musical stimuli of the study (AA, BB and CC). Tests were performed with the four training stimuli and four test stimuli, programming one trial for each stimulus in the test of each relation. Table 1 shows the order of performance and number of trials for each test.

Table 1. *Taught and Tested Relations and Number of Programmed Trials in the Stages of each Experimental Condition*

| Phase | Stage | Task | Relations/Sets | Trials | |
|---|---|---|---|---|---|
| | | | | Noncumul | Cumulat |
| | Pre-tests | Keyboard playing | A, B, C | 24 | 24 |
| | | MTS | AA | 8 | 8 |
| | | | AB/AC, BC/CB, BA/CA | 48 | 48 |
| | | | BB/CC | 16 | 16 |
| | Training | MTS | BB/CC (whenever required) | 16 | 16 |
| 1 | Training | MTS | AB | 26 | 26 |
| | | | BC | 26 | 26 |
| | | | Mixed AB/BC – CRF | 8 | 8 |
| | | | Mixed AB/BC – VR 2 | 16 | 16 |
| | Tests | Keyboard playing | A, B, C | 24 | 24 |
| | | MTS | AB/AC, BC/CB, BA/CA | 48 | 48 |
| 2 | Training | MTS | Compensatory Traininga | 44 | - |
| | | | AB | 32 | 42 |
| | | | BC | 32 | 42 |
| | | | Misto AB/BC – CRF | 8 | 16 |
| | | | Misto AB/BC – VR 2 | 16 | 32 |
| | Tests | Keyboard playing | A, B, C | 24 | 24 |
| | | MTS | AB/AC, BC/CB, BA/CA | 48 | 48 |

*Note*. A: Sound; B: Music Score; C: Keyboard. Relations separated by a bar were mixed in the same block of trials, while those separated by a comma were tested/trained in different block of trials. Relations with training stimuli were tested in block before the relations with test stimuli. a Training only in the Noncumulative Condition (P6 a P10).

If there was an error in identity trials with visual stimuli, the participant would then take the BB and/or CC Identity Training, which programmed a block of two trials with each training stimulus and provided differential consequences for correct and incorrect responses (the same as those further described to the AB and AC Training). In the event of a mistake, the block was repeated up to three times with the trials reordered. This training aimed to ensure discrimination between pentagram and keyboards among participants not familiarized with the stimuli.

Then, all participants underwent training and evaluation sessions with stimuli from Phase 1 (Figure 1). The relations AB and AC were taught; i.e., relations between melodic fragments (A) and their representations in the pentagram with Treble Clef (B) and between the two pentagrams (B) and their respective keyboard figures (C), with *do-mi-sol* and *re-fa-la* sequences. After teaching the AB and BC relations separately and combined (mixed training), the tests performed in the beginning of the study were applied again, except for the identity test.

The experimental manipulation took place during the Phase 2 training stage of the study, which taught the *mi-sol-do* and *fa-la-re* sequences in AB and BC and mixed Training sessions. Five participants (P1 to P5) participated in the Phase 2 training sessions, with trials that reviewed the sequences learned in Phase 1 (Cumulative Condition). The remainder five undergraduate students (P6 to P10) took the training only with the new sequences (Noncumulative Condition). To match the number of programmed trials for training in both conditions, the Noncumulative Condition included the Compensatory Training (Table 1) early in Phase 2. This phase ended with the reapplication of tests of keyboard playing and arbitrary conditional relations.

We further detail the procedure used in the evaluation and teaching sessions. Figure 2 presents an example of screen to each stage of the procedure.

**Playing the Keyboard Test**. The first keyboard playing test was the first task of the study and, therefore, participants were given printed instructions about the task and how to look at the stimuli of sets B and C (Figure 3). After reading the instructions, the participant clicked the "Iniciar" (start) button on the upper left corner of the digital keyboard screen (Panel a, Figure 2). A stimulus of the Set A, B or C was presented above the digital keyboard, and the "Iniciar" (start) button changed to "Próximo" (next). For auditory stimulus (Set A) a white rectangle was presented, and the auditory stimulus was repeated every 3 s, until a response was given. The participant should press the keyboard note in the order corresponding to the stimulus, using only one hand and one key at a time. Each key pressed became Gray for 0.5 s. The participant ended a trial by pressing the "Próximo" (next) button. The next trial started after a 1.5 second interval (Inter-Trial Interval - ITI), during which the screen remained gray.

