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Observing Problem-Solving Strategies in Disabled Children and Adolescents with the Use of Check-Lists

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Abstract: *This paper debates the usage of check-lists to assess behavioral patterns linked to problem-solving strategies adopted by disabled children and adolescents during the execution of different tasks (Tower of Hanoi; Tetris Game; set of Building Blocks). Together with assessment grids, these tools are frequently used in the application of observational method to value behavioral patterns in typical and atypical growth, but rarely applied in the analysis of problem-solving strategies in disabled children and adolescents. For this reason, check-lists have been created to mark the presence or absence of solution behaviors. Check-lists valued both general behaviors connected with problem-space approach and specific behaviors linked to structured, semi-structured, and unstructured tasks. These tools can be used by independent judges to assess the same problem-solving strategies used by disabled individuals, adopting the Cohen's kappa coefficient or Fleiss index for inter-rates reliability. These check-lists can allow early childhood educators and others (teachers and parents) to better evaluate the quality of cognitive abilities expressed by atypically and typically developed children and adolescents; further, scholars can examine performances of disabled individuals comparing them to those of typically developed contemporaries. Future research will be addressed towards the implementation of problem-solving strategies in disabled children and adolescents through educational trainings with systematic observations.*

Key words: *check-list, problem-solving, disability, Tower of Hanoi, Tetris Game, set of Building Blocks*

1. Introduction

Problem-solving is one of the most important components of executive functions, together with inhibitory control, working memory, sustain attention, cognitive flexibility, and planning. It is a process directly involved in the solution of problems with efficient strategies and described as a "cycle from recognizing the problem to creating a solution, evaluating the solution, and going back to recognizing a new problem encountered" [1]. In these terms, the "problem" is something that takes place when individuals pursue a goal but ignore how to achieve this goal because they are deeply blocked by an obstacle. Scholars examined the different components of problem-solving process in developmental age including specific cognitive and meta-cognitive skills [2, 3, 4, 5]; in addition, researchers developed tasks to assess each component of executive functioning (including the problem-solving process) both in atypical and typical developed individuals, predominantly disabled children. For example, the Wisconsin Card Sorting Test [6], the Tower of London [7, 8], the Dimensional Change Card Sort [9], and the Tower of Hanoi [10] have been used to examine problem-solving, planning, flexibility, and abstract reasoning. To cite one of these tasks, in detail, the Tower of London [11] is chosen to assess problem-solving processing and planning and, similarly to the Tower of Hanoi, consists of a set of three balls differing in color that are moved one at a time from one peg to another. Each of the three pegs of descending lengths can hold only three, two, or one ball, respectively. The total move score corresponds to the number of moves beyond the minimum number of moves required to reach the goal position summed over all problems; the total correct score is given by the total number of solved problems in the minimum number of moves. These scores are used to assess the ability of planning and problem-solving. The aforementioned tasks produce scores about the efficiency or inefficiency of executive functioning in different populations adopting a quantitative approach and frequently comparing the performances obtained by disabled individuals with those of typically developed ones.

Previous researchers found that students with Down syndrome (DS), Williams syndrome (WS), learning disabilities (LD), and other intellectual disabilities (ID) achieved lower scores in cognitive flexibility and meta-cognitive tasks than their mental age-matched peers with typical development using nonverbal and verbal tasks [12, 8, 13, 14, 15]. Literature reported that learning disabled students (LD) are deficient in selective attention (e.g, the ability to attend to relevant stimuli presented in a learning or problem-solving situation) and in arithmetic skills (e.g., syntax, mental and written calculation), self-regulatory and control functions [16, 17, 18, 19] and score lower than contemporaries in inferential and meta-cognition skills [20, 21]. Zelazo and colleagues [22] reported that low-functioning students with DS have greater difficulty of shifting between conflicting events and concepts with false-belief tasks than mental age-matched peers. Lanfranchi, Cornoldi, and Vianello [23] studied performances of disabled students in verbal and visuo-spatial working memory, noticing that the degree of difficulty in verbal and visuo-spatial working memory for students with DS was higher when the required control was in high-condition. More recently, the study of Meneghetti, Toffalini, Carretti, and Lanfranchi [24] on mental rotation ability (measured through the Ghost Picture Test by Frick et al., [25]) and its relation to fluid intelligence and everyday spatial activities in a group of children with DS and a group of children with typical development revealed that the former is less accurate in mental rotation than the latter and mental rotation ability is related to fluid intelligence in both groups of children. With regard to cross-syndrome comparisons, Russell, Jarrold and Henry [26] found that children with Autism syndrome (AS) utilized the articulatory loop (one of the three components of working memory model proposed by Baddeley, [27]) in a similar way to typically developed children, showed superior memory span to peers with moderate learning disabilities, and are not specifically impaired on tasks measuring working memory capacity. Costanzo et al. [8] found that individuals with DS performed worse than those with WS in verbal shifting tasks. As found by Lanfranchi et al. [12], students with DS performed at a significantly lower level in tasks of set shifting, inhibition/perseveration, planning/problem-solving, and working memory, but not in the tasks of fluency; in addition, students with DS produced an high number of errors and used inefficient strategies for the sustained attention. Lastly, Lanfranchi, Jerman, and Vianello [28] analyzed the working memory and its relationships with other cognitive processes in students with DS compared to typically developed peers, revealing that students with DS expressed deficits in both central executive functioning and verbal components of working memory.