The Keyboard Playing Test, composed by 24 trials, presented one trial to each training stimulus in Sets A, B and C (12 trials) and then to the test stimuli (12 trials). This

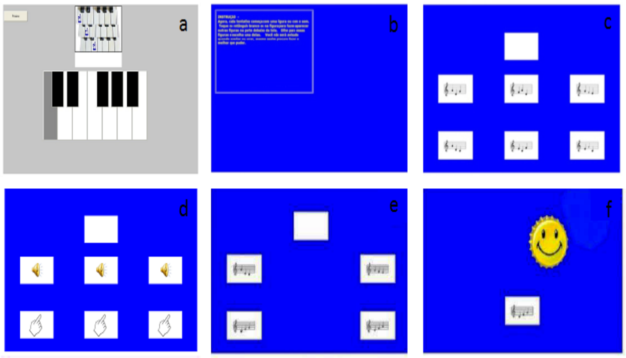
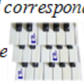



*Figure 2.* Examples of screen for each stage of the procedure. Evaluation of control by pentagram on the digital keyboard (Panel a); Initial instruction (Panel b); AB Matching-to-Sample Tests: Auditory sample stimulus and six comparisons after response to the sample (Panel c); AA Identity Testing: Window to produce the auditory sample (upper), windows of auditory comparison stimuli production (with speakers) and selection windows (with drawing of the hand) (Panel d); AB Training: Auditory sample stimulus and four comparisons after response to the sample (Panel e); and, Consequences of correct response in training (Panel f).

*In this first session we are going to evaluate your basic knowledge on some aspects of musical reading. After the assessment, we'll start the teaching procedure. You can see on the computer screen a portion of a piano keyboard. You can also see a "Start" button on the upper left corner. This button will change to the "Next" button once you initiate the session. I'm going to present sounds or pictures on the rectangle above the keyboard.*

*When the picture is similar to this one* *, look at it as you do to words: from left to right. Each sound corresponds to one dot of the picture.*

*When the picture is similar to this one* *, look at all three keyboards from top to bottom. Each finger indicates the key that corresponds to a sound.*

*After listening to the sounds or looking at the picture, touch the piano keys that you think that correspond to the sounds or to the picture. Use just one hand and touch one key at a time. When you are finished, touch the "Next" button on the upper left corner of the screen. If you don't know or prefer not to take chances, touch on the "Next" button. In this stage of the study you won't be informed whether your answer is right or wrong, but make the best you can do.*

*Thanks for your collaboration!*

*Figure 3.* Printed instruction that participants read in the beginning of the Pre-test of Playing the Keyboard, with the initial screen of the task presented on the monitor

test evaluated the control by the musical stimuli before the teaching of the conditional relations, and the likely transfer of control to the keyboard response, which was not directly taught after the training sessions that established functions for the same stimuli in the MTS task.

**Conditional Relation Tests**. Procedures of identity-matching-to-sample - IMTS (AA, BB and CC) and arbitrary-matching-to-sample (AMTS) (AB, BC, AC, CB, BA and CA) were used to evaluate the conditional relations. The identity tests were performed only on the pre-test. In these tests, responses of touching the comparison stimuli had no diferencial consequences. It started with the IMTS with melodic fragments (AA relations) and then the arbitrary relations were evaluated through the auditory comparison stimuli and the visual sample (BA/CA). The tests of relations with auditory samples and visual comparisons (AB/AC) and of relations between pentagram and keyboards (BC/CB) were performed in the same session. BB and CC were the last relations tested.

In the tests, after the presentation of the instruction screen (Panel *b*, Figure 2), the sample stimulus appeared in the upper central window, when touched, provided the comparison stimuli in the lower windows. When the sample was auditory (AA, AB and AC Tests), a white rectangle appeared in the upper central window and the sound was presented (Panel *c*). The auditory samples were repeated every 3 seconds, until a response occurred. The test trials with visual sample (BA, CA, BC, CB, BB and CC) simultaneously presented on the screen the sample and comparison stimuli. The tests with visual comparisons (AB, AC, BC, CB, BB and CC) presented six stimuli of selection on three central and three lower windows (Panel *c*). Trials of test with auditory comparisons (AA, BA and CA) provided, jointly with the sample, three central windows to present the auditory comparisons and three lower windows to issue the response (Panel *d*). To listen to an auditory comparison stimulus, the participant should touch one of the central windows with the image of a speaker (as many times as necessary). The auditory comparison was selected by touching the screen below the window that produced the sound. In AA trials, to prevent the mixing of sample stimulus and the auditory comparison stimuli, the sample was not in automatic repetition. Participants had to touch the upper white window to produce the sample stimulus again. The visual comparisons were selected by touching one of the six windows (Panel *c*). After selecting one of the comparison stimuli, a 1.5 s ITI separated the current trial from the next, leaving the screen gray.

In the identity test 24 trials were programmed, one for each training and test stimulus of the of sets A, B and C. The test of arbitrary relations was composed by 48 trials: one trial to each stimulus of training and of testing to the six relations (AB, BA, AC, CA, BC and CB). All tests first programmed the trials with training stimuli and then the trials with test stimuli. Trials with training stimuli allowed evaluating whether equivalent stimulus classes and reading with understanding would be developed after teaching AB and BC relations. Tests with new stimuli formed by three or four notes that recombined the notes of the training stimuli allowed evaluating the recombinative reading.

**Training sessions**. The AMTS procedure was used to teach two AB and two BC relations in each Phase, separately (simple training) and mixed (mixed training). In AB training the reinforcement was programmed for selecting the pentagram showing the note corresponding to the melodic fragment presented as sample. The BC training reinforced the selections of keyboards where the notes marked corresponded to the notes on the pentagram presented as sample.

In teaching sessions, after the initial instruction screen (Figure 2, Panel *b*), the sample stimulus was presented centralized on the upper part of the screen. When the participant touched the sample stimulus, the comparison stimuli were shown on the lower part of the screen (Panel *e*). The selection of one of the comparison stimuli entailed differential consequences. If the option selected was the right one, the wrong stimuli disappeared; the image of a smilie was presented jointly with the right stimulus for 1.5 s, as well as a sound record showing that the answer was right ("Great!" or "You're right!" or "Congratulations", etc.) (Panel *f*). If the option elected was wrong, all stimuli disappeared and a red "X" appeared in the middle of the screen for 1.5 s. The trial ended and a period of 1.5 s ITI began with the screen fully in grey.

In the AB and BC training, the number of comparison stimuli was gradually increased. Each relation was taught with one, two and four comparisons (different from the testing that presented six visual comparisons). After teaching the first relation (for example, A1B1) with four comparisons, the second relation (A2B2, for example) was taught with one and with two comparisons. Before presenting four comparisons, a block with two comparisons merged the two relations. Table 2 presents the structure of AB training sessions in phases 1 and 2 showing the number of comparisons and trials of each block.

In the CRF Mixed Training the AB and AC trials were mixed in each block. Three blocks of trials with four comparisons were programmed. In the VR2 Mixed Training, performed after the CRF Mixed training, the first block presented one trial of each relation, with only one comparison stimulus. From the second block onwards, it was increased to four comparisons (Table 2) and reinforcement was programmed in VR2, i.e., on average the response on every two trials had differential consequences. The instruction of this step informed that participants would not always be warned in the event of success or mistake. The mixed

Table 2. *Training Structure in Phases 1 and 2 of the Cumulative Condition: Taught Relations, Number of Comparisons (Comp) and of Trials (Tent) in each Block*

| Treino | Fase 1 | | | | Fase 2 - Condição Cumulativa | | | |
|---|---|---|---|---|---|---|---|---|
| | Bloco | Relações | Comp | Tent | Bloco | Relações | Comp | Tent |
| AB | 1 | A1B1 | 1 | 1 | 1 | A3B3 | 1 | 1 |
| | 2 | A1B1 | 2 | 2 | 2 | A3B3 | 2 | 2 |
| | 3 | A2B2 | 4 | 4 | 3 | A3B3 | 4 | 4 |
| | 4 | A2B2 | 1 | 1 | 4 | A4B4 | 1 | 1 |
| | 5 | A2B2 | 2 | 2 | 5 | A4B4 | 2 | 2 |
| | 6 | A1B1, A2B2 | 2 | 4 | 6 | A3B3, A4B4 | 2 | 4 |
| | 7 | A2B2 | 4 | 4 | 7 | A4B4 | 4 | 4 |
| | 8 | A1B1, A2B2 | 4 | 4 | 8 | A3B3, A4B4 | 4 | 4 |
| | 9 | A1B1, A2B2 | 4 | 4 | 9 | A1B1, A2B2 | 2 | 2 |
| | | | | | | A3B3, A4B4 | 2 | 2 |
| | | | | | 10 | A1B1, A2B2 | 4 | 4 |
| | | | | | | A3B3, A4B4 | 4 | 4 |
| | | | | | 11 | A1B1, A2B2 | 4 | 4 |
| | | | | | | A3B3, A4B4 | 4 | 4 |
| Misto CRF | 1 | A1B1, A2B2, B1C1, B2C2 | 4 | 4 | 1 | A1B1, A2B2, B1C1, B2C2 | 4 | 4 |
| | | | | | | A3B3, A4B4, B3C3, B4C4 | 4 | 4 |
| | 2 | A1B1, A2B2, B1C1, B2C2 | 4 | 4 | 2 | A1B1, A2B2, B1C1, B2C2 | 4 | 4 |
| | | | | | | A3B3, A4B4, B3C3, B4C4 | 4 | 4 |
| Misto VR2 | 1 | A1B1, A2B2, B1C1, B2C2 | 1 | 4 | 1 | A1B1, A2B2, B1C1, B2C2 | 1 | 4 |
| | | | | | | A3B3, A4B4, B3C3, B4C4 | 1 | 4 |
| | 2 | A1B1, A2B2, B1C1, B2C2 | 4 | 4 | 2 | A1B1, A2B2, B1C1, B2C2 | 4 | 4 |
| | | | | | | A3B3, A4B4, B3C3, B4C4 | 4 | 4 |
| | 3 | A1B1, A2B2, B1C1, B2C2 | 4 | 4 | 3 | A1B1, A2B2, B1C1, B2C2 | 4 | 4 |
| | | | | | | A3B3, A4B4, B3C3, B4C4 | 4 | 4 |
| | 4 | A1B1, A2B2, B1C1, B2C2 | 4 | 4 | 4 | A1B1, A2B2, B1C1, B2C2 | 4 | 4 |
| | | | | | | A3B3, A4B4, B3C3, B4C4 | 4 | 4 |