Concerning the type of problem-solving strategies used by disabled individuals in structured tasks [12, 29], scholars reported little empirical evidences and these strategies have been explored in this population in an indirect way. For this reason, the main goal of the current paper is to provide tools useful to observe and value problem-solving strategies of disabled children and adolescents through the observational method [30, 31] to overcome the exclusivity of quantitative approach in this field. No research present in the main databases has dealt with these analyses in atypical population in developmental age using this specific and systematic methodology probably because of the difficulty to identify the coding of observations with detailed behavioral check-lists. Pilot observations allowed us to collect a depth of information about problem-solving strategies (but not a breadth of data) and to reduce one of the most important limits of this type of research consisting of the interpretation by the observers.

2. METHODOLOGY

2.1. Purposes of Qualitative Study

The main purpose of this paper is to offer an example of check-lists to assess behavioral patterns linked to problem-solving strategies usable by disabled children and adolescents during the execution of differently structured tasks.

The secondary purpose is to suggest a project work based on the observation of behavioral patterns concerning the approach to problem-solving strategies comparing disabled children and adolescents to control groups.

2.2. Participants

Disabled children and adolescents with different levels of intellectual disability (preferably, mild and moderate disability) could be involved to answer to the first purpose. Further, two control groups, respectively, composed by mental-age matched children and adolescents with typical development (e.g. using Raven’s Colored Matrices) or matched on performance about cognitive and meta-cognitive measures (e.g. cognitive tasks and false beliefs tasks), could be included to reply to the second purpose of the project work.

2.3. Tasks

To analyze problem-solving strategies the authors suggest to use the three following tasks or others of similar composition/typology: the Tower of Hanoi (ToH, structured task1), the Tetris Game (TG, semi-structured task2), and the Set of Building Blocks (SBB, unstructured task3). The Tower of Hanoi could be substituted by the Tower of London, the Tetris Game by different types of Puzzle game, and the set of Building Blocks by LEGO, DUPLO, or Tangrams for Kids.

2.3.1. Tower of Hanoi (ToH)

This task can be chosen to observe the abilities of planning and problem-solving and consists of four disks of successively decreasing diameter (6 cm, 8 cm, 10 cm, and 12 cm) stacked on one of three vertical pegs; it requires to move the stack to another peg one disk at a time, never stacking a larger disk on a smaller one in the fewest possible moves. The purpose of ToH is to move the entire stack to another peg, responding to the following simple rules: a) only one disk should be moved at a time, b) each move consists of taking the upper disk from one of the stacks and placing it on top of another stack (i.e. a disk can only be moved if it is the uppermost disk on a stack), and c) a larger disk may not be placed over a smaller disk.

2.3.2. *Tetris Game (TG)*

This task is very similar to a puzzle game that requires the solver to strategically rotate, move, and drop a procession of Tetriminos that fall into the rectangular matrix at increasing speeds. Solvers attempt to clear as many lines as possible by completing horizontal rows of blocks without empty space. In the version to use with disabled children, it is possible to adopt a colored wooden tetris composed by a board with raised edges inside which bricks of different shapes and colors must be positioned and fit together, without leaving empty spaces, with the final goal of covering the entire surface.