*Note*. The same AB Training structure has been used to the BC Training in Phase 1 for both experimental conditions. In Phase 2 of Noncumulative Condition, trials A1B1, A2B2, B1C1 and B2C2 (marked in gray) were excluded. These trials composed the Compensatory Training in the beginning of Phase 2 of that condition.

training aimed to strengthen the relations taught and prepare the participants to the tests in extinction.

In all training sessions, the position of S+ varied along the trials of each block, so that each S+ appeared the same number of times in each window. The progress along the blocks was conditional on consecutive successes in all the block trials. In other words, if the block was made up of four trials, the participant should have four consecutive successes to conclude the block and move on to the next. In the event of a mistake, the block trials were presented again for no more than three times. If in the third repetition incorrect choices persisted, the participant returned to the previous block. To conclude the training and move on to the next training, the participant should be successful in 100% of the last block.

The main difference between experimental conditions was the programming of trials with the *do-mi-sol* and *re-fa-la* stimuli of Phase 1 in the training sessions of Phase 2 of the Cumulative Condition. The number of training trials in this condition (148) therefore was much higher than that of the Noncumulative Condition (96). To match the number of trials to both conditions, the Compensatory Training was carried out early in Phase 2 of the Noncumulative Condition. That training was made up of 52 trials of the A1B1, A2B2, B1C1 and B2C2 relations. These trials were presented in one single block with no learning criterion, and were the same as those introduced in the simple and mixed training sessions of Phase 2 of the Cumulative Condition (shadowed in Table 2).

## Results

On average, each participant underwent six sessions to conclude the study. In identity testing, scores were higher than or equal to 90% of success. Only two participants (P5 and P10) showed 100% of correct responses in identity trials with the three sets of stimuli (sound, pentagram and keyboards). The highest number of mistakes was in the CC relations (nine mistakes), followed by BB (six mistakes) and AA (five mistakes). In the Identity Training for visual relations all participants (except of P9) ended the training in the first block of trials without any mistakes. P9 repeated the block three times. No training for AA relations was carried out.

Participants started the study scoring from 22% to 50% in the pre-test for arbitrary conditional relations. Null scores were found in pre-test of touching the keyboard Keys in the presence of sounds (A) and pentagram (B). In Set C the scores were equal or near to 100% correct for all participants, since stimuli indicated the keys to be played. The calculation of percentage of success, used as selection criterion, disregarded these trials. The comparison between the average of two experimental conditions showed no significant difference for both pre-tests (t test, $p > 0.05$).

Table 3 presents the ratio between the number of attempts made and programmed to each simple and mixed training. This relative measure was used for comparing the training sessions that programmed different numbers of trials. The relative number of trials was higher in AB training sessions (sound-pentagram) than in BC (pentagram - keyboard drawing) regardless the condition. BC Training and mixed training sessions presented no systematic differences in the relative numbers of trials comparing both phases. The AB Training in Cumulative Condition reported significant increase in the number of trials in Phase 2 (t test, $p = 0.01$), whereas for the Noncumulative Condition there was a decrease, but it was not significant ($p = 0.08$). The comparison between total trials made in each condition (last column of Table 3) showed that conditions were not significantly different (t test, $p = 0.20$).

On testing performances, the first analysis presents the individual scores before and after the teaching of the four AB and AC relations considering all relations tested, separating only by type of stimulus (training and testing). Then, the

Table 3. *Ratio of the Number of Trials Obtained by the Programmed in AB, BC and Mixed Training of Phase 1 (T1) and of Phase 2 (T2), and Total Trials for each Participant*

| Participants | AB | | BC | | Mixed CRF | | Mixed VR2 | | Total |
|---|---|---|---|---|---|---|---|---|---|
| | T1 | T2 | T1 | T2 | T1 | T2 | T1 | T2 | |
| Cumulative Condition | | | | | | | | | |
| P1 | 1.0 | 2.5 | 1.2 | 1.2 | 1.5 | 1.4 | 1.0 | 1.0 | 294 |
| P2 | 1.3 | 2.7 | 1.0 | 1.0 | 1.5 | 1.0 | 1.0 | 1.0 | 292 |
| P3 | 1.1 | 2.5 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 274 |
| P4 | 1.5 | 1.4 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.3 | 244 |
| P5 | 1.2 | 1.2 | 1.0 | 1.0 | 1.0 | 1.5 | 1.0 | 1.3 | 236 |
| Average | 1.2 | 2.1 | 1.0 | 1.0 | 1.2 | 1.2 | 1.0 | 1.1 | 268 |
| Noncumulative Condition | | | | | | | | | |
| P6 | 1.8 | 1.0 | 2.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 260 |
| P7 | 6.7 | 2.9 | 1.0 | 1.1 | 3.5 | 1.5 | 5.0 | 1.0 | 510 |
| P8 | 1.4 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 219 |
| P9 | 4.9 | 1.1 | 1.1 | 1.0 | 1.0 | 1.5 | 1.3 | 3.3 | 360 |
| P10 | 1.0 | 1.1 | 1.2 | 1.0 | 1.0 | 1.0 | 2.3 | 1.0 | 236 |
| Average | 3.2 | 1.4 | 1.3 | 1.1 | 1.5 | 1.2 | 2.1 | 1.5 | 317 |

average scores of participants of each condition per relation are analyzed.

Figure 4 shows the percentages of success in the pre-test (white bars) and in the last test (gray bars) of arbitrary conditional relations for each participant of the Cumulative Condition (P1-P5, graphics on the left-hand side of the figure) and of the Noncumulative Condition (P6 - P10, graphics on the right-hand side). The scores calculated for trials with stimuli used in training sessions are shown on the upper side of the figure, while those for trials with testing stimuli are on the bottom side. The pre-test analyses separated by type of stimulus show that three participants (P5, P9 and P10) scored little more than 50% of success (54.2) for testing stimuli, although the general scores fit into the selection criterion. For all the remainder cases, the scores for each type of stimulus were equal to or lower than 50% of success. There was an increase on the percentage of success in Post-testing for participants of the two experimental conditions, both for training and testing stimuli. Overall, the increase size was higher for participants of the Cumulative Condition that ended the study with the highest percentages of success. All differences of score in pre and post-testing were significant (t test, $p < 0.03$), as well as the difference between post-testing from both experimental conditions for training stimuli (t test, $p = 0.001$) and testing stimuli ($p = 0.03$). For participants in both conditions the post-testing scores with training stimuli were higher than those with testing stimuli.

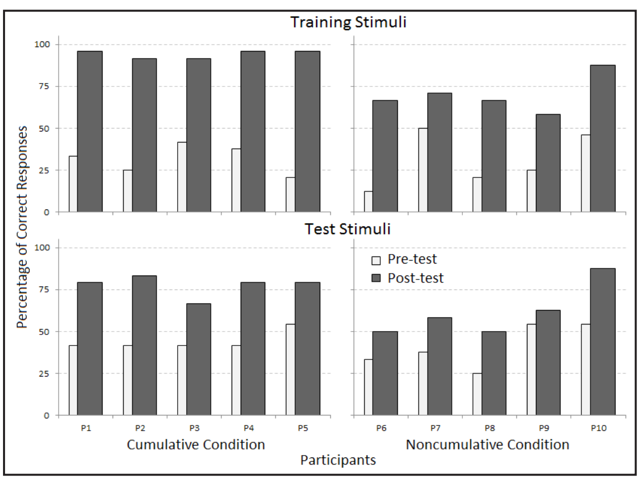



*Figure 4.* Percentage of correct responses in pre and post-testing of stimulus relations, by participants of each experimental condition for training and testing stimuli

To evaluate whether one or more relations were responsible for the differences found in the general measure of the previous analysis, the percentages of success in each relation tested were compared in Figure 5. Graphs show the average scores to each condition and the respective standard deviation (vertical line). For training stimuli (upper graph), the relations were ordered by taught, transitive/equivalent and symmetric relations. To the Cumulative Condition scores were high for all relations (75% to 100%) and with low or no variability between participants (the SD ranged from 0 to 17.7), with the lowest score for the AC relations (75%). The percentages of success for the Noncumulative Condition were lower (from 40% to 95%) and varied more between participants (the SD ranged from 11.2 to 33.5). In this condition, the highest percentages referred to visual-visual relations (BC and CB), while the lowest ones were to auditory-visual relations (AB and AC).