2.3.3. *Set of Building Blocks (SBB)*

This task consists of a container with 100 plastic pieces divided into five geometric forms (20 blocks for each form with a specific color: yellow hexagon, red pentagon, blue rhombus, orange square, and green triangle) and it can be used to assess the ability to create multiple objects, forms, and ideas starting from unstructured stimuli, combining them as individual preferred. The number of plastic pieces can be changed for increasing or decreasing the complexity of task; the major number of pieces increases the complexity of solution, while the minor number of pieces decreases it. The solver can use these plastic blocks by categorizing them according to different strategies and in a creative way.

For summarizing, the choice of ToH (structured task) can be justified with the presence of a minimum number of moves according to established rules necessary to its solution and only one possible correct solution; also, the main intent of its application is linked to the observation of behaviors adopted by disabled children and adolescents to solve the task and not directly to the analysis of correct responses. The choice of TG (semi-structured task) is due to the presence of different ways (and not only one) used by children and adolescents to occupy the given space; so, the main goal for the use of TG is represented by the observation of behaviors showed by disabled children and adolescents to complete the task rather than by the analysis of type and computation of well-documented correct responses. Finally, the selection of SBB (unstructured task) is completely free from specific rules in its resolution and allows children and adolescents to mentally operate in a more autonomous way compared to previous tasks; for this reason, it can activate divergent and creative thinking in problem-solving strategies.

2.4. Check-Lists and Procedure

Two types of check-lists have been created by the first, third, and fifth author to mark the behaviors concerning the general way to solve the tasks (Table 1) and to notice the behaviors about the strategies to solve each specific task (Table 2). In a preliminary phase, the authors carried out audio- and video-taped pilot observations of disabled children and adolescents' performance for the three chosen tasks in order to test the goodness and validity of these check-lists. The total time spent for execution of the three tasks was recorded. According to suggestions provided by specialist literature and the videotaped observations coded by three independent judges (first, third, and fifth author), it has been possible to modify the following elements:

-the execution time of tasks without the indication of timeout;

-the presentation of tasks with a more clear and intuitive instructions for use with child-friendly words;

-the elimination of redundant behaviors in the same part;

-the difficulty of tasks in relation to the number of disks in the Tower of Hanoi reduced from six to four disks or the number of plastic pieces in the set of Building Blocks.

The final check-lists were revised by the second and fourth author eliminating the ambiguous items and then accepted by all authors. The general checklist contains a list of 20 items (Table 1) for behaviors adaptable to the three tasks with reference to the comprehension of goals and rules of task, manipulative behaviors applied to the whole structure and single disks/bricks/blocks, procedural behaviors to reach the solution of tasks (use of specific strategies; for example, thinking loud), and adaptive behaviors during the explanation by the observer and execution of tasks (e.g., to listen the explanation, to ask for additional information, to search eye contact, and to indicate color and shape of bricks).

Table1. *General check-list*

List of behaviors
1.He/she respects the instructions
2.He/she interrupts the execution of the task
3.He/she understands the goal to be achieved
4.He/she reasons aloud
5.He/she counts the pieces of the object
6.He/she manipulates the single pieces
7.He/she composes and decomposes the whole structure
8.He/she changes strategy when he/she does not reach the expected result
9.He/she realizes that he/she has made a mistake
10.He/she proceeds in a confused and random way
11.He/she asks for further explanations
12.He/she listens to the explanation of the task
13.He/she fixes his/her gaze on the object he/she is manipulating
14.He/she works on the task constantly and without interruption
15.He/she accepts and follows the suggestions
16.He/she seeks eye contact with the observer
17.He/she asks for feedback
18.He/she interrupts the task without completing it
19.He/she indicates color or shape of the pieces
20.During the execution of task he/she is distracted
Note - Response format: [√] presence of behavior; [ ] absence of behavior