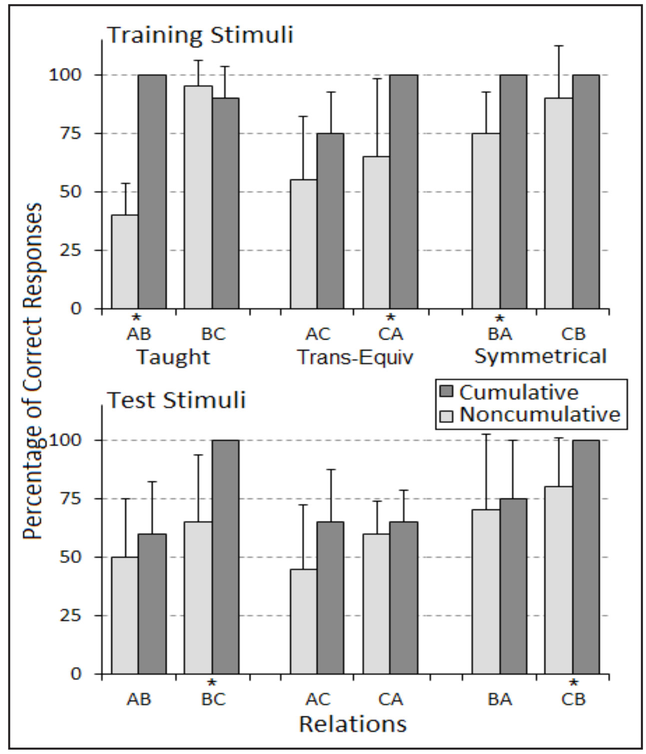



*Figure 5.* Percentage of correct responses (average) of each experimental condition in the last test of arbitrary conditional relations with training and testing stimuli, by tested relation. Vertical lines represent the average standard deviation. The asterisk under columns indicates significant difference between conditions (t test, $p < 0.05$) to the specific relation

AB and BC relations were taught during the training sessions, and the final post-testing scores served as a retention measure. The BC relations (visual-visual) were retained for both conditions, but in the AB relations (auditory-visual) retention occurred only for the Cumulative Condition. The retention in this condition was significantly higher (t test, $p < 0.01$) than in the Noncumulative Condition. The relations that have not been taught also presented higher scores to the Cumulative Condition, but differences were significant only to the BA and CA relations (t test, $p < 0.03$), both visual-auditory.

For testing stimuli (graph on the bottom side of Figure 5) the average performance by tested relation was lower than the training stimuli ones. There were exceptions for BC and CB relations in the Cumulative Condition, and AB in the Noncumulative Condition. Average post-testing scores for both conditions were statistically different (t test) only for two types of visual-visual relations (BC and CB, $p = 0.01$ and $p = 0.3$, respectively). For relations between stimuli of different modalities (AB, AC, BA and CA), differences were not significant ($p > 0.10$).

Figure 6 presents successes in the last post-testing of Playing Keyboard per participant of each condition. On the left side it shows the number of correct responses in Set A (sound) while on the right it presents the correct responses in Set B (pentagram). Although the playing keyboard behavior has not been taught, most of the participants correctly played one or more sequences of keys corresponding to the sounds or pentagrams. In general, there were more correct responses in the Cumulative Condition against the Noncumulative and in trials with pentagram than with the presentation of sound. There were inter and intra-conditions variability. The difference between percentages of correct in both conditions was significant (t test, p = 0.05) only for testing with auditory stimuli.