The specific check-list contains three parts, each for single task (see Table 2). For the Tower of Hanoi, it includes four items for behaviors referred to the comprehension of hierarchical structure of task and to specific behaviors such as the reiteration of same movements from a peg to another, the overlapping of disks to understand their size, and so on (e.g. to complete the task even if the disks are overlapped in wrong way). For the Tetris Game, the check-list encloses a total of eighteen items articulated in sub-dimensions to analyze rigidity/flexibility, organizational style, type of errors, and spatial orientation. In detail, it is possible to verify the ability to modify spatial orientation of pieces, modality of task execution according to established schema or flexible format, to observe self-correction and self-control ability, and the way in which each piece or brick is rotated inside the wooden board. Lastly, for Building Blocks, the check-list keeps ten items referred to behaviors analyzing operational style, organizational style, and final configuration; specifically, it allows to observe the way in which the building blocks are selected and chosen by children or adolescents (e.g., randomly or in a specific way for the related position), the way in which the building blocks are inserted and allocated in the wooden board (e.g. vertically or horizontally), and the behavior adopted by each child or adolescent to create the final product in convergent or divergent way.

Table2. *Check-list for each task*

TASK 1 (ToH)	He/she realizes that a disk is bigger than another only after overlapping them
	He/she repeats several times the same movement
	He/she starts again if the move is wrong
	He/she completes the task even if the disks are overlapped in wrong way
TASK 2 (TG)	**I - Rigidity / flexibility**
	He/she puts a brick with the same spatial orientation in the wooden board
	He/she maintains the connection between two or more bricks
	He/she fits the bricks even if they do not fit correctly in the wooden board
	II - Organizational style
	He/she organizes the bricks out off the wooden board
	He/she adopts an organized schema or fixed strategy (e.g. e.g., from top to bottom, from bottom to the top, and from outside to inside, from the right to the left)
	He/she associates the bricks for color or shape
	He/she proceeds in symmetric way
	He/she correctly fits one brick at a time in the wooden board
	He/she realizes joints between the two spaces
	III - Type of errors
	He/she notes the empty spaces between a brick and another
	He/she puts the bricks in a vertical way
	He/she verifies the final position of all bricks
	He/she reorganizes the entire board taking into consideration the empty spaces and adding the missing bricks
	He/she reorganizes the entire board starting from the first sequence of bricks
	He/she corrects the mistakes without the help of observer (or other people)
	IV - Spatial orientation (or mental orientation)
	He/she rotates the bricks inside the wooden board
	He/she rotates the bricks only after the established contact with the other bricks
	He/she marks the empty space with his/her hands and after inserts the correct bricks
TASK 3 (SBB)	**I - Operational style**
	He/she puts all the blocks in the table and after he/she selects them for color or shape
	He/she organizes the blocks in a random way
	He/she selects each block at a time from the container
	II - Organizational style
	He/she combines geometrical figures using the same color and shape (e.g. all block of green triangle)
	He/she creates only geometrical compositions
	He/she associates different blocks to create new configurations (e.g. a train)
	He/she arranges the blocks vertically in a tridimensional way
	III - Final configuration
	He/she produces correspondences between the shape of blocks and their function (e.g., triangle for the housetop, rhombus for the eyes of puppet)
	He/she puts together different blocks for the final product
	He/she arranges the blocks dividing them for the same color and shape (e.g. all green triangles, all red pentagons), not mixing up them
Note - Response format: [√] presence of behavior; [ ] absence of behavior	

During the observed sessions, participants must be instructed and encouraged by the observer to solve the tasks verbalizing their own thoughts and thinking aloud [32]. As in Short and colleagues' study, learning disabled and developmentally disabled children perform better in verbal and spatial analogies tasks in the "thinking aloud" condition rather than in the "silent" one.

The check-lists allow to record information quickly about how each participant profits in relation to specific problem-solving strategies. Written in a dichotomous format (presence or absence of behavior) and with spaces for brief comments, check-lists are easily usable by educators, teachers for special needs students, or experts in techniques of observation of behaviors. To verify the reliability and validity of direct observations by the two or more independent judges, it is necessary to calculate the inter-observer agreement using the Cohen's Kappa coefficient or Fleiss index. Written permission by parents of observed children or adolescents must be obtained prior to data collection and to start the observations. Parents must give their informed consent in accordance with the Code Regulating Personal Data Protection for data privacy.