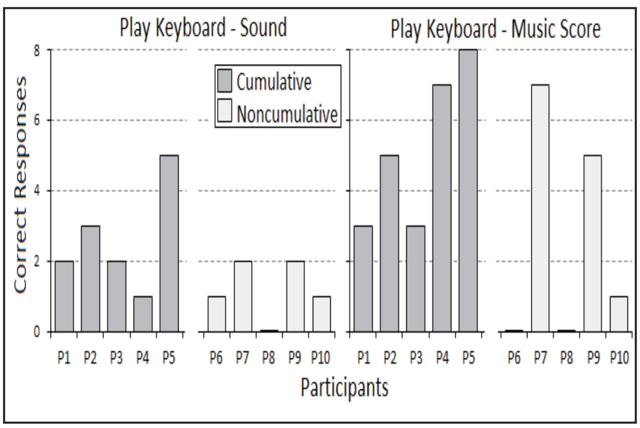



*Figure 6.* Percentage of correct responses in the last test of playing the keyboard in the presence of sounds and pentagrams for participants of each experimental condition

## Discussion

This study advances the investigations about music reading teaching using the paradigm of stimulus equivalence. Previous studies (e.g., Acin et al., 2006; Arntzen, Halstadtro, Bjerke & M. Halstadtro, 2010; Hanna et al., 2016; Hayes et al., 1989; Peres & De Rose, 2010; Tena & Velázquez, 1997) have documented the learning of arbitrary relations between musical stimuli using the MTS and also the development of equivalent stimulus classes. This experiment replicated those studies, expanded them to new musical stimuli and evidenced the importance of teaching in the cumulative baseline relations to achieve higher results.

After the training of conditional sound-pentagram and pentagram-keyboard relations, with four sequences of three natural notes, the condition that accumulated relations throughout training sessions enabled the acquisition of the eight relations (four AB and four BC), which remained in testing situation with higher number (six) of comparison stimuli. Other studies that have also presented all relations mixed during training (e.g., Madeira, 2012; Tena & Velázquez, 1997) achieved similar results in the acquisition of taught relations and in symmetry and transitivity testing, but with the same number of comparisons used for the training.

For the Noncumulative Condition, relations were learned with a number of trials similar to those for the Cumulative Condition (Table 3), but performance when testing the sound-pentagram relations was poor (less than 50%) and significantly lower than that of the Cumulative Condition (Figure 5, graph on the upper side). If in both conditions participants presented 100% success in tests with similar number of trials, why have the AB relations been retained only in the Cumulative Condition? A first important aspect to be considered is the time span between the last presentation of trials with samples in Phase 1 (in the Compensatory Training) and the performance of Tests in the Noncumulative Condition. As the Compensatory Training took place early in Phase 2, simple and mixes testing may have served as distracting tasks that influenced the retention of taught relations.

A second important aspect to be considered is that in simple and mixed training for Noncumulative Condition, only two auditory samples were alternated in each session with different notes. This allowed the development of discriminations controlled by irrelevant or partial aspects of stimuli. This phenomenon is known as superselectivity (Lovaas & Schreibman, 1971). In a contingence that alternates only two samples, the differentiation between the do-mi-sol and re-fa-la sequences, for example, may happen from one of the notes or through global aspects of the stimulus (e.g., configuration of the representation of notes and melodic variation). In the second stage of the study, training sessions not accumulated with two new samples also programmed reinforcement with strong likelihood for behaviors under partial control of stimuli. Since the control by a note or melodic variation has been established, although behavior meets training criteria (maximizing reinforcements), partial control may have been insufficient in tests with higher discrimination complexity. Besides suspending the reinforcement, tests presented the four samples do-mi-sol, mi-sol-do, re-fa-la and fa-la-re) as samples in six types of relation (AB, AC, BA, CA, BC and CB) and with higher number of comparisons (six). Moreover, the wrong comparison stimuli (S-) shared some characteristics with S+ (one or more notes, variation between notes, space configuration) and relations with the testing samples were also evaluated in the same session. High scores in these tests may depend on discriminations refined with control by a larger number of characteristics/elements of the stimuli.

Skinner (1953) named as abstraction the narrowing or refining of the control exerted by the stimuli's properties. Evidences of abstraction with musical stimuli have been reported in studies with pigeons that learned simple discriminations between sample of Bach and Hindemith (Porter & Neuringer, 1984) and between music chords (Brooks & Crook, 2010), with multiple samples. Studies on textual reading that taught conditional discriminations between auditory stimuli (dictated words) and visual stimuli (images and printed words) also evidenced the development of abstraction of control by letters with the increase on the number of samples taught (e.g., for review please refer to De Souza et al., 2014). This literature shows the importance of using stimuli overlapping constitutive elements such as, for example, teaching a set of words composed by part of similar letters in different positions. This study has also used stimuli overlapping notes both in the sample (e.g., do-mi-sol and mi-sol-do) and in the comparison functions. The difference of results in literature against those achieved with musical et al., 2011) in general the results showed retention of the relations taught. This discrepancy may be attributed to the higher number of stimuli than that used in this study.

These arguments help understand the difference of retention between conditions, but are not enough to explain why similar results were not found for both types of taught relations (AB and BC). The little or none discrimination experience of participants with stimuli allied to the cross sensorial modality of the task could be important additional factors, as reported by Watanabe and Masabe (2010) in a study with pigeons. Manipulations of the present study do not allow conclusions about this issue, but suggest the need for additional studies manipulating the sensorial modality and familiarity with musical stimuli.

The low retention of AB relations could explain poor scores in relations expected to emerge if the equivalent stimuli classes had been formed. Equivalence relations result from the reinforcement contingencies programmed in the teaching of baseline relations and during tests (Sidman, 1994). In an analysis that resembles Saunders and Green's (1999), one can say that noncumulative training has not comprised all the successive and simultaneous discrimination further requested in testing. Moreover, as tests were conducted in extinction, the inclusion of baseline relations (AB and BC) served only to evaluate the retention of such relations, but did not ensure their maintenance or re-acquisition.

Since the AB baseline was not retained it was expected that the BA symmetry relations would also be compromised, as occurred (Figure 5, upper side graph). However, the low scores in AC and CA relations testing, and high scores in the BC and CB suggest that the Noncumulative Condition compromised only the conditional discriminations that included auditory stimuli. The high scores in visual stimuli are likely to be evidences of stimuli generalization (Guttman & Kalish, 1956) due to the existing regularity between the heights of notes drawn in the pentagram and the position of keys on the keyboard. Although regularity also exists for auditory stimuli, the difference of modality could hinder generalization. Additional investigations are required to study the independent and interactive effects of the training type, of the cross modality of the relation and/or the short discrimination experience (familiarity) with auditory stimuli on the emergence of non-taught relations.

In the tests of conditional relations with new stimuli performed to assess the development of recombinative reading, once again the Cumulative Condition scored higher (Figure 4, graphs on the bottom side). However, only in the BC and CB relations that involved visual stimuli significant differences between conditions were found (Figure 5, graph on the bottom side). It is worth mentioning that all participants in the Cumulative Condition have succeeded in all trials of testing these relations, while in the Noncumulative Condition only P10 reached this result. Since recombinative reading is understood as a consequence of the development of control by units smaller than the taught ones (De Rose, 2005; De Souza et al., 2014; Suchowierska, 2006) or abstraction, the results of this study suggest that alternation of samples in the same discrimination training (Cumulative Condition) is a facilitating factor to the recombinative reading.

The variability in testing results with recombination stimuli found in this study replicates the results of studies on textual reading (e.g., De Rose et al., 1996) and musical reading (Hanna et al., 2016; Hayes et al., 1989). The learning of new conditional relations from previously learned discriminations is influenced by the learning history and, usually, scores increase as the number of training stimuli increases (De Rose et al., 1996; De Souza et al., 2014; Hanna et al., 2008; Serejo et al., 2007). This study used only four stimuli of each set and yet effects of the kind of training on recombinative reading were observed.

In music, playing an instrument with a pentagram is the closest task to what is known in the everyday language as "reading" or "writing". Playing the keyboard with the pentagram was not directly taught herein, but tested in the beginning and end of this study with a virtual keyboard that produced no sound when the key was touched. The Cumulative Condition produced more consistent results than the Noncumulative Condition in this post-testing, but three participants of the Noncumulative Conditions succeeded in more than half of the trials (right-hand graph on Figure 6). These results also resemble those of studies on textual reading (e.g., de Rose et al., 1996) that taught to select stimuli and found control transfer from printed words to oral reading.

It is worth noticing that, in the analysis of successful hit-by-note in the Playing the Keyboard Test (not included in the study), nine of the ten participants have correctly played from 80% to 100% of the C notes presented on the pentagram with Treble Clef. In this clef, the C appears below the pentagram and, therefore, is added to the representation of the music note on a horizontal line. This could highlight the note and facilitate the discrimination in relation to the remainder notes, generating restrict control (Lovaas & Schreibman, 1971). Further studies should either exchange the C note for B in the Treble Clef, or use a Bass Clef so that all notes are represented on the pentagram.

The transfer of the control of auditory stimuli to the response of playing the keyboard was observed for a short number of stimuli (one or two to seven participants). This confirms in an additional measure the low control by auditory stimuli, pointing out the need for introducing the evaluation of auditory accuracy as information to help understanding the individual's differences, as well as additional procedures to refine discriminations.

This study showed the superior position of cumulative teaching of conditional relations with musical stimuli in different behavioral measures. Nonetheless, it approached only one of the aspects of pentagram reading (discrimination of the music notes pitch) using one type of musical notation. The generality of results reported herein could contribute to generate alternative teaching technology and awaits further investigations with other sound parameters (e.g., timbre, rhythm) and notations (e.g., key of a chord).

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