3. Discussion and Conclusions

This paper is likely to provide a contribution to fill the lack of suggestions in reference to this aspect of assessment of abilities in disabled students. We believe that it is useful formulate an idea of project work focused on the analysis of problem-solving strategies, starting from the choice of tasks adequate and similar for definition to those used in this observational study, and concluding with the comparison between performances of typically developed students and those of disabled ones. So, in the hypothetical and longitudinal project work, it could be very important to carry out the qualitative assessment of problem-solving abilities, using the abovementioned check-lists both in pre- and post-training for evaluating the enhancement of these abilities in disabled students after realizing educational and process-based trainings focused on the exercise of executive functions [33, 34]. The comparison between the check-list filled in pre-training and that in post-training can be useful to highlight the most deficient areas of problem-solving, the areas where improvements have been recorded following a specific intervention, and the areas where improvements have not be realized**.**

This *modus operandi* could have an effect on school achievement also in children without disability [35, 36]. As reported by Thorell et al. [35], preschool children receiving computerized training of visuo- spatial working memory and inhibition for five weeks improved significantly on trained tasks respect to control groups. Holmes et al. [36] found that the majority of children with low working memory skills, assessed on measures of working memory, IQ and academic attainment before and after training on either adaptive or non- adaptive programs, showed substantial and sustained improvements in working memory linked to reading and mathematical abilities with adaptive trainings.

The effectiveness of cognitive training has been also confirmed in children with ADHD: in Klingberg, Fernell, Olesen, Johnson et al.' study [37], it emerged that 7 to 12-years-old children with ADHD trained with computerized programs for over 20 days reached good performance in span and visuo-spatial working memory in post-training and follow up at three months and improved inhibition and reasoning abilities. Similar results were obtained by Holmes, Gathercole, Place, Dunning, et al. [38], indicating that 8 to 11-years-old children with ADHD and children with deficient working memory, trained with cognitive and pharmacological programs for 20 days, obtained good performance in verbal and visuo-spatial working memory using cognitive training. In addition, Söderqvist, Bergman Nutley, Ottersen et al. [39] tested the efficacy of computerized training for five weeks on working memory and non-verbal reasoning in two groups of 8 to 11-years-old children with intellectual disability (IQ < 70): experimental group of children significantly enhanced performance in non-verbal reasoning and working memory tasks compared to control group.

To improve the sustained attention and shifting in disabled children and adolescents it could be adequate the usage of "barrage activities" (target: colors, letters, numbers, or figures) in presence of distractors stimuli for increasing the concentration on the given task [40, 41] or the "organization of points" according to the Feuerstein et al.'s method [42] for the building of geometrical shapes alike to given model combining the points in a datasheet. To increase the working memory, the number span (e.g. remember list of numbers), word span (e.g. remember list of words), and alpha span tasks (e.g. remember list of words in different types of presentation) could be used [43, 44]. Proficiently, the Tower of Hanoi and the Tangrams for Kids could be adopted with disabled children in order to enhance their planning and problem-solving abilities. In detail, the tangram is a two-dimensional re-arrangement puzzle created by cutting a square into seven geometric shapes named "tans" [45]; each tangram puzzle contains two large right triangles, one medium-sized right triangle, two small right triangles, one parallelogram, and one small square, and, arranged correctly, these pieces can be fitted together as a large square, rectangle, or triangle or in a creative way. Solving tangram puzzles appears to activate parts of the brain associated with creative thinking and trial-and-error problem-solving [46].

The application of check-lists for observing the behavioral patterns of disabled children and adolescents in the execution of the abovementioned tasks requires a good level of expertise in the observational methods, in direct or indirect form. Some suggestions in this contribution could be provided to overcome limits in this qualitative approach. Firstly, the choice of different types of participants will allow us to extend the analysis to the other cases and the inclusion of control group will permit us to understand if the strategies adopted in the solution of these tasks are peculiar to this population or similarly present also in individuals with typical functioning. Furthermore, the three tasks (ToH, TG, and SBB) will be applied without reference to standardized and quantitative scores but rather to qualitative analyses, observing the type of solutions adopted by participants for the tasks and the adequate or inadequate strategies of problem-solving employed by participants in each task. We think that the application of this type of observation with the use of check-lists could be useful to create a linkage between qualitative and quantitative research to enhance the knowledge of the problem-solving strategies in atypical developed children.

Future research with the application of these check-lists could be carried out with children with DS and WS to deep the knowledge of problem-solving strategies in atypically developed target.

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